TIME USE DIARY DESIGN FOR OUR TIMES: GENERAL PRINCIPLES FOR ONLINE DESIGN

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Abstract

We present a multi-field digital time-use diary design matching the information collected in best practice pen-and-paper designs such as the Harmonised European Time Use Survey (HETUS). Many diary tools for online self-administration use a survey-style iteration of repetitive questions, and have consequently had to compromise on the amount of information collected in an effort to reduce respondent burden.

A general-purpose design, incorporating multiple continuous independent diary fields, is important because it offers both continuity with historically collected time use diary data, and versatility, providing data for a wide-ranging and still growing corpus of substantive research and policy applications. We provide the guiding principles underlying decades of design development of general-purpose time use diary surveys.

We then illustrate how the general-purpose multiple field design is important in the estimation of several key policy-related issues: 1) Child-related time (primary and secondary care activities, together with child co-presence can be used to generate a full picture of 'child-related time'); 2) ICT use ('computing' as a primary or secondary activity, plus time spent using ICT devices can be compared, and/or added to demonstrate the penetration of digital devices into our daily lives); 3) Behavioural risk assessment for the transmission of infectious disease (combinations of activity, location and co-presence fields permit the assignment of daily risk for different population subgroups).

The online design developed at the Centre for Time Use Research (CTUR) mimics the 'light diary' visual presentation, including all the fields and activities of the HETUS diary. Methodological work to date suggests that this visually intuitive design does not lead to an erosion of data quality or increased respondent burden. For use with interviewers, a Computer Assisted Telephone Interview (CATI) version of this diary was developed, which may be extended to a Computer Assisted Personal Interview (CAPI) version – with the advantage that respondent and interviewer can look together at the diary day.

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1. Introduction: The uses of general purpose time use diary data

Time use diary data is increasingly recognised as a crucial part of the tool-kit of researchers and analysts across a wide and growing range of research and policy-related applications. Indeed, there is a growing case for making time-use data collection a centrepiece of any system of social and economic statistics. It has been shown to make important contributions to (at least) five key areas of public policy:

1.1 Estimating extended economic output and tracking economic processes. Technological change moves work both into and out of the money economy; paid and unpaid and care work appear together in time diary accounts. Time use data therefore provides a basis for quantifying and valuing non-money output, to be included alongside conventional GNP (*nb SDG 5.4 'recognize and value unpaid care and domestic work'*)

1.2 Distributional (in)equalities and human capital formation. The time-use diary's comprehensive coverage allows analysis of (particularly gender) differentials in all work and consumption time *(SDG 5.4 aims to achieve gender equality and empower women and girls by addressing the unequal distribution of unpaid care and domestic work)*

1.3 Estimates of the contribution of experienced time to instantaneous wellbeing. There is widespread dissatisfaction with GDP as the metric to gauge social progress, and a chorus of influential voices have called for the incorporation of subjective enjoyment based on time use data into a more comprehensive dashboard of alternative measures (Kahneman et al 2004, Krueger et al 2009, Stiglitz, Sen and Fitoussi 2009).

1.4 Estimating health consequences of daily activities. As well as providing direct information on sleep and eating frequency and duration, exercise levels (metabolic equivalents) can be applied to time-use data on activities; and infection risks of daily activity patterns may be estimated by combining evidence of activity, location and co-presence (Sullivan et al 2021).

1.5 Predicting environmental sustainability. Populations' activity patterns have 'footprints' in the form of energy and other material requirements, and in terms of pollution and other consequences. Time-use diary data enables the capturing of such 'footprints' both inside and outside the home, providing potential inputs to scenario modelling of alternative futures (Jiang, Motose and Ihara 2022; Madsen and Weidema 2023).

It is by now recognised that the well-established measures of the market do not capture the whole economy. A high proportion of the world's population survives by subsistence agriculture, consuming the products of their labour economy without any exchange of cash. In advanced economies households also produce goods and services – meals, laundry, accommodation, care, education and transport – without paying each other wages. The importance of the burgeoning 'care economy' is becoming more evident as the population ages. The contribution of this household-based, non-market, production is only properly captured by times use surveys.

As an example, in recognition of the fact that time use surveys hold a privileged position in the measurement of these non-SNA (System of National Accounts) activities, particularly unpaid domestic or care work, the International Labour Organization recently commissioned a report on what time use diary surveys can contribute to the understanding of child labour in Lower and Middle Incomes Countries (LMICs) over and above the survey-type questions used in standard surveys (Lamote de Grignon Perez, in preparation). Adding diary estimates of non-SNA work to SNA work for LMIC countries selected on the basis of their data quality (compare left side and right side graphs of Figure 1 below) shows firstly how the amount of total work done by children increases when non-SNA work is added, and, secondly, how it becomes clear that girls rather than boys are in fact the main source of child labour.

Figure 1. SNA and All Work (SNA + non-SNA) by gender.

SNA activities only   SNA and non-SNA activities
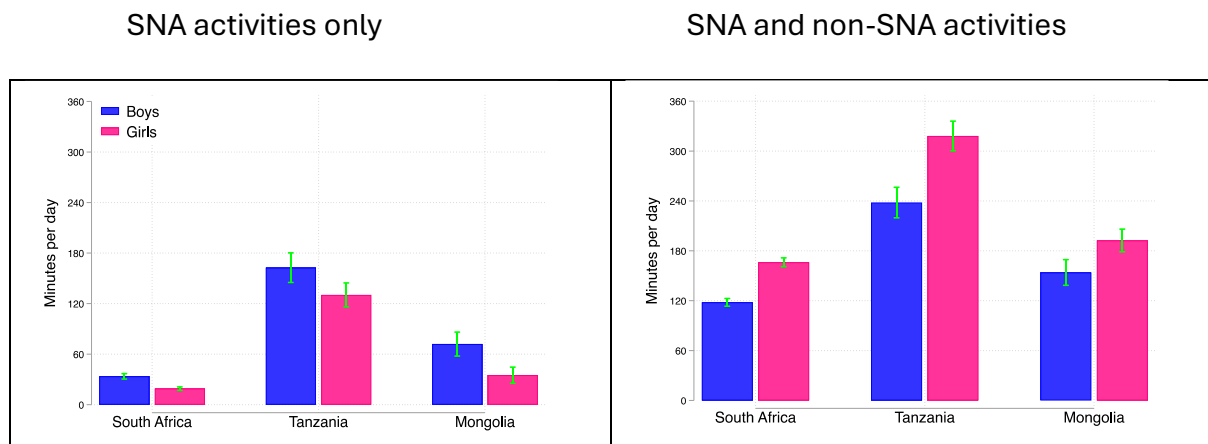
The figure on the left shows the amount of SNA work done by boys and girls aged 12-17. The figure on the right shows the amount of all work (SNA+non-SNA). Data are weighted. The figure shows clearly how the amount of work increases when non-SNA work is added and how girls become the main source of work (rather than boys).

The above example illustrates how the importance of time use data collection and analysis is no longer confined to Europe, North America and Australia, and is likely to spread further with the increasing support of key international organisations (the United Nations, International Labour Organization, World Bank, International Conference of Labor Statisticians and the Asia-Pacific Economic Commission are all urging more than 193 national statistical organizations to conduct time use surveys on a

regular basis). Time use diary surveys have to date been collected across five continents: Europe, North America, Central and South America, Asia (including the Indian Sub-continent), Australia and Africa.

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, methodological attention has switched to the feasibility of the collection of good quality data using digital devices. There are substantial challenges in moving the standard pen and paper diary online - nevertheless, for reasons of cost and convenience this is undoubtedly the future. There is a need for a digital diary instrument that is not excessively burdensome for respondents, but which can provide good quality general-purpose time use data that ensures continuity with previously collected data.

2. Background: Paper-based time use diaries

In order to provide a background to the main considerations involved in designing a time use diary survey for online, web-based or smartphone, deployment, it is instructive to consider the history and development of the standard, pen and paper, time use diary survey design. Time use diary research has a long history, and current best practice in diary design is the outcome of this long tradition of development across many decades and continents (for a fuller description see Cornwell et al., 2019). This extensive pre-history meant that by the time of the first properly designed, ex-ante (pre-fieldwork) harmonised cross-national time use study across 12 countries, funded in the mid-1960s by UNESCO (Szalai, 1972), there was already a considerable international convergence of design and research practice in relation to pen and paper time use diaries.

The next substantial exercise in ex-ante harmonised cross-national comparative time diary collection, the Harmonised European Time Use Survey (HETUS), organised by Eurostat (Eurostat, 2009, 2020) developed from this design. Two tranches (1999-2006 and 2009-2015) of nationally representative data for all the larger EU countries using pen and paper diaries are complete, with a third tranche (2019-25) in the field, some of which are experimenting with online designs. The American Time Use Study (ATUS), run by the US Bureau of Labor Statistics, departs from the basic Szalai design protocol, in particular by using a phone interview for the collection of data, and by collecting only a single activity category per timeslot (United States 2020).

Time use diaries were traditionally pen-and-paper based, and the majority of the nationally-representative time use diary surveys included in the Multinational Time Use Study archive[i] were collected in this way. The standard methods were a small diary booklet left behind by an interviewer for respondents to complete on a designated day (the 'self-complete diary'), or completed in retrospect by an interviewer during an arranged call-back interview ('day-before interview'). More recently, the 'day before' interview has been completed by interviewers with the use of Computer Aided Personal Interviews (CAPI) technology, or by telephone (as in the ATUS), as Computer Aided Telephone Interviews (CATI). These developments represent the first step of the move to the full use of digital technology by allowing diary information to be simultaneously input to an online database. However, the basic design of the time use diary as collected in most large-scale, nationally-

representative, surveys has remained largely unchanged, with one important design distinction. The number of diary fields and activity categories recorded in pen and paper designs now generally takes one of two forms: 'full' or 'light'.

2.1 Full diaries

In 'full' diaries, respondents write in their own words what they are doing, and, post-survey, coders code up their responses into a hundred or so 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 HETUS. Figure 2 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 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. 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 both Figures 2.

The two activity fields (main and secondary) are each coded into 120+ distinct activity categories. An innovation of this particular diary design was the addition of two columns recording whether the respondent was using an ICT device (smartphone/tablet/computer), and how much she/he enjoyed each 10-minute timeslot. Note the 'whole day' visual approach of the HETUS diary design, a legacy of previous successful pen and paper diary formats. This gives respondents an intuitively visual picture of the interactions between the different components of their diary day (who they were with when they were doing a particular activity, for example).

2.2 Light diaries

So-called 'light' diaries were designed in the 1990s to lower both respondent and coder burden. This diary format was used by the UK Office of National Statistics for national time use diary collections in 1995 and 2005. The light diary design, presented on a single sheet of paper, retains the visual 'whole day' approach of the full diary, but is restricted to the collection of primary (and sometimes secondary) activities. It includes a limited menu of pre-coded activities for respondents to choose from (typically between 30-40 activities). These features rendered it both less complex/time-consuming to complete and more visually accessible than the full diary. The limitation is that only information on activities is collected, and respondents have to choose from a restricted range of activities. As an example, Figure 3 shows the light diary used in the UK Understanding Society Innovation Panel 7 survey. The diary is formatted into a day's sequence of 10-minute timeslots across the page, with between 30-40 pre-coded activities listed. Respondents indicate by marking on the diary (with a tick or continuous line) which pre-coded activities they were doing at what times.

Figure 2: Completed 'full' diary example: the HETUS UK time use survey diary 2015

Figure 3: Completed 'light' diary example from the Understanding Society Innovation Panel 7

Because of its apparent simplicity, some of the key international agencies with interests in the collection of time use diary data have recently recommended what they refer to as a 'light diary' format for the collection of time use data (Hirway, forthcoming). These recommendations characteristically embrace a 'light diary' collection of 20-40 activities, accompanied by various contextual questions, including on child supervision. See, for example: United Nations Statistical Division (2024); International

Labour Organisation Department of Statistics (2023); Charmes (2021 – for the Centre for Excellence in Gender Statistics, UN Women).

However, in most cases the appellation 'light diary' as used by the above agencies does not refer to the visually intuitive light diary format as illustrated in Figure 3. Rather, it is a reference to the very restricted list of pre-coded main activities characteristic of the light diary, collected according to a 'survey-style' approach (see section below on **Extending the general principles of time use diary design online** for a discussion of this approach). The result of this is to greatly restrict the data collected by these instruments, without the benefits of the light diary visual interface aiding recall.

3. Guiding principles for the design of general purpose time use diaries

Based on the long history of development in the design of traditional time use diaries outlined above, we present here a list of guiding principles for the design of general-purpose time use diary instruments. Consideration of these principles should underpin the development of any diary designed to collect good quality time use diary information, whether in the form of paper diaries, CAPI/CATI instruments, or digital diaries. With one exception these principles correspond to the minimum requirements of the Eurostat Harmonised European Time Use Study (HETUS), the accepted 'gold standard' in the pen and paper time use diary design (the exception is the 'affective response' field, collected by the UK, French, and Italian contributions to the 2010-15 HETUS tranche but not included in the 2018 Guidelines). The HETUS design drew on several decades of time-diary research and design expertise from Europe, Australasia and North America, and represents the most comprehensive expression of the design for a general purpose time use diary survey.

3.1 **Multiple fields.** The instrument should collect, in addition to a background questionnaire, diary information on activities (primary and secondary), locations (places or transport modes), copresence (multiple codes), ICT devices used (multiple codes) and affective responses to current activities.

3.2 **Continuous fields spanning the entire diary day** (normally 1440 minutes). Characteristics which may apply to all activities (eg co-presence) should be collected as complete diary fields, providing flexibility in both collection and analysis.

3.3 **Independent fields**. A diary 'episode' is defined as 'a period of no change in any diary field'. So, ***start and end timings for each field should be collected independently of all other fields*** to enable recording and analysis of variations and overlaps between the timings of the various diary fields (eg eating while watching TV).

3.4 **Visual interface to aid recall**. Diary instruments should reveal all diary fields (or as many as possible) throughout the day. Decades of design work on time use

diaries have established the principle of a ***visual presentation to help respondents to envisage and recall their entire day.***

These principles emphasise both the visual benefits of the HETUS-type diary for respondents, and the full range of analytic options available from that design. Below we illustrate some empirical examples of the importance of the above general design principles, with reference to key policy-related issues. We then move on to discuss how these general principles may be applied in the design of online time use diaries, in particular how an online design can take advantage of quality enhancements available online (eg *requiring* responses throughout the day before proceeding to the next field).

4. The multiple independent continuous field design: examples in practice

In this section we illustrate why a multiple continuous independent field design is important in the estimation of several key policy-related issues:

1) Child related time (primary and secondary care activities, together with child copresence can be used to generate a full picture of 'child related time').

2) ICT use (computing use as a primary or secondary activity, plus time spent using ICT devices can be compared, and/or added to illuminate the full penetration of digital devices into our daily lives)

3) Behavioural risk assessment for the transmission of infectious disease (combinations of activity, location and co-presence permitting the assignment of daily risk)

4.1 The need for multiple continuous diary fields: 1) The measurement of childcare time

The meaning, and the appropriate recording, of childcare is a long-standing subject of debate. There is a fundamental distinction to be made between childcare *tasks* and *responsibilities*, between time spent doing activities directly with children, and time involving being or feeling aware of or responsible for them. This distinction has been fundamental to the debate around the meaning and interpretation of 'childcare time' (e.g. Folbre and Yoon, 2007; Stewart and Allard, 2015; Doucet, 2018). Where an activity is oriented to a direct provision for a child, or enabling a child's participation in an activity (eg feeding, or homework support) respondents are likely to identify this in a time use diary as a primary or secondary activity.   But the awareness of being with, or responsible for, a child, while engaged in another activity, may be recorded not as an activity-in-itself, but rather as a secondary childcare activity, or co-presence with a child.

This difficulty of definition has long been recognized as a feature leading to inconsistencies in research results based on different measures (Budig and Folbre, 2004; Folbre and Yoon, 2007; Mullan and Craig 2009; Stewart and Allard, 2015). For example, in contrast to the HETUS, which includes both primary and secondary childcare activities as continuous diary fields, secondary childcare is not recorded as a

diary field in the ATUS. Instead, in recognition of the more diffuse nature of childcare, there is a special module in which respondents are asked about time that children were "in your care" during the diary day, while in the Canadian Time Use Survey the equivalent phrase is "looking after" children. However, this solution does not fully answer these uncertainties of interpretation, because such questions impose an *ex-post* interpretation that may have been absent in real time. In addition, assessing whether one has children "in ones' care" also contains a degree of subjectivity, depending on location, activity etc. A multiple field time use diary including both primary and secondary activities and a co-presence field provides a quantitative picture of how much time is spent with children, doing what (to which supplementary questions about respondents' interpretations of that time may always be added).

Table 1 is based on data from a 2023 UK nationally representative sample using the CTUR online Extended Light Digital Diary (ELiDDI - described more fully in a later section of the paper). It provides an example of a complex hierarchical summary of all child-related activity. The primary activity column shows the total average minutes spent in 12 summary activities where neither the secondary activity nor the 'co-presence' field include childcare or the presence of children. Of the 1246 minutes in this column, childcare was reported as the primary activity for just 30 minutes. In a diary collecting only primary activity this 30 minutes often becomes, by default, the headline estimate of time spent caring for children.

Table 1: Child-related time (Minutes/day, UK Adults, ELiDDI, March-April 2023); primary & secondary activity & child (<12) co-presence

	Primary activity	Secondary childcare	Child co-presence	Row total	Child co-presence as % of primary time
sleep, rest, personal care	481	5	78	564	**16%**
eat, drink	60	2	11	72	**18%**
paid work @ workplace	121	0	6	128	5%
paid work @ home	52	1	5	59	10%
unpaid work & education	107	4	16	126	**15%**
shopping @ shops	20	1	2	22	10%
shopping @ home	6	0	1	6	**16%**
computing	27	0	3	30	11%
out-home leisure	113	3	6	122	5%
home leisure	175	3	29	207	**17%**
all travel	52	2	8	62	**16%**
childcare	**30**	10		39	(100%)
missing	3	0	1	3	
Column total	1246	**31**	**166**	**1440**	

The addition of a continuous independent "secondary childcare" field provides the total minutes declared by diarists as childcare that happened simultaneously with any of the primary activities. So, in addition to the 481 minutes spent in sleep etc with no mention of children, there is an additional 5 minutes spent (presumably) resting while *also* undertaking some childcare activity, 2 minutes of secondary childcare while *also* eating and drinking, and so on. Ten minutes on average are reported as engaged in a second or further childcare task while *also* undertaking some other primary childcare-type activity. The 31-minute total of secondary childcare time doubles the headline childcare total to just over one hour.

The third column shows the total time in each primary or secondary activity in which a child is reported as co-present. So, in addition to the 486 minutes of primary or secondary "sleep, rest, personal care" with no child-copresence, is an *additional* 78 minutes reported in these activities with children co-present. The sum of this column adds a further 166 minutes to the total child-related time; far in excess of the combination of primary and secondary childcare time. So the 'child-related time' of the title of Table 1 refers both to time spent engaged in childcare activities, and also to time recorded as being co-present with children whilst doing other activities.

Of course, these 3 diary fields reflect different qualitative levels of engagement. Childcare reported as a secondary activity is likely different in nature to that reported as the primary activity; the economic value of a minute of secondary childcare may be

some fraction of that of primary childcare. And evidently the two and three-quarter hours of child-co-presence shown in the third column has a different quality. However, as the table relates to children aged under 12, their copresence during other activities undertaken by their parents implies awareness of parental custodial responsibility during this time.

If multiple diary fields were not recorded, these additional amounts of child related time beyond the primary would simply be invisible. Certainly it would be *possible* to decide that childcare is the main interest and instruct diarists to over-write non-childcare primary activities with secondary childcare or child copresence wherever they occur. But then this would cease to be a general time use survey and become instead a childcare survey...which would mean it could not be used for the myriad of other potential applications of this data relating to other primary activities.

Note that all the broad activity categories include some child-copresence time (column 4). Plainly there is a need to take account of the volume of responsibility for children outside time explicitly reported as childcare — and capturing this child-related time implies a requirement for a continuous whole-day diary field registering co-presence.

The standard nationally-representative time use diary designs, such as the HETUS and ATUS, include a complete 24 hour co-presence field for recording who respondents were with (or accompanied by, or in the same room as) while doing activities, in which children are explicitly coded. Because, in paper or phone collected diaries such as the HETUS and ATUS, this field is voluntary, non-response is often high, particularly in self-complete HETUS-type surveys. An advantage of the online diary survey format is that it is possible to require diarists to complete the continuous co-presence field in order to submit the survey. Including this feature has the potential to avoid some of the ambiguity of, on the one hand, the non-response in the HETUS co-presence field, and, on the other, the complexities, sometimes ambiguities, of the relationship between children being recorded as 'in your care', and the co-presence diary field of the ATUS (Stewart and Allard 2015). Although there will always be some ambiguity about the recording of co-presence where this is not precisely specified (e.g. co-presence in the same house, the same room?), it is reasonable to suppose that someone who records the co-presence of their own child is at least conscious of the presence of their children in the near vicinity, and in some sense feels responsible for them.

4.1.1 Child-related time through the UK COVID-19 pandemic: an illustration

To show the potential of the continuous 'compulsory' online copresence field, we present here an analysis of a unique 6-wave (cross-sectional) time use diary data set - collected using the same online instrument and methodology in 2016 (pre-pandemic baseline) and across the main periods of pandemic social restrictions in the UK, including 3 periods of 'lockdown', two periods of the relaxation of restrictions and a final wave after the announcement of 'freedom day' in the UK (August 2021). The online diary instrument that we used (an earlier version of the ELiDDI), that required diarists to complete the co-presence field in order to submit the survey.

Note that for these analyses we focused on parents of children aged 16 and under, in contrast to the 'all UK adults' results shown in Table 1. We examined how the pattern of child co-presence across the waves of the survey varied for mothers and fathers across activities. We showed firstly that, in accordance with the arguments made in the previous section, time recorded with child co-presence (during activities other than childcare) far exceeded that for primary and secondary childcare, for both mothers and fathers. We attribute this to the requirement to complete the copresence field (however, it is worth considering too that conditions of lockdown, where many parents and children found themselves together at home over longer periods than they were used to, and under conditions of stress and uncertainty, may have heightened this sense of awareness of both the presence of, and responsibility for, children).

Figure 4 shows simple distributions of time recorded across the 6 waves of the survey, broken down into the (mutually exclusive) components of primary childcare time, secondary childcare time (when done with a primary activity other than childcare), and time spent co-present with children. The left side figure shows these three components separately – the right side figure shows cumulated totals of child-related time.

Figure 4. Primary and secondary childcare and child co-presence: fathers and mothers, UK CTUR 6-wave pandemic time use survey.
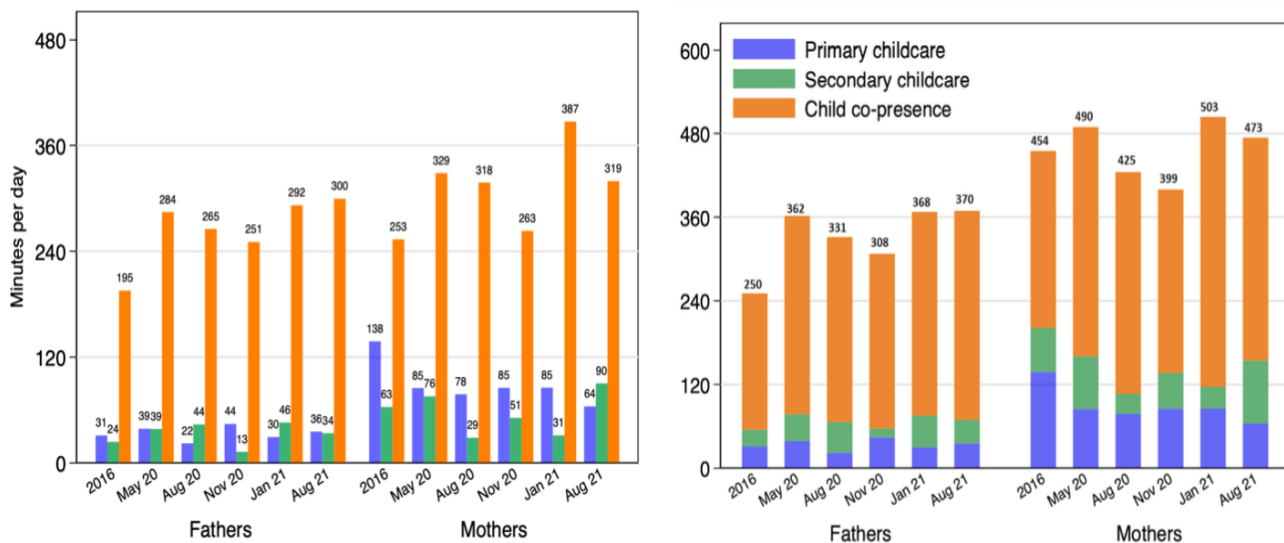
The figure shows changes in childcare time (mins per day) across the 6 waves of the UK CTUR pandemic survey data for mothers and fathers separately. The sample of parents is made up by men (945) and women (1,039) up to 55 years old living with children (N=1,984 quite homogeneously distributed across waves). Childcare time is broken down into three non-overlapping categories: childcare as defined by the primary activity, childcare as the secondary activity and other time with children.

For both mothers and fathers time spent with children recorded as co-present was higher across the pandemic period than in the pre-pandemic period. In contrast to the findings of some pandemic-related literature which did not include full diary fields of childcare and child co-presence (eg Adams-Prassl et al 2020; Chatot, Landour and

Pailhe 2023; Craig and Churchill 2020; Del Boca et al 2020; Giurge, Whillans and Yemiscigil 2021; Pabilonia and Vernon 2023), childcare recorded as a primary activity only by mothers during the pandemic decreased in relation to the pre-pandemic baseline. Fathers, on the other hand, increased (from a much lower base) their child-related time compared to the 2016 pre-pandemic survey, also increasing their share of child-related time, from 36% pre-pandemic to 44% post-pandemic (i.e. this increase persisted after the lifting of all restrictions).

As expected, certain activities were more likely than others to have children co-present: in particular the home-based activities of housework, home leisure activities and paid work at home. As an example, Figure 5 shows child copresence and total child-related time during housework activities.

Figure 5. Child co-presence during housework (fathers and mothers: UK CTUR 6-wave pandemic time use survey)
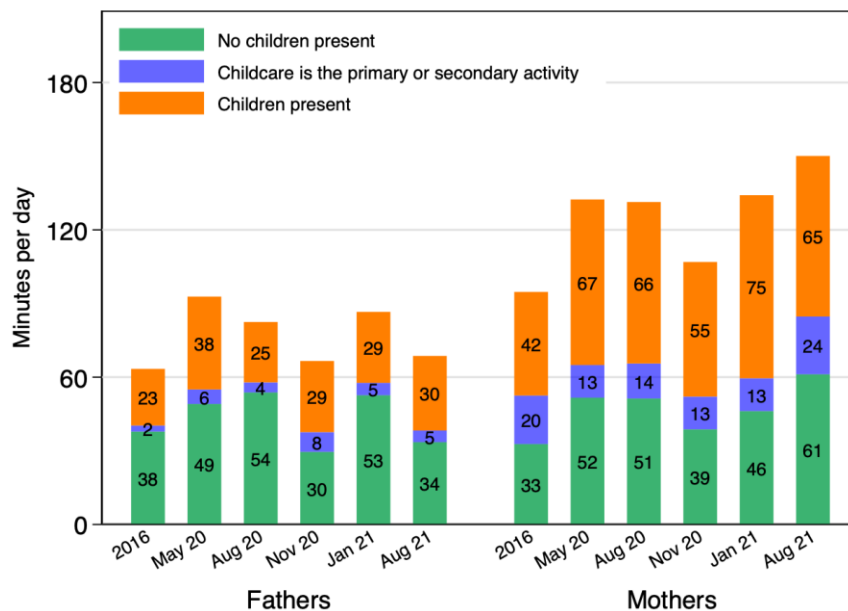
Housework is broken down into three non-overlapping categories/types: doing the activity without children being present, doing the activity with children co-present (but not declaring childcare as the activity) and doing the activity while doing childcare as well. The sample includes all fathers and mothers in the sample, N=1,984. Housework includes: Preparing food, cooking etc; Cleaning, tidying; Clothes washing, mending; and Maintenance diy, etc. It does not include other unpaid work such as shopping or care activities.

In accord with previous literature on the gender effects of the pandemic, time spent in housework was considerably higher for mothers across the pandemic period than before it, even following the end of restrictions in August 2021 (note this was a summer holiday period). An equivalent rise in housework time from a much lower base was evident for fathers during first lockdown (May 2020), although thereafter through the pandemic waves levels remained more or less similar, at around a 40% overall share

(unlike in the case of childcare where fathers' overall share increased), reverting after the end of restrictions to close to pre-pandemic levels.

Child co-presence whilst doing housework constituted a higher proportion of mothers' housework time than it did of fathers'. Indeed, total child-related time while doing housework (i.e. including housework done together with primary and secondary childcare, and, particularly, housework done with child co-presence) constituted the majority of mother's housework time throughout the pandemic waves. The percentage of child-related housework time that fathers reported was lower than for mothers. Nevertheless, it increased from 40% pre-pandemic in 2016 to 47% during the first lockdown. Even after the lifting of restrictions in August 2021 it remained a full 11% higher than in 2016, at 51% of their housework time.

4.2 The need for multiple continuous diary fields: 2) Computing activity and computing device-use

The "digital economy" is a substantial and rapidly-increasing part of all economic activity. Yet it is not well represented in economic statistics, in part because the use of IT devices spans the boundary between activities within the System of National Accounts (SNA), and activities that are clearly productive but lie outside the SNA. Time use diaries with multiple fields provide a range of what may prove to be key information for this extension to national accounting practice. Table 2 illustrates a range of different ways of measuring computer use from the ELiDDI dataset.

Table 2. Multiple measures of computing time (minutes): All UK adults, ELiDDI, March-April 2023		
	Mean	N
Using computer as primary activity	18	3754
Using computer as primary or secondary activity	28	3754
Tablet/desktop use, no primary or secondary mention	181	3754
All use of tablet or desktop (including where mentioned as primary or secondary activity)	200	3754

The primary and secondary activity fields tell us that just under 30 minutes per day are reported by respondents as the activity 'using a computer'. However, there are in addition just over three hours of *other* use of tablets or desktops reported. (This usage could be occurring perhaps in the context of paid work, perhaps for unpaid work such as childcare or shopping, or for streaming films/reading print media on-screen.) This addition substantially increases the time reported as involving ICT use.

4.3 The need for multiple continuous diary fields: 3) behavioural infection risk

At a time when capacity is still limited both in respect of immunization and track-trace technology, governments must continue to rely on changes in people's daily behaviors to contain the spread of COVID-19 and any future similar viruses. Using the same 6-wave UK pandemic dataset we were able to assign different levels of risk to combinations of three separate diary fields: activities, locations and copresence, to compare risk-related behavior across successive 'lockdowns' (Gershuny et al 2021). These assignments are made taking cognizance of the literature on COVID-19 infection transmission, which considers time at home alone or with members of the same household as lowest-risk, with the main focus for transmission being contact with non-household members, both at, or away from, home. The virus is more likely to be transmitted indoors, in unventilated spaces, in crowds, and through prolonged personal contact (eg Mugglestone et al 2022). Table 3 shows our detailed assignments for each combination of the three diary fields to one of four risk categories, ranging from lowest (1) to highest risk level (4). Estimates of risk vary according to the activity (e.g. cinema implies the presence of other, non-household, individuals), and are also influenced by location (e.g. indoors enclosed, vs open-air).

Table 4. Risk level assignments, by activity, location and co-presence combinations

	AT HOME		AWAY FROM HOME	
ACTIVITIES	**Alone/HH**	**Non-HH**	**Alone/HH**	**Non-HH**
Sleeping	1	4	2	4
Resting	1	4	2	4
Washing, dressing	1	4	2	4
Preparing food, cooking, washing up	1	4	2	4
Cleaning, tidying house	1	4	2	4
Clothes washing, mending, sewing	1	4	2	4
Maintenance of house, diy, gardening	1	4	2	4
Caring for own children	1	4	3	4
Help, caring for co-resident adults	1	4	3	4
Watching tv, video, dvd, radio, other music	1	4	3	4
Reading including e-books	1	4	3	4
Playing sports, exercise	1	4	3	4
Playing computer games	1	4	3	4
Spending time with friends, family	1	4	3	4
Telephone, text, email, networking, letters	1	4	3	4
Hobbies	1	4	3	4
Walking, dog walking			2	3
Travelling: walking, jogging			2	3
Travelling: cycle			2	3
Travelling: car			2	4
Travelling: bus, tram			4	4
Travelling: train, tube			4	4
Travelling: other			4	4

Going out to eat, drink eg pub, restaurant			4	4
Cinema, theatre, sports, cultural event			4	4
Eating, drinking, meal,at home	1	4		
Caring for other children	3	4	3	4
Help, caring for non-coresident adults, unpaid	3	4	3	4
Services: Doctor, dentist, hairdresser		4	4	4
Church, temple, mosque, synagogue, prayer	1	4	4	4
Shopping, bank etc including internet	1	4	4	4
Paid work including at home	1	4	4	4
Formal education	1	4	4	4
Recreational courses, study	1	4	4	4
Voluntary work for club, organisation	1	4	3	4
Work, study break	1	4	2	4

This process illustrates the imputation of rates or indices associated with one or more diary fields, to be applied across the population of diary days in a national time use diary survey. Examples include the metabolic expenditures (METs) associated with different activities, home energy usage (heating/lighting and domestic appliance consumption while doing home activities), the pollution footprint associated with different travel modalities etc. In this example, quantifiable information on changes in risk-related behaviour associated with different regulations on social behaviour can be provided to policy-makers (see Figure 4). We found that during the second UK lockdown (November 2020) there was an increase in high-risk behaviors relative to the first starting March 2020. This increase is shown in Sullivan et al 2021 to be associated with more paid work time spent in the workplace.

Figure 4:

UK daily risk-related behaviour across successive stages of the pandemic mins/day
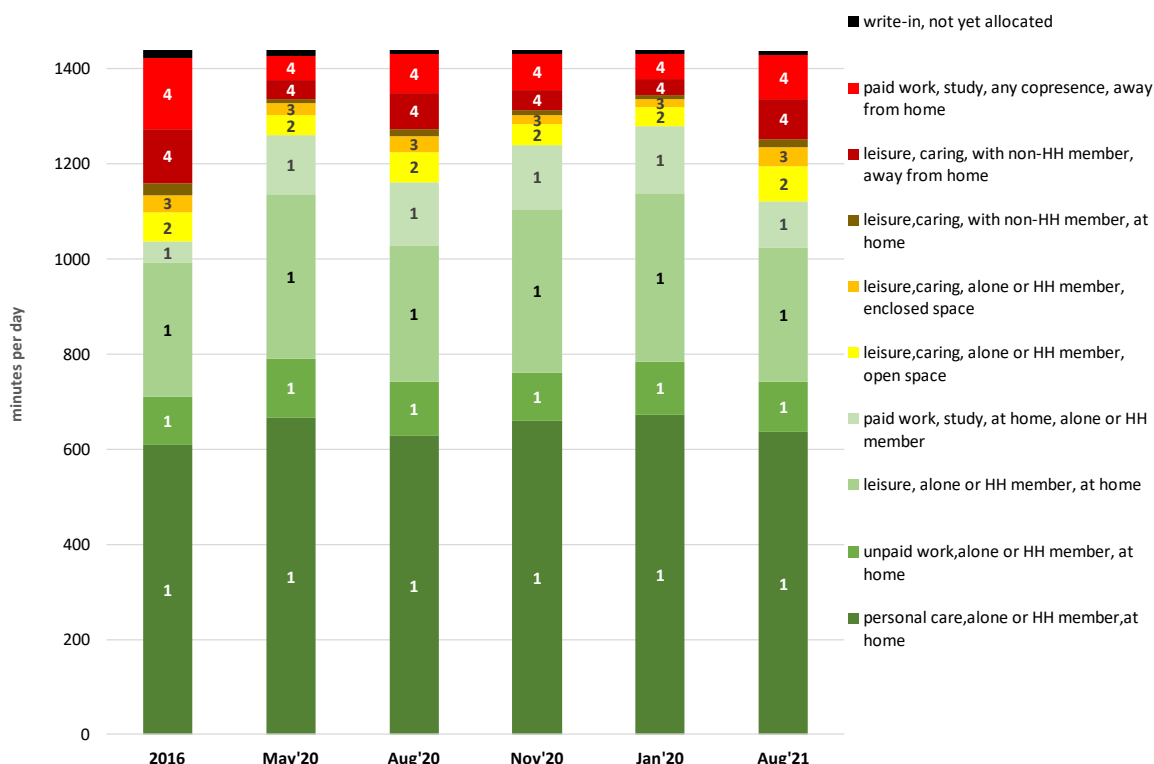
1 = low risk, 2-3 = medium risk, 4 = high risk of behavioural infection
Source: UK CTUR 6-wave pandemic time use survey

4.5 The need for independent timing of diary fields

Sequential continuous time-use diary data has a strong methodological connection to longitudinal event history data, from which analytic techniques are directly transposable (e.g. in multichannel sequence analysis; Gauthier et al., 2010, and in optimal matching analysis; Lesnard and Kan 2011, Lesnard et al., 2016). In longitudinal life-course analysis where there are multiple fields of events (e.g. employment and childbirth events), 'episodes' are conventionally defined as periods during which all fields remain unchanged. When a change occurs in any one field, a new episode starts.

In a time-use diary, a single unchanging main activity period may form part of several episodes defined in this way, during which a different secondary activity might be done, or the 'who with' field might change. Secondary activities often have quite different lengths to main activities (e.g. snacking while watching TV, reading while on public transport, using the phone at a family meal); enjoyment levels can vary according to whom one is with where the main activity is unchanged; digital devices can be used during just part of a main or secondary activity, etc.

In diary designs such as the ATUS and the MOTUS (see below), where the start and finish times of the main activity determine the timing of the other diary fields, these are

constrained to coincide with the timing of the main activity—precluding analysis of the true timing of the overlapping activities. The gold standard HETUS diary design, on the other hand, is based upon the independent timing of each of the diary fields, with no automatic link between the timing of the main activity and all of the other fields of the diary. This flexibility not only better reflects our lived experience of time, but accords with the accepted statistical convention for event history longitudinal data collection and analysis.

The additional detail provided by the independence of the timing of fields has important analytic consequences. Certain activities are particularly prone to being recorded as secondary (for example, snacking). Where episodes are delimited according only to main activities this results in: *either* the secondary activity being recorded as lasting the full duration of the main activity (e.g. a snack eaten for only 15 minutes at work is recorded as lasting the full five-hour work episode); *or* the secondary activity is simply omitted (e.g. using a smartphone for ten minutes is not considered worth recording during a 30-minute period where the main activity is 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 phones.

Table 5 shows the increase in the number of average daily episodes as more fields are added for both the whole sample, and for parents with children in the household, calculated from the ELiDDI 2023 sample. Average daily number of episodes has long been a measure of diary quality in the assessment of time use diary surveys, with greater numbers of episodes being regarded as a measure of success in eliciting accurate response. The first row shows that the average number of episodes increases from 16.8 (primary activity only) to 24 when episodes from all fields are added; a large jump in the context of this measure of time use diary quality, and an increase of 43% above the episodes of primary activity only (see row 2). For parents with children, important in the proper assessment of secondary child care and child co-presence, the increase in even more pronounced (note rows 3 and 4). For parents, adding the additional fields to the primary activity episodes results in an increase of a full 50% in recorded episodes (16.6 to 24.9 episodes per day). This additional increase results both from the reporting of a greater number of episodes of ICT device use (a probable effect of the younger age of parents compared to the full sample) and also, crucially, a greater number of copresence episodes (an important effect of the continuous record of child copresence).

Table 5: Change in the number of episodes as more activity fields are added. ELiDDI 2023

Part of day	Primary only	+secondary	+location	+copresence	+ICT	+enjoyment
Whole day: all	**16.8**	**19.7**	**20.7**	**21.4**	**23.0**	**24.0**
N episodes/N episodes primary only	1	1.2	1.23	1.27	1.37	1.43
Whole day: parents with children	16.6	19.7	20.8	22.0	23.9	24.9
N episodes/N episodes primary only	1	1.19	1.25	1.32	1.44	1.5

5. Extending the general principles of time use diary design online

In what follows we present a multi-field digital time use diary design modelled on the information collected in best practice pen-and-paper time use diary designs, and conforming to the four general principles of time use diary design outlined above. Many online diary tools designed for online self-administration, or CATI/CAPI collection, have compromised on the amount of information collected in an effort to reduce respondent burden. In part, this has resulted from a design that is based on repeated iterations of repetitive questions taking respondents through their day from the first activity from waking onwards in a series of repetitive questions: the 'survey-style diary design'.

In terms of design for online data collection there are currently three main approaches. The 'point-estimate' approach, developed mainly for collecting information on how people are feeling at particular times of the day, relies on the digital sampling of a few activities through a designated day. The other two approaches (the 'survey-like' approach and the 'light-diary-like' approach) follow the continuous diary method, collecting the full sequence of activities across the day; necessary for knowing about the timing or sequencing of activities. However, they vary substantially in their visual approach and functionality.

5.1 Point-estimate approach

In this approach, often referred to as the Experience Sampling Method (ESM), respondents are sampled (alerted) 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). 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).

The obvious disadvantage of this approach in respect of the full potential of time use data 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, 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).

5.2 Survey-style approach

This online method was pioneered by the Netherlands Institute for Social Research (Fernee and Sonck, 2014) and the TOR research group at Vrije Universiteit Brussel (Minnen et al., 2014). It 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 (incorporating a 'write-in' option). This is followed by the collection of further information for the same activity period, such as any secondary activities, who the activity was done with, and perhaps location information. This sequence of questions is then iterated for each main activity episode of the day. Figure 5 illustrates (top panel) the initial selection of the timing of an activity slot for the main activity, followed (lower panel) by instructions for selecting secondary activities for the same main activity episode.

Figure 5: Diary design using the survey-style approach (MOTUS)

In terms of respondent experience, this design can be likened to filling in an online survey, with repeated iterations of questions through the day for each main activity episode. The respondent does not receive a full visual representation of their diary day. MOTUS is available in both online and smartphone modes, and Statistic Belgium trialled a version for their 2021 HETUS data collection (Sabbe, 2022). The UK Office of National Statistics use a similar digital survey-type design for their ongoing annual collection of online time use diary data begun during the COVID-19 pandemic (East et al., 2021). An app based on a similar design was also used as an option in the Danish Time Use Survey of 2017 (Bonke and Christensen 2019). Problems using this approach have been identified, however, with issues of complexity and respondent burden due to the repetitive nature of the information gathering for each successive main activity (Te Braak, 2022 – see section below on comparisons of approaches).

5.3 Light diary-like approach

Because of its apparent simplicity, some of the key international agencies with interests in the collection of time use diary data have recently recommended what they refer to as a 'light diary' format for the collection of time use data (Hirway, forthcoming). These recommendations characteristically embrace a 'light diary' collection of 20-40 activities, accompanied by various contextual questions, including on child supervision. See, for example: United Nations Statistical Division (2024); International Labour Organisation Department of Statistics (2023); Charmes (2021 – for the Centre for Excellence in Gender Statistics, UN Women).

However, the appellation 'light diary' as used by the above agencies does not in most cases refer to the visually intuitive paper light diary format as illustrated in Figure 3 above. Rather, it is a reference to the restricted list of pre-coded main activities characteristic of the light diary, but collected according to a digital 'survey-style' approach (see above). The result of this is to greatly restrict the data collected by these instruments, without the benefits of the simplicity/speed of the light diary or its visually intuitive interface aiding recall.

The CTUR light diary-like digital diary, in contrast, is a direct development of the paper light diary visual format, but extended and enhanced for online use. This enables including more diary fields, and extending the list of activities to the full HETUS, or International Classification of Activities for Time Use Statistics – (ICATUS), classifications through the use of drop-down lists and menus. The basic idea is to mimic the visual intuitiveness and simplicity of the light diary design, while taking advantage of online functionality to extend and develop the light diary approach to include a full classification of diary fields and activities.

The approach was developed by the CTUR in response to calls for lower respondent burden in online time use diary instrumentation, while at the same time preserving the principles of general-purpose time use diary data collection (Sullivan et al 2020). In the original design (that we named CaDDI for its 'Click and Drag' functionality), respondents select an activity, then click and drag their pointer across a horizontal timeline bar (marked in 10-minute timeslots across the hours of the day) to indicate the length of

time they spent doing each main activity. This is directly analogous to drawing a line across (or down) the page in the pen and paper light diary design (refer to Figure 2). However, while the traditional pen and paper light diary is only able to collect a limited range of activities in order to fit on a single page (for ease of viewing and completion), the online functionality of the light diary-type digital approach enables the expansion via dropdown menus to the richness of the full diary design, while maintaining the simple and intuitive light diary visuals. It can overcome the main restriction of the light diary design by using 'unfolding' (sequentially nested) drop-down lists of activities, to provide levels of detail rivalling those of the HETUS or ICATUS classifications. A parallel version designed for a vertical, smaller, screen (such as a smartphone), uses a vertical scroll functionality designed for a touch screen.

Figure 6 shows a screenshot of a completed example of the most recent version of the CTUR digital diary instrument (Extended Light Digital Diary Instrument - ELiDDI) in horizontal mode. Activities are identified using drop-down menus and are shown along the timeline in different colours. The screen is filled using the same 'click and drag' functionality with successive rows of the standard time use diary fields 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 completed picture represents in visual form a day's worth of time use with the same diary fields as the HETUS.

Figure 6: A completed Extended Light Digital Diary (ELiDDI): horizontal mode
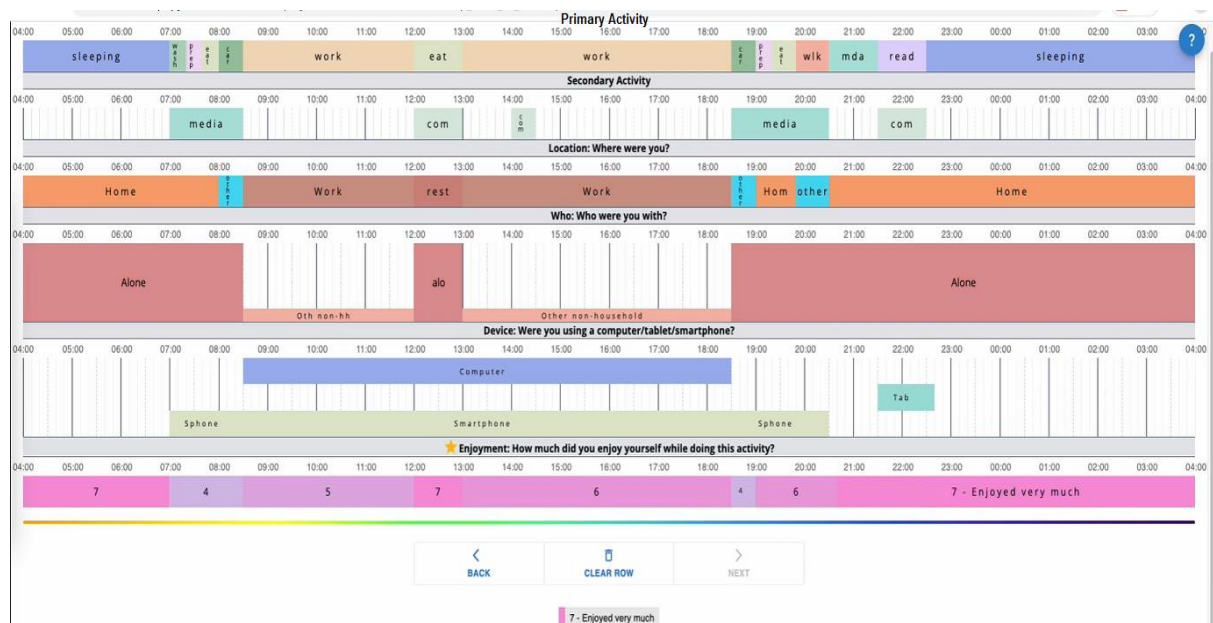
In the completed diary the coloured record for the entire day is displayed, permitting the identification of any gaps, errors or inconsistencies, that may then be edited. Figure 7 shows, as an example, filling in the main activity field in the horizontal mode, while Figure 8 shows completion of the 'who with' field on the vertical screen mode. (Due to the more limited screen size, the vertical mode diary for smartphones shows

only main and secondary activity in vertical columns as an aide memoire to the completion of the other fields of the diary).

Figure 7. Filling in the main activity (1ˢᵗ diary field): horizontal screen mode

Figure 8. Filling in the 'who with' field of the diary: vertical screen mode
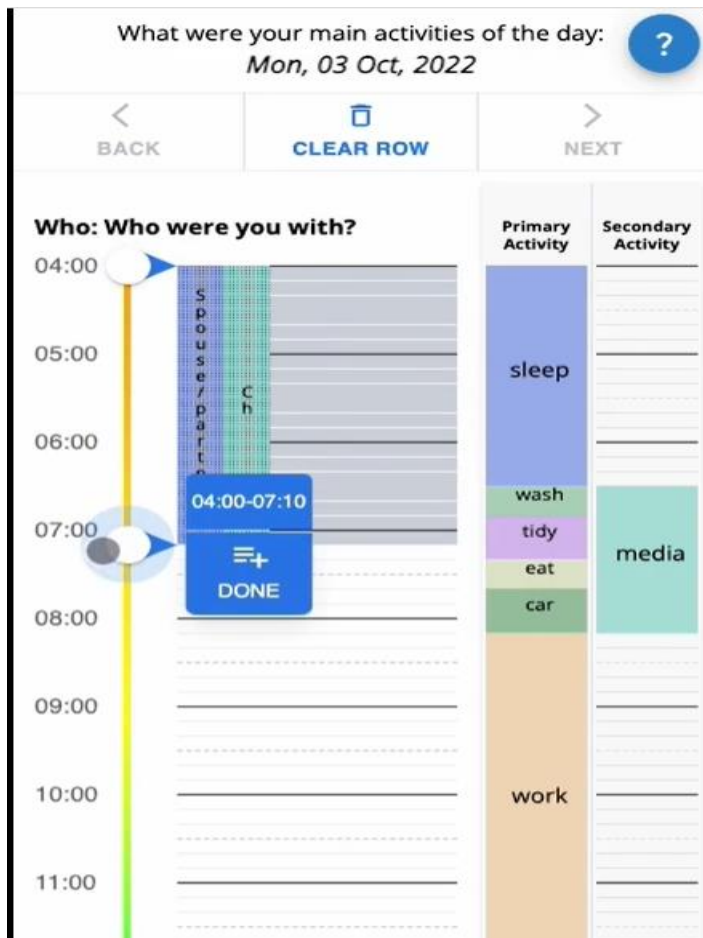
A demonstration file showing the process of completion for both a horizontal (computer/laptop screen) or vertical (smartphone) functionality is available from the CTUR website: timeuse.org (under the 'New HETUS-compatible CaDDI' box on the home page).

A central feature of the light-diary type digital design is that it collects and displays the entire sequence of activities through the whole diary day, as in the light diary design. It is intuitively easy for respondents to fill by moving a pointer across the day's timeline, and the complete diary creates a visually intuitive and informative picture of the day's activities. There is growing evidence that this alternative to the survey-style online model may be less burdensome in terms of repetitiveness (avoiding the burden of having to enter each main activity into the time-log, followed by iterated lists of drop-down menus to complete the remaining diary fields for each main activity episode). While full 'click and drag' functionality is not accessible to some, variants are available using zoom pointers and click-click technology (as opposed to click and drag) to enable greater accessibility.

As in the pen and paper light diary, the extended digital light diary design also exhibits complete independence between the diary fields ('who with' information is not tied to the duration of a primary activity, for example), permitting full flexibility in analysis.

6. Survey-style vs 'light-diary'-type visual presentation compared

Several countries and organisations are starting to reconsider the 'survey-style' approach to online time use diary data collection. The ILO recently concluded that a graphical approach would be preferable, stating that a "more intuitive visual open-source application' should be adopted, once this becomes available (ILO 2023).

A recent PhD thesis from Vrije Universiteit Brussel, analysing the performance of the survey-style MOTUS instrument, concluded that:

"In sum, it can be concluded that the shift to self-administered online time-diaries is mainly beneficial for researchers, whereas it has proved less positive for respondents who still struggle with the complexity and high participation burden. To overcome this, respondents adapt their participation behaviour, which undermines the validity of the method. *Future adaptations to the measuring instrument should prioritise the reduction of the complexity and the burden of participation from the respondent's perspective*."
Te Braak, 2022 (our italics)

Clearly, respondent burden is an issue with the survey-style instrument. There have been two recent research papers directly comparing results from a traditional pen-and-paper light diary with both a 'light diary-like' web-based diary and a MOTUS-style 'survey-like' smartphone-based app for the UK Millenium Cohort age 14 cohort study (Chatzitheochari et al., 2018; Chatzitheochari and Mylona, 2022*). The authors concluded that diary completion quality measures demonstrated the superiority of the web-based 'light' diary:

"It was found that, for these young people at least, after controlling for observable characteristics associated with diary mode selection and adolescent time-use, the web and app diaries yielded higher quality data than paper diaries. *However, the web-based 'light diary' design yielded a higher average of episode changes per day (a measure of diary detail and hence quality) compared to both paper and app diaries*"
Chatzitheochari et al, 2018 (our italics)

and:

"our analyses show that app diarists were more likely to use the 'any other activity' code than paper or web diarists. We argue that this is associated with the markedly different diary format of the MCS app instrument, *which is more cognitively demanding than the paper and the web instrument, both of which provide a visual representation of the surveyed day* and the range of broad time-use domains available to the diarist."
Chatzitheochari et al., 2018 (our italics).

From methodological work to date on the ELiDDI design (refer to Table 5 above on mean number of episodes, and section below on completion time), its mimicking of the light diary visuals while including the multiple independent fields of the HETUS diary, does not lead to an erosion of data quality, or increase respondent burden.

7. The extension to CATI/CAPI formats.

A general-purpose design, incorporating multiple continuous diary fields, is important because provides a versatile dataset that is being increasingly used internationally across a wide range of substantive and policy applications.

However, in recognition that not everyone will be able to access an online time use diary, perhaps particularly in LMICs, a CATI version of the ELiDDI diary was also developed, in which interviewers record the diary day in the same way as online respondents[ii].

A test of the CATI version was undertaken in the ELiDDI UK nationally-representative time use survey, undertaken in March-April of 2023, fielded by NatCen and supported by the ONS-funded Economic Statistics Centre of Excellence (ESCoE). For this survey 10% of the sample were interviewed using the CATI instrument. NatCen have compiled a detailed report on the use of ELiDDI, including recommendations for its future improvement. They found that the CATI version collected information that was as good quality as the online version, with slightly higher response rates. It was also regarded highly by the telephone interviewers, who found it easy to understand and complete.

The CATI version of the ELiDDI took on average a couple of minutes more time to complete than the web version (excluding very long and very short completion times): approximately 28 minutes vs approximately 26 minutes. The CATI format would be transposable and equally applicable to a CAPI design, with the advantage that respondent and interviewer could look together at the diary day.

Conclusion

One of the problems that has beset the design of time use diaries for digital application is that they did not start from first principles – they did not begin with the guidelines developed historically for the best collection of time use diary data, accumulated over decades of data collection. These first principles most notably include multiple continuous independent diary fields, and the visual look and feel of the diary. In part this lack of attention to previous design development may have been due to technical issues in the digital platform – at the time when the first such diaries were developed, the survey style approach may have seemed 'top of the art'. However, repetitive iterative questions are burdensome for respondents, and the obvious compromise from many survey agencies has been to cut the number of diary fields and/or the number of surveys. Further, the repetitive iterative survey-style formula, based primarily on ease of programming, has necessitated eliminating the principle of independent diary fields, so that respondents are asked these questions based on the sequence of successive primary activities.

Design technologies have now developed to a point where much greater flexibility is possible. In the current state of the art there is no need to persist with an online diary design that does not follow the principles of established best practice. What is important for the design of a good general-purpose time use diary is that it retains the principles of multiple continuous independent diary fields, and a visual interface that reproduces for the respondent as far as is possible the look and feel of their actual diary day in order to aid recall. The visual interface represented by a design such as ELiDDI

can now be reproduced by any competent programmer, and the design is as flexible as the purposes for which it is needed via the use of drop-down menus and pop-up boxes. Evidence is accumulating that this approach is less burdensome for respondents and at the very least leads to no degradation in data quality compared to the survey-style approach. Moreover, its visual intuitiveness makes it suitable for interviewer use in contexts where digital literacy cannot be assumed.

Acknowledgements

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[i] The Multinational Time Use Study (MTUS) archive, assembled, harmonized and disseminated by the ESRC Centre for Time Use Research (CTUR) is the largest available collection of comparative and historical time-use diary data, including 2.2 million days from more than 100 surveys across 30 countries, all harmonised ex-post (www.timeuse.org/mtus; Lamote de Grignon Perez, 2023).

[ii] The CATI version of the ELiDDI diary was developed by the National Centre for Social Research (UK), The software used is Unicom Intelligence (UI), with the scripting language Unicom Intelligence Professional.