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Does mode matter? The impact of using a mixed mode time use diary on data quality and measurement in the Age 14 Survey of the Millennium Cohort Study

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Introduction

Time diary data provide a comprehensive and sequential account of daily life and are used for a wide range of analytic purposes. Recent years have witnessed a steady growth of large-scale time diary data collection in cross-sectional as well as longitudinal surveys, driven by the increased research interest in population activity patterns and their relationship with long-term outcomes. The majority of social surveys collect paper-administered diaries, which have been shown to produce accurate and reliable daily activity estimates, but present challenges relating to respondent burden and administration costs. The use of new technologies for data collection could address these weaknesses by providing less burdensome diary instruments, improving data quality, and reducing post-fieldwork data coding costs.

The Millennium Cohort Study (MCS) was, to our knowledge, the first large-scale longitudinal survey in the world to use a mixed-mode approach for the collection of time use data among teenagers. A smartphone app, web diary, and paper diary were specifically designed for the sixth wave of the survey, when cohort members were aged 14. This was a highly innovative approach, utilising new technologies to collect comprehensive accounts of the daily lives of teenagers.

Respondents were asked to choose between the web and app mode during the interviewer visit. Paper diaries were only offered to those who did not have access to a personal computer or a smartphone, as well as those who refused to use the web/app modes. The web and app instruments allowed the use of soft and hard checks in order to reduce missing data and to improve overall data quality, leading to simplified post-fieldwork data coding procedures. The MCS approach is therefore particularly important for the future of time use research, opening up avenues for methodological innovation and for the use of new technologies for large-scale time diary data collection.

Background

Previous sweeps of MCS have asked respondents questions about how they spend their time and the activities they do, focusing on age-relevant activities such as after-school activities, leisure activities and homework. This provides researchers with some idea of how young people spend their time, but asking a limited number of questions on pre-defined activities does not give a complete picture of how young people spend their time. For this reason, a time use diary was included in the Age 14 Survey of MCS, in order to better understand the time allocation of teenagers.

Time use diaries ask respondents to report sequentially their activities, and the context, across 24 hours of a day. This method of collecting time allocation data has shown to produce better estimates of daily activities than survey questions (Carp & Carp 1981; Juster, Ono & Stafford 2003). It is thought that time use diaries help respondents to recall activities better, and reduce social desirability bias (Robinson & Godbey 1999; UNECE 2013). Additionally, time diaries can provide more detailed information than survey questions, covering activities undertaken, duration of each activity, time of day for activities and a number of contextual bits of information, such as who the respondent was with when doing the activity, where they were, and how much they enjoyed it.

Traditionally time diaries have been administered in paper format, with the respondent required to complete a time grid within a booklet. The grid is formatted so as the pre-coded

activities are down the side, and time slots across the top. In order to complete the diary, respondents draw horizontal lines to indicate what they were doing for each of the time slots (usually 10-minute slots). Alternatively, the activities may not be pre-coded, so respondents are required to write each activity they do across the day. The grid format has been shown to facilitate respondent recall of events, creating more accurate estimates of time spent doing each activity (Robinson & Godbey 1999).

However, scanning, coding and processing of paper time use diaries can be prohibitively expensive, particularly for studies who have large-sample sizes. One way to reduce costs is to administer diaries electronically. This cuts out the need to scan and code diaries. Electronic diaries may also offer other benefits. In a world where technology is now routinely used by the population in all facets of life, there may be benefits for response rates of offering the opportunity to complete surveys electronically, be that via PCs or smartphones. In addition, web- and app-based time use diaries can be programmed with data quality checks, something which is not possible for paper diaries. The electronic diary can prevent respondents selecting more than one activity for a given time slot, and highlight improbable inputs, such as a large amount of time doing one activity that wouldn't be expected. The respondent can also be provided with a summary of their activities once they go to submit the diary, showing any timeslots missed and encouraging users to go back and complete the diary more fully. The app in particular also facilitates real-time data collection in a way that is easier than with paper diaries; one would expect that most people who own smartphones carry them around day-to-day, and so their diary is always accessible. It may be that data captured closer to real time is more accurate, through the reduction of recall bias (Bell et al. 2019).

Web-based time use diaries are becoming more common, although the majority follow a question-based approach to capture time allocation, rather than utilising the traditional grid format (e.g. Bonke & Fallesen 2010). However, as discussed previously, the grid format has been shown to be better at generating a more accurate picture of daily activities.

There is also a rise in the use of smartphone apps to collect time use data. With the increased use of smartphones across the population of the UK (Ofcom 2018), researchers are increasingly interested in collecting data via smartphones. In terms of time use research, a grid-based approach would not work well on a small screen, so designers have been turning to question-based apps to collect this data (Fernee & Sonck 2014; Vrotsou et al. 2014).

In the context of MCS, collecting data from teenagers in the UK, the research team decided it was crucial to offer the option of filling in the time use diary via web or smartphone app. Data collected from cohort families in the past suggested that the vast majority of families would have a PC and internet access at home, and many cohort members would have access to a smartphone, or own their own device. The ownership of smartphones among adolescents in the UK is high and increasing (Ofcom 2014), and offering this option for filling in the time use diary was deemed crucial for engaging participants in this age group.

The MCS web diary was, to our knowledge, the first stand-alone diary in the world administered on a large scale that utilised the grid format online, retaining the benefits of the traditional time diary method. It was also the first large-scale longitudinal survey to employ a mixed-mode approach to time diary data collection, combining app, web and paper formats.

Research questions

The interests of this paper are threefold, namely:

1. Do electronic methods of time use data collection improve data quality over traditional paper diaries?

2. Does a non-grid format work as well as a grid format for time use data collection?

3. Does measurement differ between the different modes of data collection?

Design and Methods

The study

The Millennium Cohort Study is a large-scale longitudinal survey following the lives of 19,000 children born between 2000 and 2002 in the UK. The Age 14 Survey took place across 2015, and included a wide range of in-home survey elements. The cohort members completed an electronic self-completion questionnaire, cognitive assessments, physical measurements, and provided a saliva sample for DNA extraction. They were also asked to wear an accelerometer after the interviewer's visit, and complete a time use diary. The inclusion of a time diary in the sixth sweep of MCS, alongside accelerometer data collection for the same time period, provided unique information on daily life in early adolescence (age 14), thereby increasing the utility of MCS as a major longitudinal resource.

Diary design

Respondents were asked to fill in a 24-hour time diary for two randomly selected days, a weekday and a weekend day. Sampling one random weekday and one random weekend day is increasingly common in time use research. This approach achieves a balance between the depth of information available to researchers and burden placed on the respondent (European Commission 2008).

In order to further minimise respondent burden, the MCS diary was a light, pre-coded diary, providing 44 age-appropriate activity codes, grouped under 13 broad categories, which cohort members could use to describe their time allocation during the two designated days. Activity codes were devised in line with existing harmonized activity categories in time use research. The activity scheme is age-appropriate, including activity codes that are particularly relevant for young people of the new century, such as use of social media.

As well as asking for the main activity, the diary also collected contextual information: location, who the respondent was with, and their enjoyment of the activity.

For further information on diary design and implementation, and the piloting phases, see Chazitheochari et al. 2015 and Chatzitheochari et al. 2018.

The instruments

Paper

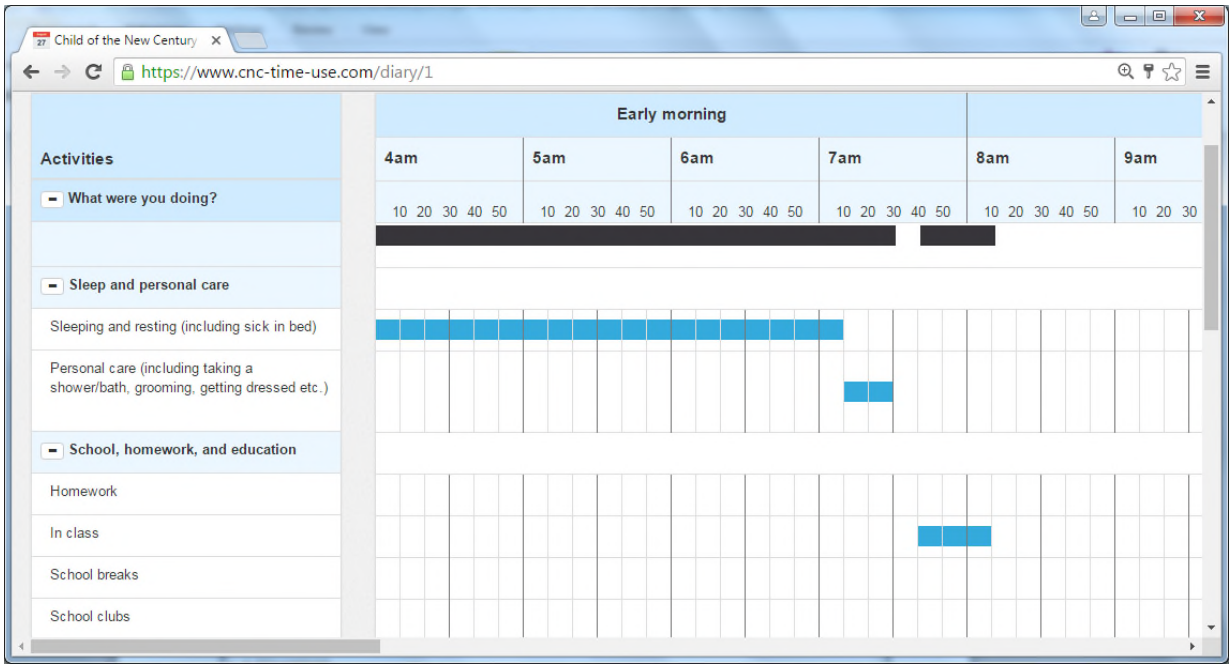
The paper diary was a traditional, pre-coded grid. The activity codes were listed down the side of the page, and 10-minute time slots across the top. In order to fill in the diary, respondents were required to draw horizontal lines to indicate the activity they were doing for each time slot.

The contextual codes (location, who with, and enjoyment) were listed beneath the activity codes.

Web

The web instrument was set up in the same "grid" format as a traditional paper diary, with the activity codes listed down the side, and 10-minute time slots across the top. In order to input an activity, respondents had to drag and drop a horizontal line across the screen to indicate which activity they were engaged in for each time slot. The 44 activity codes were initially 'hidden' underneath their top-level categories, so to select an activity respondents had to first select the broad category which would then unfold the specific activity codes for them to choose from. Figure 1 shows activity entry for the first part of a day. The black bar across the top is a progress bar, showing respondents which slots they had entered an activity for. This is an easy way to indicate to the respondent any slots which they have missed, and improve data quality.

Figure 1: Entry of activities into the web diary



Due to the grid structure of the web diary, respondents could report a change in location, who they were with, or their enjoyment of an activity part way through an activity record. Participants were not required to complete every time slot for activities or contextual codes.

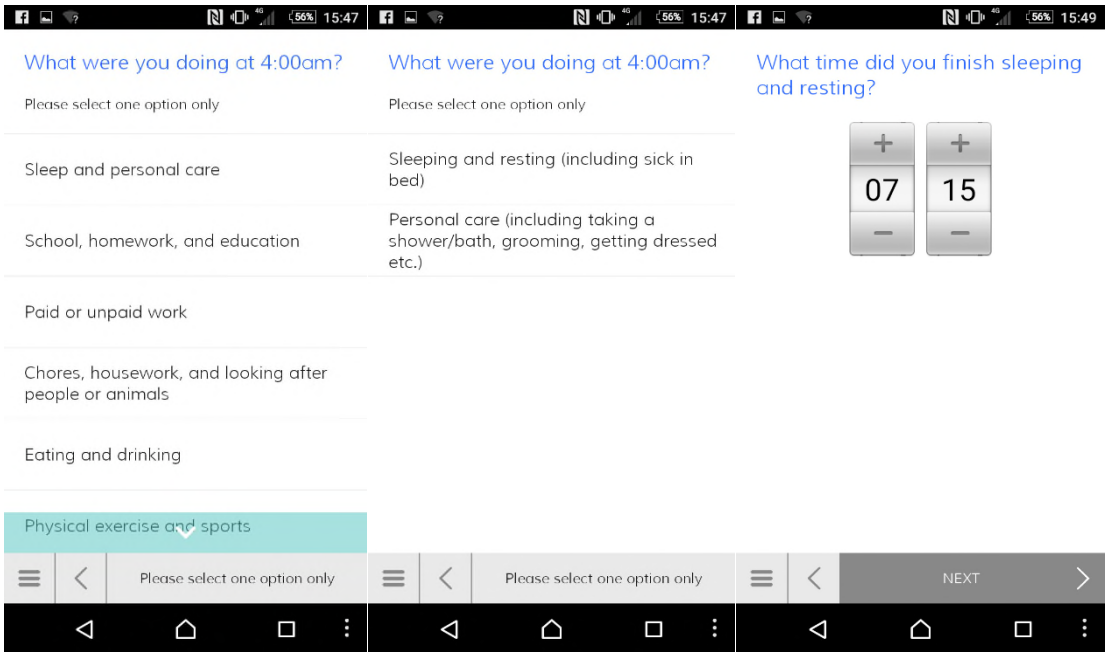
App

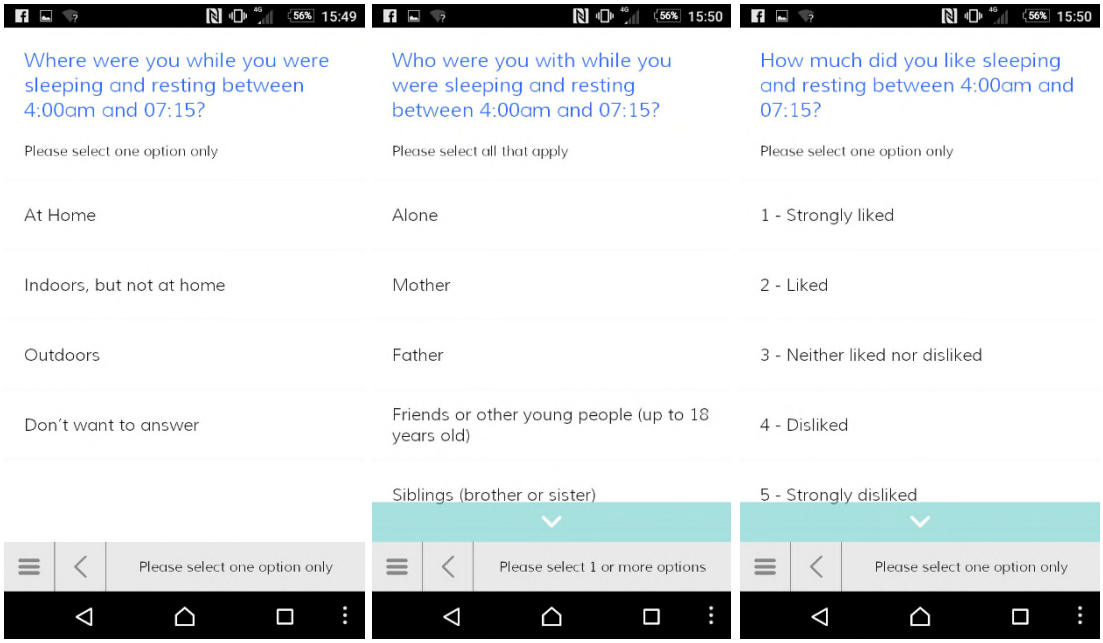
The app diary was set up in a very different way to the paper and web versions; instead of a grid layout, a question-based approach was used. In order to complete the diary, respondents were first required to select the top-level code that their activity fell under, then the activity itself, followed by the time it ended, where they were, who they were with and how much they liked it, in a linear format. Instead of using 10-minute slots (as the web and paper versions did), the app allowed cohort members to assign the ending times of their activities. More specifically, the first starting time was set at the start of the day (4am), and the subsequent starting times were set to match the ending times of the previous activity reported by the user.

Due to the structure of the instrument, contextual elements were coterminous with the main activity. This means that app diarists were not able to specify changes in enjoyment or location of their recorded activities like the paper and the web instrument allowed. However, diarists could register two consecutive episodes for the same main activity, with different contextual elements. Contextual dimensions were “intrusive” in the app, which means that users had to provide information on all domains before registering another activity. For this reason, a “Don’t want to answer” option was provided for each contextual question.

Figure 2 shows the sequence of screens for entering the first activity of the day.

Figure 2: Entry of activities into the app diary





Implementation of the instruments

Once the mode choice was made by the cohort member, the Computer-Assisted Personal Interviewing (CAPI) program randomly selected one weekend day and one weekday within a seven-day period for the young person to complete the time diary. For cohort members completing the web or app version of the diary, interviewers gave them a unique login code, which allowed them to log into the instrument. The code also allowed the survey team to link diaries to cohort members' survey data. Cohort members were advised to log out of the web or app diary when they were not using it in order to protect privacy on shared devices.

The web and app diaries allowed for the implementation of a range of error messages in order to improve data quality. The main one was triggered when an activity other than sleeping or school was reported to last more than three hours. This was a soft check and respondents could confirm whether their report was correct or not. Additionally, errors were triggered if respondents tried to submit the diary with no data (a hard check, which prevents submission), or with the full 24-hour period not completed (a soft check, allowing the submission of incomplete data). In the web diary, hard checks were implemented which prevented the user entering more than one activity for any given time slot.

For cohort members completing the web or app diary, an 'aide-memoire' was provided; a paper booklet where participants could note down what they were doing throughout the day for periods when they could not access their electronic diary (such as when they were at school).

Summary of modal design differences

Table 1 provides a summary of the main design differences between the three modes, focusing on the overarching approach to information collection, the time-unit, the collection of different diary dimensions, the data quality checks available, and whether an aide-memoire was used.

Table 1: Summary of design differences between modes

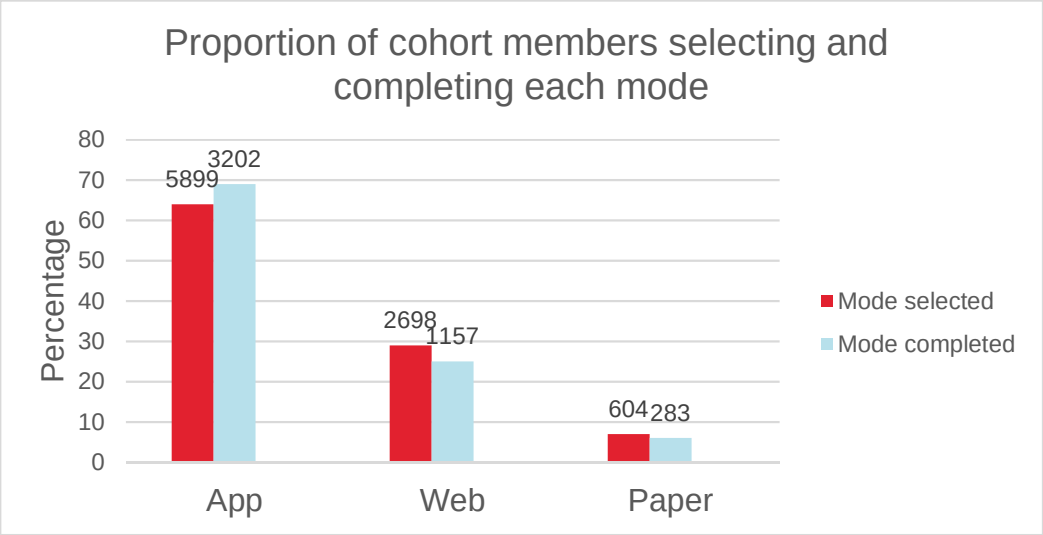
	Paper	Web	App
Approach	**Time-grid**	**Time-grid**	**Question-based**
Time-unit	**10 minute slots**	**10 minute slots**	**User-assigned start and end times**
Diary dimensions	**Overlap**	**Overlap**	**Coterminous**
Soft and hard checks	**No**	**Yes**	**Yes**
Aide-Memoire	**No**	**Yes**	**Yes**

Results

Take up and selection into mode

In total, 9,238 cohort members agreed to complete the time use diary, 89% of eligible respondents. Sixty four percent chose to use the app, 29% web and 7% paper. 4,642 cohort members actually completed the time use diary, 69% using the app, 25% web and 6% paper. A higher proportion who initially opted for the app actually went on to complete the diary, when compared with web and paper, as seen in figure 3.

Figure 3: Proportion of cohort members selecting and completing each mode



We observed some differences in characteristics of those who completed a diary across modes (these characteristics were all measured at age 14):

- 64% of boys and 74% of girls chose the app.
- Those who used social networks for more hours per week were more likely to use the app (no use = 43% chose app, over 7 hours per week = 80% chose app).
- Those whose parents owned their homes were more likely to use the app than those who lived in rented houses or other arrangements (70% own home, 67% renting, 65% other).
- No differences between one and two parent households.
- Those who are above the OECD 60% median income are more likely to use the app than those below the median (70% vs. 65%).

Table 2 shows the sample composition profile for a number of different samples. The first is the achieved sample for the Age 14 Survey as a whole, the second is the group of respondents who completed the time use element of the survey, and the final three are the modes of time use diary completed. Survey non-response weights have been applied.

Table 2: Sample composition profiles for the survey, the time use component, and the three modes

Demographics	Age 14 Survey respondents	Time use respondents	App (95% CI)	Web (95% CI)	Paper (95% CI)
Cohort member gender - female	47.7%	52.8%	58.2% (56.5-59.8)	46.1% (43.3-49.0)	51.2% (45.4-57.0)
Mother's age at 1st live birth (mean)	24.6 years	25.6 years	25.4 years (25.2-25.6)	26.3 years (26.0-26.7)	24.4 years (23.8-25.1)
Cohort member ethnicity – white	84.6%	86.8%	88.1% (86.9-89.2)	82.6% (80.3-84.8)	78.2% (72.7-82.8)
Cohort member ethnicity – mixed	3.3%	2.8%	1.9% (1.5-2.5)	3.1% (2.2-4.3)	3.4% (1.8-6.5)
Cohort member ethnicity – Indian	2.1%	2.2%	2.5% (2.0-3.1)	3.7% (2.7-5.0)	1.9% (0.8-4.5)
Cohort member ethnicity – Pakistani	3.4%	2.7%	3.1% (2.6-3.8)	3.6% (2.7-4.9)	7.3% (4.7-11.1)
Cohort member ethnicity – Bangladeshi	1.3%	1.0%	1.4% (1.0-1.9)	2.1% (1.4-3.1)	2.7% (1.3-5.5)
Cohort member ethnicity – Black Caribbean	1.3%	0.9%	0.6% (0.4-1.0)	0.8% (0.4-1.6)	0.8% (0.2-3.0)

Cohort member ethnicity – Back African	2.1%	1.9%	1.0% (0.7-1.4)	1.9% (1.2-2.9)	4.2% (2.3-7.5)
Cohort member ethnicity – other ethnic group	1.8%	1.7%	1.4% (1.0-1.8)	2.2% (1.5-3.2)	1.5% (0.6-4.0)
Housing tenure at previous sweep – home owners	55.1%	63.9%	75.5% (74.0-77.0)	77.1% (74.6-79.5)	59.7% (53.8-65.4)
Main parent's highest educational qualification – none	12.8%	8.2%	6.0% (5.3-6.9)	4.5% (3.4-5.8)	11.7% (8.4-16.1)
Main parent's highest educational qualification – NVQ1	7.9%	5.7%	4.5% (3.8-5.3)	4.6% (3.6-6.0)	7.7% (5.0-11.5)
Main parent's highest educational qualification – NVQ2	26.4%	26.6%	22.2% (20.8-23.7)	18.7% (16.7-21.1)	27.7% (22.7-33.3)
Main parent's highest educational qualification – NVQ3	14.6%	15.2%	15.7% (14.4-17.0)	14.4% (12.5-16.6)	12.4% (9.0-16.9)
Main parent's highest educational qualification – NVQ4	27.9%	33.0%	38.2% (36.5-40.0)	41.5% (38.6-44.4)	27.0% (22.1-32.6)
Main parent's highest educational qualification – NVQ5	7.5%	8.6%	11.3% (10.2-12.4)	13.1% (11.3-15.2)	10.6% (7.4-14.8)
Number of parents living in the household at previous sweep – 2	72.4%	77.4%	81.2% (80.6-83.3)	84.8% (82.6-86.8)	76.4% (71.0-81.0)

Main parent's social and economic status – none	35.5%	30.1%	26.6% (25.0-28.1)	28.8% (26.2-31.5)	42.9% (37.2-48.8)
Main parent's social and economic status – managerial and professional	25.3%	25.6%	31.4% (29.8-33.0)	31.0% (28.4-33.8)	20.7% (16.3-25.9)
Main parent's social and economic status – intermediate	15.2%	17.4%	17.9% (16.6-19.3)	18.4% (16.2-20.7)	16.0% (12.1-20.8)
Main parent's social and economic status – semi-manual employee and self-employed	6.0%	7.4%	7.4% (6.5-8.4)	6.8% (5.5-8.4)	3.6% (2.0-6.6)
Main parent's social and economic status – Lower supervisory and technical	2.0%	2.0%	1.9% (1.4-2.4)	1.5% (0.9-2.4)	2.5% (1.2-5.2)
Main parent's social and economic status – semi-routine and routine	16.0%	17.1%	14.9% (13.7-16.2)	13.5% (11.7-15.7)	14.2% (10.5-18.8)
Country – England	82.6%	80.0%	60.0% (58.3-61.7)	65.5% (62.7-68.2)	65.8% (60.0-71.2)
Country – Wales	4.9%	5.2%	15.0% (13.7-16.3)	12.7% (10.9-14.7)	18.2% (14.0-23.2)
Country - Scotland	8.3%	10.2%	13.9% (12.7-15.1)	12.7% (10.9-14.7)	5.5% (3.3-8.9)
Country – Northern Ireland	4.2%	4.6%	11.2% (10.1-12.3)	9.2% (7.6-11.0)	10.5% (7.4-14.8)

Family size – 3-5	57.2%	57.9%	58.6% (56.9-60.3)	55.8% (52.9-58.6)	54.2% (48.2-60.0)
Family size – 6-8	40.2%	39.9%	39.3% (37.6-41.0)	42.4% (40.0-45.3)	42.2% (36.5-48.1)
Family size – 9+	2.7%	2.2%	2.1% (1.7-2.7)	1.8% (1.2-2.8)	3.6% (2.0-6.6)

The sample composition profiles show differences between the whole sample and the time use diarists, and between those completing the diary across the three modes.

Sex

Time use diary respondents were more likely to be female than for the whole sample. Girls were significantly more likely to use the app diary than the web.

Mother's age at first live birth

The average age of the mother of the cohort member at their first live birth was higher for the time use respondents than for the whole sample. Cohort members with an older mother were significantly less likely to complete the time use diary using paper, and significantly more likely to use the web.

Ethnicity

White and Indian cohort members were overrepresented in the sample completing the time use diary compared with the whole sample for the Age 14 Survey. Conversely, Pakistani, Bangladeshi, Black Caribbean, Black African, those with mixed ethnic backgrounds and other ethnic groups were underrepresented. White cohort members were significantly more likely to use the app than the other modes. Pakistani and Black African cohort members were significantly more likely to use the paper diary than the app.

Housing tenure at previous sweep

The time use sample were considerably more likely to live in a household who owned their home (either outright or with a mortgage) at the time of the Age 11 Survey than the whole of the sample – 64% versus 55%. The home-owning group were also significantly less likely to have completed their time use diary using the paper version than the other two modes.

Main parent's highest educational qualification

Cohort members whose main parent had no qualification, or NVQ1 or equivalent were underrepresented in the time use sample compared with the main sample, and those with parents with qualifications equivalent to NVQ2 or higher were overrepresented. Those whose parents had no qualifications were significantly likely to use the paper diary over the two other modes, and those whose parents had an NVQ2 or equivalent were more likely to use the paper over the web. Conversely those whose parents had an NVQ4 were less likely to use the paper diary than the two other modes

Number of parents in the household

Cohort members who were living in household with two parents at the previous sweep were overrepresented in the time use sample. This group were also less likely to use the paper diary than the web version.

Main parent's social and economic status

Cohort members whose main parent reported not having a job at the previous sweep were underrepresented in the time use sample. All other groups were overrepresented, except those parents who reported having lower supervisory and technical positions, where the proportions were equal across samples. Cohort members of parents with managerial and professional jobs at the last sweep were significantly less likely to use the paper than the other two modes, and young people of parents who didn't have a job at the last sweep were significantly more likely to use paper than the other modes.

Country

Cohort members in England were underrepresented in the time use sample, and those from Wales, Northern Ireland and Scotland were all overrepresented. Young people living in England were significantly more likely to use the web diary than the app. Cohort members in Scotland were less likely to use the paper diary than both the web and app versions.

Family size

Family size didn't generally differ much across the Age 14 Survey sample and the time use respondents, although families with 9 or more members were slightly lower in the time use sample. No differences in family size were seen across the three time use diary modes

Response patterns

Forty six percent of participants who were eligible to complete the time use diary returned at least one diary day. Given the time use diaries were a small component of a much larger survey, this return rate is respectable. Stand-alone time use surveys of adult populations tend to provide similar response rates: for example, the 2000-01 UK Time Use Survey had a response rate of 45% (Fisher & Gershuny 2013).

Data quality

In order to fully understand response patterns and diary quality, it is necessary to provide a definition of a good quality time use diary (which can be essentially understood as a

“productive” diary in social survey terms). We adopted the three criteria followed by the Multinational Time Use Study (Fisher & Gershuny, 2013). A good quality diary should:

1) not include more than 90 minutes of missing activity time;
2) report at least seven episodes (that is, at least six reported changes in activity or any contextual dimension across 24 hours); and
3) report at least three out of four basic activity daily domains (sleep or rest; personal care; eating or drinking; and movement, exercise, or travel).

Diaries that do not fulfil these criteria are not of sufficient quality for analysis.

When we apply these criteria, the number of diary days is reduced from 8625 to 6327 – 73% of total diary days completed were considered to be good quality. When split by mode, 73% of the app diary days were considered to be good quality, compared with 78% for the online diary and just 55% for the paper diary.

Activity episodes

Number of activity episodes reported in a day is often used as a metric of diary quality. On average, those using the app reported 15 activity episodes a day, with 18 for web and 14 for paper (statistically significant differences at the $p<0.05$ level, between groups).

Measurement

As well as understanding selection differences, it is also important to assess measurement differences across modes.

When we look at time spent in each top-level activity, differences can be seen across the three modes, shown split by weekday and weekend day in tables 3 and 4. Statistically significant differences, at the $p<0.05$ level, are seen in the highlighted rows.

However, at present, the analysis of measurement does not account for selection into mode, so the results shown are likely to be a combination of selection differences and measurement differences. Once selection into mode is controlled for, it may be that the differences in measurement seen across the three modes change or disappear. Future drafts of this paper will assess measurement differences once selection has been controlled for.

Table 3: Mean number of minutes in each activity, for diaries completed on a weekday

Activity	App	Online	Paper
Sleep & personal care	624	600	619
Education related	280	278	188
Work	7	3	2
HH chores	18	20	25
Eating & drinking	72	71	83
Exercise and sports	**52**	**45**	**77**
Travel	68	69	63
Social events, outings	**64**	**57**	**37**
Digital media	**177**	**208**	**271**
Volunteering, spiritual	2	5	4
Hobbies inc. relaxing	**77**	**84**	**71**

Table 4: Mean number of minutes in each activity, for diaries completed on a weekend day

Activity	App	Online	Paper
Sleep & personal care	674	657	685
Education related	**31**	**41**	**62**
Work	9	7	0
HH chores	34	30	32
Eating & drinking	85	86	75
Exercise and sports	67	53	66
Travel	56	56	54
Social events, outings	**115**	**80**	**54**
Digital media	**259**	**320**	**328**
Volunteering, spiritual	**7**	**14**	**15**
Hobbies inc. relaxing	**103**	**97**	**70**

For weekdays, the app recorded significantly more exercise and sports than the other modes, more social events, less time using digital media, and more time participating in hobbies than paper diarists but less than web. For weekends, those using the app reported less time doing education-based activities, digital media, and volunteering, and more time on social outings and hobbies than the other two modes.

Conclusions

The Millennium Cohort Study was the first large-scale longitudinal survey to employ a mixed-mode approach to time diary data collection, combining app, web and paper formats, as well as using the first stand-alone web diary that utilised the grid format. Time use data was successfully collected from 4642 teenagers from across the whole of the UK.

The app diary proved to be the most popular instrument, with over two thirds of respondents completing the diary using this more. Differences were observed in the characteristics of respondents choosing to complete the diary in each mode. Cohort members with an older mother were significantly less likely to complete the time use diary using paper, as well as those who lived in a household who owned their home, two-parent households, those whose parents had higher social and economic status, and higher levels of education, as well as those living in Scotland.

The two online instruments provided data of the highest quality when compared with the traditional paper diary, measured using the three criteria followed by the Multinational Time Use Study (Fisher & Gershuny, 2013), as well as number of activities reported across a day.

Some measurement differences were observed across the three modes, but concerns about large measurement differences between the app and the two grid-format diaries were unfounded. The app diary, using a question-based approach rather than a grid format, appear to collect comparable data to an online grid format, and outperforms traditional paper diaries in terms of quality.

The electronic instruments also reduced the time spent on data entry and coding, and as such reduce cost. This makes them attractive prospects for collecting time use data in the future.

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