

Measuring young people's physical activity using accelerometers in the UK Millennium Cohort Study

By Emily Gilbert, Anne Conolly, Stephan Tietz, Lisa Calderwood, Nickie Rose

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Contact the author

Emily Gilbert
Survey Manager
Centre for Longitudinal Studies
UCL
emily.gilbert@ucl.ac.uk

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UCL Institute of Education
University College London
20 Bedford Way
London WC1H 0AL
www.cls.ioe.ac.uk

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Please contact the Centre for Longitudinal Studies.
tel: +44 (0)20 7612 6875
email: clsfeedback@ioe.ac.uk

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Abstract

Measuring physical activity presents methodological challenges for survey research. Most large-scale population based studies use respondent self-report to measure physical activity, which is subject to both recall and social desirability bias. The use of wearable devices that measure physical activity directly can offer a solution to these problems. Activity monitors, also known as accelerometers, are capable of capturing a wide range of movements as well as the differing intensity of activities. Increasingly, accelerometers are also being recognised for their ability to measure sedentary behaviour.

The Millennium Cohort Study (MCS) follows over 19,000 young people in the UK born in 2000/1. The sixth sweep of the study collected data from cohort members when they were 14 years old and included the collection of physical activity data using wrist-worn activity monitors. Field interviewers placed wrist-worn accelerometers with respondents during face-to-face visits and asked them to wear the device for two complete days; one during the week and one at the weekend, which were randomly selected at the time of placement. Young people and their parents were sent text messages reminding them to complete the tasks on the selected days. Upon completion of the second day of activity data collection respondents were asked to return the accelerometer in a pre-paid envelope. Two different types of accelerometer were trialled during the pilot studies to inform the choice of device.

The feasibility of collecting accelerometer data from 14-year olds was assessed during the development phase of the survey using both qualitative and quantitative methods. This informed the approach taken at the mainstage of the survey. This paper presents the approach taken to the implementation of activity monitors on the main stage of the Millennium Cohort Study Age 14 Survey, and highlights a number of considerations for the implementation of objective physical activity data collection in large-scale face-to-face surveys.

Introduction

The importance of physical activity for disease prevention and healthy ageing is being increasingly recognised. There is a large amount of interest in patterns of physical activity and inactivity among young people, and how these impact growth patterns, including the incidence of obesity, as well as the effect more broadly on mental wellbeing, long-term health and social outcomes.

The Millennium Cohort Study follows over 19,000 children born in the UK in 2000/1. The sixth sweep of the survey collected data from cohort members when they were 14 years old and included the collection of objective physical activity data using activity monitors.

The decision to measure objective physical activity at age 14 was taken in the context of substantial interest from the scientific and policy communities for understanding patterns of physical activity and sedentary behaviour at a time in young people's lives considered crucial in terms of their future pathways and development. In addition, activity monitor data has been collected from cohort members before, at age 7. Repeat collection allows for longitudinal analysis.

Measuring physical activity presents methodological challenges for survey research. Most large-scale population based studies use respondent self-report to measure physical activity, which is subject to both recall and social desirability bias. Physical activity intensity is also subjective in self-reported data. The use of devices that measure physical activity directly can offer a solution to these problems. Accelerometers are capable of capturing a wide range of

movements as well as the differing intensity of activities. However, there are some limitations. For example, it can be very difficult to understand exactly which activity someone wearing a monitor is doing, and some physical activities can be difficult to detect using accelerometry – for example, cycling, in the case of wrist-worn devices.

As well as measuring physical activity objectively in the Millennium Cohort Study Age 14 Survey, cohort members were also asked to report their physical activity through a self-completion questionnaire at the time of the interviewer's visit. In addition, they also completed time-use diaries on the same two days the activity monitor was worn. These diaries collected information on cohort members' daily time allocation for the two 24-hour periods and provide a unique opportunity to compare self-report time-use data with objectively measured activity data.

Extensive development work was carried out to inform the research design for the study and the choice of device. Qualitative research was carried out with young people and their parents, including some cohort members, prior to the Age 14 Survey to assess, among other things, the acceptability of collecting activity monitor data, and initial thoughts on the selected devices. Following the qualitative work, two pilot surveys were completed, to assess the feasibility of including the collection of accelerometer data in the Age 14 Survey.

The first pilot took place in January 2014, where 50 newly recruited families were asked to complete all elements of the survey. The second pilot was carried out with 97 families in summer 2014, comprising both newly recruited and longitudinal pilot families. The aim of the development work was to refine and optimise the research design, particularly in relation to fieldwork implementation and to select the most appropriate device for the main stage of the Age 14 Survey.

This paper presents findings from this development work, reports the approach taken to the implementation of activity monitors on the Millennium Cohort Study Age 14 Survey, and highlights a number of considerations for the implementation of objective physical activity data collection in large-scale face-to-face surveys.

Research design

This section outlines the research design and how this was implemented during fieldwork. The main aim of the design chosen was to maximise compliance and data quality, whilst at the same time minimising respondent burden and ensuring informed consent. The operational feasibility of implementing activity monitor data collection in the context of a large-scale face-to-face study using field interviewers was also a key consideration, including cost and efficiency of fieldwork.

Wear requirements

Cohort members were required to wear the activity monitor for two randomly selected 24-hour periods in the ten days following the visit (with the day of the visit and the following three days ineligible for selection). One selected day was a weekday and the other a weekend day. Both days were selected by the CAPI program during the interviewer visit. The two selected days were the same as those for the time-use diaries. Sampling one weekday and one weekend day constitutes an increasingly common design in time-use studies in particular, achieving an optimal balance between time coverage and respondent burden (European Commission 2004). Given the Age 14 Survey collected a wide range of data during a three-hour interviewer

visit, it was important to minimise burden as far as possible, to help ensure longitudinal retention of cohort members.

Consideration was given to asking the cohort members to wear the activity monitor for seven continuous days, in part as it was felt this might be easier for them. However, as the aim was to collect activity monitor data concurrently with the time-use data collection this was not considered optimal. In particular, we were concerned that respondents would stop wearing the monitor before the second selected day. During the pilots young people were told that they could choose to leave the monitor on for the duration between the two selected days (rather than taking it off after the first selected day and putting it back on at the start of the second selected day). However feedback from respondents indicated that this option was not chosen, therefore at the mainstage the protocol was to wear the monitor on the selected days only.

Device placement and return

It was important for the monitors to be placed with cohort members in such a way that ensured they had full understanding of the purpose of the task and what they were required to do. It was decided that asking interviewers to place the devices during the Age 14 Survey home visit would be the best way to achieve this. Interviewers were required to explain the activity monitoring task to cohort members during the visit, and place the monitors in instances where consent was obtained from parents and cohort members. Interviewers recorded the device serial number in the CAI program immediately prior to placing them (specific devices were not pre-allocated ahead of placement).

The alternative device distribution option that was considered was administering the devices from the office, by posting them to cohort members with instructions about how and when they should wear them. It was felt that interviewers administering the device during the visit would lead to higher compliance rates, and improved data quality, for a number of reasons. If it was placed during the visit, it was more likely to be seen as an integral part of the survey, which wouldn't necessarily be the case if it was sent from the office. Additionally, it gave cohort members the chance to ask questions about what they were required to do. The requirement to administer this element alongside the time-use diary also meant that interviewer placement was viewed as more efficient and straightforward.

The main practical concern with this placement approach was device supply to interviewers. If interviewers ran out of activity monitors, they were able to record in the CAPI program that they did not have a device available. Interviewers explained the task as usual, along with the time-use record, and an activity monitor was despatched directly to the cohort family from the office by post. In such cases the two 'selected days' had a two-week lag in order to provide sufficient time for interviewers to send the placement data back to the office electronically and for a device to be configured and despatched to the respondent ahead of the first selected day.

Another practical consideration was the need for devices to be configured, fully charged and switched on before placement with a respondent. The configuration required bespoke software and was carried out systematically by a dedicated and trained member of staff in the office. Devices were also fully charged in the office. However, given the time lag between office set-up and the placement of devices, interviewers were required to charge the activity monitors at home before placing them.

The devices allowed the recording to be started following configuration or following a press of a button ('on button press'). Although the devices could be switched on to record data immediately after configuration, as configuration was done in the office this was not a feasible option due to the limited memory and battery life of the devices, either of which were likely to

expire before the selected days of activity monitor data collection. As such, it was decided that the 'on button press' function would be used by interviewers at the time they were placing the device with a cohort member. Interviewers were trained to charge devices before placing them with cohort members and to switch them on at the time of placing them. While this placed a burden on the interviewer, it was less risky than requiring interviewers to understand the bespoke piece of software and to configure the monitors themselves.

Due to the high cost of each activity monitor, only a limited number could be purchased, requiring them to be re-used during the fieldwork period to ensure a high coverage of all cohort members. Therefore, it was important that monitors were returned to the office as soon as possible after the second selected day, in order that the data could be downloaded and the device reconfigured and sent out to another interviewer. The time needed in the office before a device could be returned to the field needed to be minimised too by ensuring an adequate level of resource was available to process incoming devices.

To ensure quick return, cohort members were asked to post the monitor back to Ipsos MORI's office after the task was complete, using a pre-paid envelope which was left by the interviewer. The envelope was suitable for posting in a standard post box, so cohort members would not need to take it to a Post Office. The envelope also contained a despatch slip, which interviewers completed while they were in the household. The slip contained the cohort member's first name, date of birth, sex and device serial number. None of the respondent's information (i.e. name, date of birth and sex) was programmed into the activity monitor itself, hence the need to record it separately on a despatch slip. The information on the despatch slip was then used by the office when the monitor was received in the post from the cohort member as a check when reconciling the data, to ensure the correct data was linked to the correct respondent (for example, to accurately match data if the device number had been recorded incorrectly in the CAPI program by the interviewer).

The alternative activity monitor return approach that was considered was asking interviewers to return to each household after the task had been completed by the cohort member to collect the device. It was decided that this option would be burdensome on interviewers and families, as they would have to arrange another appointment purely for collection. It would also have added substantially to fieldwork costs.

Acceptability and consent

The qualitative work suggested that an activity monitor task at age 14 would be generally acceptable, with many young people intrigued by the idea of wearing a device that could measure their physical activity over the course of a day. The research with cohort members suggested that their views on activity monitors were generally related to their previous experience of being asked to wear one for the Age 7 Survey. They felt that an activity monitor task at age 14 would be acceptable if the device was less bulky and more comfortable than the waist-worn device used previously.

The qualitative work also highlighted concerns around whether the activity monitor would be able to track the cohort member's whereabouts through GPS technology, or take pictures using a hidden camera. Therefore, on the information leaflets for cohort members and their parents, it was explicitly stated that the monitor did not contain GPS technology or a camera. The feedback from the qualitative research also suggested that it would be useful to provide cohort members with letters for schools and sports clubs, as some 14 year olds worried that they would not be allowed to wear it at school, or while playing sport. To address these concerns, these letters were developed and used in the field.

It was extremely important to ensure cohort members participating in the activity monitor task were able to provide informed consent. As the cohort members were children, parents were gatekeepers to their participation and parental consent was required to approach the young person and invite them to take part. Information about the activity monitoring task was provided to both the parents and young people in advance of the interviewer visit in the form of separate leaflets, which contained information on why the Age 14 Survey included an activity monitoring component and briefly explained that physical activity data would be collected using a wrist-worn monitor. Interviewers obtained written consent from parents and verbal consent from young people, using a structured consent form which the interviewer read out

Maximising compliance

One of the main challenges in maximising compliance was ensuring high wear and return rates following the device placement by the interviewer. A number of materials were developed that interviewers left with the cohort member in order to boost compliance. Parents and young people were each given a leaflet containing instructions about when cohort members should put on and remove the monitor, information about how to wear the monitor, details of the selected wear days, and contact details in case they had further queries after the interviewer had left. As described above, cohort members were also given two letters, one for their school and for sports clubs, explaining what the monitor was and why they were wearing it.

A number of reminders were sent to cohort members and parents in relation to the activity monitoring task, in order to boost compliance and encourage the prompt return of monitors after the second selected day. The first reminders were sent by text message (SMS), with a final reminder sent via post. These reminders are outlined in Table 1. Text messages were only sent if consent to receive them had been provided by cohort members and their parents.

Table 1.1: Overview of the reminders sent to cohort members and parents

| | Mode and time | Content |
|---|---|---|
| 1 | SMS on the evening prior to each selected day | Reminder of tasks, request to put on monitor before going to bed |
| 2 | SMS on the morning of each selected day | Reminder to wear the monitor and complete the time-use record today |
| 3 | SMS on the morning following each selected day | Reminder to submit the time-use record |
| 4 | SMS one week after end of task (if activity monitor not returned) | Request to return the activity monitor |
| 5 | Paper slip included in thank-you mailing 2-3 weeks after end of task (if activity monitor not returned) | Request to return the activity monitor |

The device choice, discussed below, was also a major consideration for maximising compliance.

Device choice

It was decided from the outset to use a wrist-worn activity monitor in the study. Evidence suggests that wear compliance is greater with wrist-worn than with waist or thigh-worn monitors (Freedson & Dinesh, 2013; Fairclough et al. 2016). The two pilot stages allowed a test of two different wrist-worn devices: the GENEActiv Original and the ActiGraph GT3X+. A different ActiGraph model, worn on a belt around the waist, had been used in the age 7 sweep of the study.

Both of these models are technically capable of the requirements MCS had in relation to both the data produced and the design of the activity monitoring component of the survey.

They are both triaxial, meaning they measure motion on three axes. The measurement frequency of each device is selectable, meaning measurement can be obtained at 40Hz, chosen after examining the existing accelerometer literature, on both devices. Both types of monitor have batteries capable of lasting for the duration of the period in which measurement would be required (which was 10 days, given the selection of the second day could fall nine days after the interview date), and sufficient internal memory to record data for that length of time. Neither of the devices provide respondents with any feedback when they are wearing them. This was important in order to minimise the risk that respondents would change their behaviour if they were able to monitor what the device had recorded, hence compromising data quality and representativeness. Finally, both devices are robust and waterproof. Robustness was essential given that 14 year olds would be wearing them, and waterproof devices meant that cohort members wouldn't have to remove them for activities like swimming, or for bathing or showering. This was important as the concern was that if respondents had to remove the device for such activities some may forget to put the monitor back on afterwards, thereby reducing wear-time compliance. Both of the models were within budget, and there was not a significant price difference between them, so this was not a major consideration.

In both pilots, half of respondents were allocated to wear the GENEActiv, and half the ActiGraph. Each interviewer was allocated one type of device and respondents were not aware that there were two devices. Feedback on each device was collected from respondents, interviewers and staff who were processing the devices in the office. In addition, device return rates and compliance rates were assessed following the piloting.

Feedback from respondents suggested that the GENEActiv was generally more comfortable to wear, whereas the ActiGraph was bulky and less comfortable. Those who wore the ActiGraph also commented on it being indiscrete, whereas the GENEActiv was seen to be reasonably sleek and discrete. However, there were no large differences between respondents reporting wearing the monitor for their two selected days – it seems that whilst the ActiGraph was reported to be uncomfortable, respondents (who returned feedback) wore it anyway.

Interviewer feedback highlighted that the serial numbers on the GENEActiv devices could be quite difficult to read. However, there were no issues reconciling the data from devices returned from respondents with information interviewers had entered into the computerised questionnaire at the time of interview, suggesting interviewers had recorded all serial numbers correctly. Additionally, interviewers reported being unsure about whether they had turned on the GENEActiv device, though all of these devices were turned on successfully by interviewers during piloting. Two of the devices were turned on early by the interviewer, that is, before they visited the cohort member.

In terms of office administration, the ActiGraph was considered to be slightly easier and quicker to charge, calibrate and download data from. However, GENEActiv devices offer the option of charging, calibrating and downloading from more than one device at once, which was an advantage. Overall it was felt that either device would be acceptable for in-office administration, and this aspect should not impact strongly on the final decision on which device to use.

During the first pilot, all respondents who took part in the survey agreed to wear the activity monitor. The return rate of the devices in this pilot didn't differ by device type and the vast majority (92%) of devices were returned to the office, having been posted by respondents. However, for the pilot respondents were incentivised to return the monitor, which was not planned for the main stage. In terms of wear-time compliance rates, the GENEActiv achieved better compliance, with the data showing that cohort members wore the devices for much longer on their selected days than those who were allocated to ActiGraph devices.

During the second pilot, 89% of cohort members agreed to wear an activity monitor – 84% for the GENEActiv and 94% for the ActiGraph. The return rates of the devices were much lower than at the first pilot, with 64% of devices being returned. It seems likely that this was due to the lack of incentive for device return. Returns also differed by device – 76% of GENEActivs were returned compared with 52% of ActiGraphs. In terms of wear-time compliance, returned devices for which there were 10 or more hours (between 4am of the selected day and 4am the next day) of wear per day were considered to be compliant. The threshold of 10 hours as a measure of 'good' data was chosen in line with numerous other accelerometry studies. 72% of respondents wore the GENEActiv for 10 hours or more, compared with 70% for the ActiGraph. GENEActiv was worn on average (mean) for 21h 50min of the day on day 1 and 19h 12min on day 2. This was 15h 7min and 15h 22min for ActiGraph. Table 1.2 summarises this information.

Table 1.2: Summary of dress rehearsal activity monitoring compliance

| | GENEActiv | | Actigraph | | All | |
|-------------------------|-----------|-----|-----------|-----|-----|-----|
| | n | % | n | % | n | % |
| Eligible respondents | 50 | 100 | 47 | 100 | 97 | 100 |
| Agreed to accelerometry | 42 | 84 | 44 | 94 | 86 | 89 |
| Device returned* | 32 | 76 | 23 | 52 | 55 | 64 |
| Valid data obtained | 23 | 72 | 16 | 70 | 39 | 71 |
| Wear time Day 1 | 21h 50min | | 15h 7min | | - | |
| Wear time Day 2 | 19h 12min | | 15h 22min | | - | |

* Proportion of placed. Returned within 4 weeks of placement.

Following the piloting, a decision was taken to use the GENEActiv for data collection in the mainstage of the Age 14 Survey. Firstly, the device seemed more acceptable to respondents in terms of discreteness and comfort. Secondly, both return rates and wear-time compliance rates were higher for the GENEActiv devices, with a larger proportion of respondents providing valid data and wearing the device for longer each day. As well as being crucially important from a scientific perspective, high return rates are also beneficial from an operational perspective to facilitate the reuse of devices during fieldwork.

Research implementation and results

This section reports on the experience of implementing the activity monitor element of the Age 14 Survey during the main stage, including respondent compliance, device administration and data management.

Eligibility criteria

Based on the evidence from the second pilot on the rate and speed of return of the devices and the anticipated volume of interviews for the main stage, it was estimated that the stock of activity monitors available for the main stage was insufficient to cover all of the cases in England. In part this was also due to the large sample size in England and the requirement for fieldwork in England to take place in the first part of the data collection period. For this reason, a random sub-sample of 81% of cohort members in England was drawn, and only these cohort members were asked to complete the activity monitoring task. This was a simple random sample at the level of interviewer assignments or sample points i.e. a random selection of sample points was made after cases had been assigned to points rather than a selection of cases. Fieldwork was split into nine waves. Before the start of each wave an estimate of the number of available devices was calculated. The estimate was modelled using assumptions about the fieldwork coverage, household response rates, the proportion of cohort members who would agree to do the activity monitor task, the proportion of returned devices and the time taken to return them. At each wave the sub-sample was maximised based on estimated device availability. In England, all cohort members in waves 1 and 5 were eligible, but the proportion sampled was reduced to between 70 and 80% for waves 2-4 (waves 6-9 contained no cohort members in England). All cohort members in Wales, Scotland and Northern Ireland were invited to complete it throughout the entire fieldwork period (waves 2-4 and 6-9). This results in 87% of cohort members overall being eligible for the activity monitoring task.

Respondent compliance

Overall, 11,726 families took part in the Age 14 Survey. Within these productive families, 10,337 cohort members were eligible for the activity monitor element (87% of cohort members within productive households). Response to the activity monitor element among eligible cohort members is shown in Table 1.3.

Table 1.3: Response to activity monitor element within productive households

| | N | % of eligible respondents | % of placed devices | % of returned devices | % of returned devices containing some data |
|---|---------------|----------------------------------|----------------------------|------------------------------|---|
| Device not placed ¹ | 1,153 | 11 | - | - | - |
| Device not returned | 2,448 | 24 | 27 | - | - |
| Device returned, but broken or no data | 810 | 8 | 9 | 12 | - |
| Device returned, but insufficient data | 956 | 9 | 10 | 14 | 16 |
| Valid data for only one selected day | 749 | 7 | 8 | 11 | 13 |
| Valid data for both selected days | 4,221 | 41 | 46 | 63 | 71 |
| Eligible for activity monitor task | 10,337 | 100 | n/a | n/a | n/a |

A device was not placed with 11% of eligible respondents. This was almost always due to respondent refusal. About a quarter (24%) of eligible respondents were given an activity monitor to wear but the device was not received in the office, 8% returned a device that was broken or no data could be downloaded, 9% returned a device that contained insufficient data (i.e. not worn or worn for less than 10 hours on the selected days). Of eligible respondents, 48% returned a device that contained valid data² (41% had valid data for both days; 7% had valid data for one day). Among respondents with whom a device was placed, 54% returned a device with valid data. Among all returned devices, 74% had valid data (63% for both days and 11% for one day) and among all returned devices containing some data 84% had valid data (71% for both days and 13% for one day).

Table 1.4 shows wear times, broken down by Day 1 and Day 2, among those with valid data.

¹ Placement data for two cohort members' monitors was lost on interviewer's laptops/tablets. In this table these have been treated as "not placed".

² Valid data means that the activity monitor was worn for at least 10 hours, between 4am of either of the selected days and 4am the next day. The threshold of 10 hours as a measure of 'good' data was chosen in line with numerous other accelerometry studies.

Table 1.4: Wear time for activity monitors containing valid data

| Hours worn | Day 1 | | Day 2 | |
|------------------------------|--------------|------------|--------------|------------|
| | n | % | n | % |
| 10 hrs +, less than 15 hours | 395 | 8.5 | 403 | 9.1 |
| 15 hrs +, less than 20 hours | 613 | 13.2 | 1,112 | 25.2 |
| 20 hrs +, less than 24 hours | 1,350 | 29.1 | 1,339 | 30.4 |
| 24 hrs | 2,287 | 49.2 | 1,551 | 35.2 |
| Total | 4,645 | 100 | 4,405 | 100 |
| Mean | 21h 46m | | 20h 48m | |

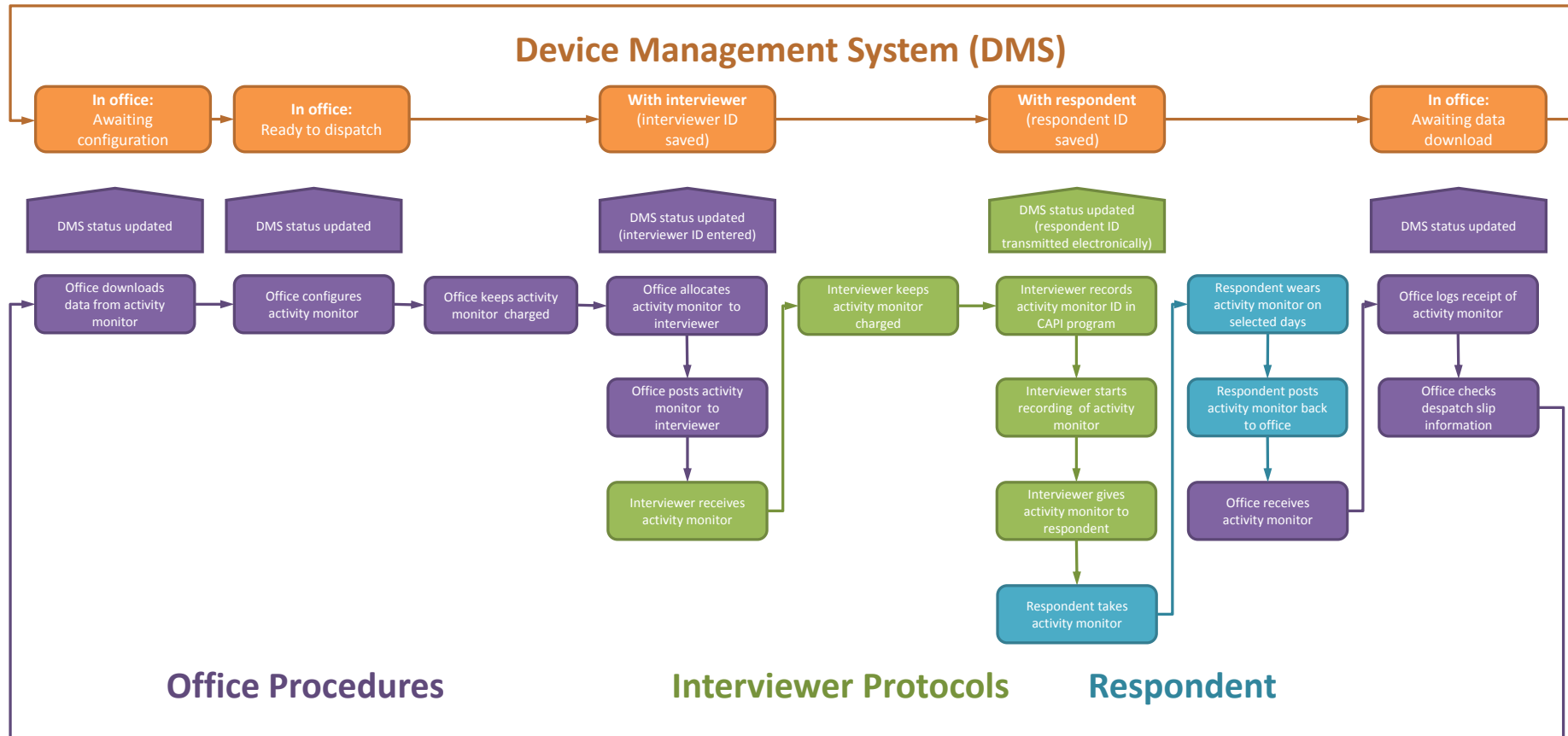
For devices containing valid data the average (mean) wear time for day 1 was 21 hours 46 minutes and 49% were worn for the full 24 hours. The average (mean) wear time for day 2 was 20 hours 48 minutes and 35% were worn for the full 24 hours.

Device management

In total 4,000 devices were available for main stage fieldwork, which took place between January 2015 and March 2016. Over 10,000 cohort members were eligible for the activity monitoring task and it was planned that each device would be used multiple times throughout the fieldwork period. Interviews were not evenly spread across the fieldwork period as there was a scientific requirement for the data collection to take place during specific school years, which meant that the fieldwork was significantly front-loaded between January to July 2015, particularly in England and Wales. In order to ensure that the 252 interviewers working on the Age 14 Survey didn't run out of devices, particularly during the months when fieldwork was at its peak volume, it was critical that the data was downloaded and devices were returned to the field as soon as possible following receipt in the office. Given the re-use of the devices, it was also crucial that the data could be accurately reconciled and allocated to the correct individual. This was a major operational and logistical challenge for the study.

A Device Management System (DMS) was set up to keep track of the activity monitors, whereby each device was allocated a status as illustrated in Figure 1.2. There were five different statuses: three to indicate the office process of receipt, data download and configuration, one to indicate the device had been allocated to an interviewer and posted out and one to indicate the device had been placed with a respondent

Figure 1.2: Activity Monitor Device Management System (DMS)



Devices were charged and configured to the following specification prior to despatch:

- Measurement frequency: 40Hz
- Recording Start Mode: 'On button press'

A batch of devices was allocated to a specific interviewer and despatched in their 'work packs' for each assignment. The size of assignments varied, with an average of 14 addresses in each one. Interviewers were initially provided with 8-10 activity monitors to have enough monitors to cover the expected number of placements in each assignment. Interviewers were able to request further devices throughout fieldwork, as required. The devices each had unique serial numbers and the device management system recorded for each device the unique identifier for the interviewer who had been sent the device.

After respondents had completed the activity monitor task they were asked to return the monitors to the office using the pre-paid envelopes containing a despatch slip, both left with them during the interviewer visit. On receipt of the devices in the office, they were logged on the DMS. The enclosed despatch slips were cross-checked against the expected respondent ID for the device as recorded in the CAPI program by the interviewer (and any discrepancies were flagged and reconciled).

An activity monitor was placed with 9,184 respondents and a device was returned to the office on 6,736 occasions (73% of placements).

The time between the end of the activity monitor task and the receipt of devices varied a great deal. The mean return time was 21 days after the task and the median was 12 days after the task. The longest was returned 339 days (approximately 11 months) after the task³. A summary of return times can be found in Table 1.5.

Table 1.5: Activity monitor return times

| Return time after end of task | n | % |
|--------------------------------------|--------------|-----------------------|
| 7 days or less | 1,750 | 26 |
| 8-14 days | 2,154 | 32 |
| 15-21 days | 1,137 | 17 |
| 22-31 days | 671 | 10 |
| 31 days or more | 1,024 | 15 |
| Returned devices | 6,736 | 100 |
| Min | | -16 days ⁴ |
| Max | | 339 days |
| Mean | | 22 days |
| Median | | 12 days |

Table 1.6 shows the number of times each device was placed throughout fieldwork. Although 33% of devices were only placed once, it is worth bearing in mind that 26% of placed devices were not returned after placement. On average (mean), each device was placed 2.4 times. A

³ For reporting purposes, a cut-off date was set four months (c120 days) after the end of fieldwork. This reduced the time available for returning the device for cohort members interviewed in the later half of the fieldwork period.

⁴ Some devices were returned before the end of the task (n=26). This was possible if respondents returned the device before completing the task. For devices which needed to be dispatched from the office, the second selected day could be 24 days after the home visit (10 days plus an additional 14 days).

limited number of devices were kept in the office as 'reserve stock' (originally 200 out of a total stock of 4000) to ensure requests for devices to be sent to participants directly could be fulfilled in a timely manner. The reserve stock was replenished with returned devices throughout fieldwork.

Table 1.6: Activity monitor uses

| No. of device placements | n | % |
|---------------------------------|--------------------------|------------|
| 1 time | 1,281 | 33 |
| 2 times | 1,008 | 26 |
| 3 times | 763 | 20 |
| 4 times | 475 | 12 |
| 5 times | 207 | 5 |
| 6 or more times | 96 | 3 |
| Devices | 3,831⁵ | 100 |
| Min | 1 time | |
| Max | 9 times | |
| Mean | 2.4 times | |
| Median | 2.0 times | |

At the peak of fieldwork careful stock management was required to ensure the devices were available for interviewers to place. The following steps were taken (often in a short timeframe) to ensure the availability of activity monitors:

- log receipt
- download data
- charge & re-configure the device
- allocate & despatch to an interviewer

After testing during the pilot stages, it was calculated that a maximum of 140 devices could be processed in a working day by a single member of staff, if necessary. This was sufficiently quick to ensure there was no backlog of devices. It is also important to note that the staff member dealing with the activity monitors had been trained, and it was important for quality control that only trained staff worked with the monitors in the office. Our model of stock levels as described above proved reasonably accurate and the 'reserved stock' was never fully depleted⁶.

⁵ There were a number of devices that were never placed with a respondent because they were kept as reserve stock.

⁶ The 'reserved stock' was lowest when devices which had been in field for 2 months or longer needed to be swapped due to the unexpected problems described in the next section: "Technical problems during fieldwork".

If an interviewer ran out of devices during fieldwork they were advised to request additional stock before their next appointment. However, if they already had an appointment booked but had no activity monitors, they were able to record in the CAPI program that they are 'out of stock' and a monitor was despatched from the office directly to the cohort member within one week. Activity monitors were despatched from the office for 577 placements (8% of all placed devices).

Data download and storage

Data was downloaded from activity monitors using the GENEActiv software. Data from up to 16 devices could be downloaded to a single computer at any one time using USB hubs.

The raw activity monitor data for each respondent was up to 750MB in size. This size of the raw data and volume of cases presented an operational challenge in relation to data storage. The data was stored on external hard drives at Ipsos MORI. All files were backed-up on a second drive before being deleted from the activity monitor when it was re-configured for re-use.

Data files were analysed using the GGIR package in R to establish whether they contained valid data. Data is considered valid if there are 10 or more hours of wear-time on a selected day, in line with a number of accelerometry studies. The data validation process matched the data downloaded from the activity monitor to the respondents' placement data. The wear time was calculated for both the 'selected days' (between 4am of the selected day and 4am the following day) by analysing the downloaded data.

The GENEActiv monitor has an internal temperature sensor which is warmed through body heat when being worn. This reading, together with a minimum requirement of movement (to exclude false positives where the activity monitor was not worn, but the ambient temperature high), was used to decide if the monitor was worn. A survey outcome code of 'fully productive' was assigned if valid data was recorded for both of the selected days and a 'partial productive' outcome was assigned if valid data was only recorded for one of the selected days.

Data files were physically transferred from Ipsos MORI to CLS on encrypted hard drives at regular intervals. Ipsos MORI retained the back-up of the file until CLS had confirmed transfer of the data onto their system and created a backup.

Technical problems experienced during fieldwork

During the course of fieldwork it became apparent that a number of devices were being returned to the office with no data recorded.

Two unexpected problems were encountered when the devices were connected to the GENEActiv software:

1. A "Device not configured" message appeared and there was no data present
2. A "Recording interrupted" message appeared and there was no data present⁷

Activinsights, who manufacture the GENEActiv devices, explained that the first problem occurred because devices had lost their configuration settings. When devices lose their

⁷ The "recording interrupted" message would also be displayed if the device was still successfully collecting data at the time of download but, in those instances, there would be data present. Devices recorded until either the memory was full or until the battery depleted.

configuration the activity monitor does not record data. This happened if the device battery drained to 0%, even if interviewers subsequently charged them prior to placement.

Prior to this, understanding among the research team was that a device would retain its configuration settings until the device was either used or re-configured using the GENEActiv software. It was also understood that once a device's battery depleted completely interviewers would not be able to re-charge the device and, therefore, that there was no possibility of interviewers placing a fully-charged, but unconfigured device.

Activinsights had initially advised that each device should retain its charge for two months⁸. Therefore interviewers had been trained to fully charge the devices a minimum of every two months and that if the device would not take a charge they must return it to the office for repair. However, it was subsequently discovered that some devices lost their charge, and therefore configuration settings, before two months from the last charge.

After identifying the cause of this problem, it also became apparent that it was possible to identify an unconfigured device at the time of placement by the length of the green flash when the start button was pressed. A long green flash indicated that the device had started collecting data and a short green flash simply indicated that the device was charged (but not configured).

Following advice from Activinsights, the following steps were taken to attempt to rectify the situation:

1. All devices that had been in field for two months or longer were recalled and replaced with fully charged and re-configured devices.
2. The instruction to charge devices every two months was replaced with one month and a reminder to charge was implemented on a monthly basis.
3. Interviewers were asked to pay extra attention to the 'green flash' when turning on the device. They were asked to only place devices that displayed a 'long flash' when turned on. If the devices displayed a short flash they should return it to the office and either use another device (if available) or code the 'out of stock' option in the CAPI program. A video was sent to interviewers demonstrating the difference between a long and short green flash.

The incidence of these problems was only recorded when it became clear that there was a systematic problem. From that point, 553 devices were received with no data and the message "Device not configured" (or 8% of returned devices). However, it should be noted that there were additional devices that showed the message "Device not configured" but did contain some data.

The second type of problem, where no data was present on the device but the message "Recording interrupted" was displayed was much less common. This was recorded in 22 instances (or 0.3% of returned devices).

Apart from these issues, interviewers did not report any other technical problems. The other problem that was anticipated before fieldwork was that the device had not been turned on by the interviewer at the time of placement, although it was expected that there would be very few occasions where this occurred. This happened in only 35 instances throughout fieldwork (0.5% of returned devices). Interviewers who had failed to turn a device on before placing it were notified immediately.

⁸ Although the device manual states three months, we were advised that two months was a sensible precautionary approach.

Activinsights agreed to amend their instruction manual to advise future customers that:

1. Devices require charging more frequently than every 3 months
2. A depleted battery results in lost configuration

Summary and conclusions

Accelerometry data was successfully collected from over 4,900 14-year-olds who are part of the Millennium Cohort Study. This is a large sample for data of this kind and represents 48% of those eligible. It will be an extremely valuable resource for researchers interested in a range of research questions, spanning healthy living, growth, ageing, disease prevention and mental health. Additionally, the activity monitor data can be analysed alongside the time-use data collected over the same two days. This provides a unique resource combining detailed self-report information on daily activity levels with objectively measured physical activity data.

The overall compliance rate is comparable with the activity monitor collection at the MCS Age 7 Survey where valid data for two days was collected from 6675 (48%) of cohort members. It is also broadly comparable to compliance rates from a general population sample in the 2008 Health Survey for England (see Craig, Mindell and Hirani 2009).

The development work undertaken prior to the mainstage of the MCS Age 14 Survey was key to the success of activity monitoring with this cohort. The qualitative work, which involved speaking with 14 year olds (some of which were cohort members) and their parents, showed that activity monitoring would be acceptable among 14 year olds. However, it also highlighted some information crucial to engaging and reassuring this group – namely that there were concerns around whether the monitor would have GPS or a camera, whether it could be worn in the bath or shower, and whether schools or sports clubs would allow the young people to wear the monitor. To address these concerns, materials providing reassurances on these issues were developed for fieldwork.

Piloting two devices was also helpful for the success of activity monitoring in the Age 14 Survey. This allowed identification of a device that would both meet the technical data requirements of the survey, but also be acceptable for 14 year olds, and therefore have a high compliance rate in terms of wear, maximising the quality and utility of data collected.

The two stages of piloting also allowed an operational model of return times to be developed, which highlighted that there would not be enough activity monitors available for the main stage to cover the entire sample. This led to the decision to subsample cohort members at the mainstage. Doing this in advance of fieldwork enabled a probability-based sub-sample to be selected and meant that no serious problems relating to device supply arose during fieldwork. If a serious problem with device supply had arisen during fieldwork, there is a high likelihood that this would have led to non-random missing data and potentially to sample bias.

Related to this, piloting also provided an opportunity to gauge the time needed to process each device in the office – from receipt of the device in the post from the cohort member, through downloading data and reconfiguring the device for its next use, to posting the device back out to an interviewer to be placed with another cohort member. The pilot surveys highlighted the need for dedicated resource in the office, and so for the main stage a full time equipment co-ordinator was employed to process activity monitors.

It is clear from the experience on the MCS Age 14 Survey that the collection of objective physical activity data on a large-scale survey is possible alongside more traditional types of

data collection. However, a number of issues encountered along the way are worth bearing in mind for researchers hoping to collect high quality, objective physical activity data in the future.

Implications for practice

Implementing activity monitor data collection on the MCS Age 14 Survey has highlighted a number of considerations for others wishing to collect this type of data on large-scale surveys.

In relation to device placement and return, MCS used interviewers to place activity monitors with cohort members, but this raised a number of issues. Firstly, there were a large number of devices where the battery drained completely, resulting in the configuration setting being lost, and therefore data not being collected once the monitor was placed with a cohort member. Secondly, some monitors were not turned on by interviewers, again resulting in no data being recorded. Although much of this data loss was caused by an unanticipated technical problem, it may be the case that sending cohort members the activity monitors directly from the office would have prevented at least some of this data loss, but doing so could have reduced participation rates.

In terms of device return, MCS asked respondents to post them back once data collection had finished. This resulted in approximately 26% of devices not being returned by the cohort member. Whilst there is no way of knowing whether any of those devices contained data, it may be that some of them did. If the device loss rate had been lower, a larger number of cases could have been covered with the same number of devices. The decision was taken not to ask interviewers to return to collect devices for reasons of both respondent and interviewer burden and cost, but doing so may have improved return rates, compliance rates and coverage.

Another consideration that should be borne in mind for researchers wishing to collect objective physical activity data is the type of device used. There are now many different devices on the market, from the more traditional research accelerometer like those used in MCS to personal activity trackers that are widely used among the general population to monitor their activity levels – such as Fitbits and Jawbones. These are often considered to be sleeker and more attractive, so it would be worth investigating whether these devices could increase compliance while still collecting data that is acceptable to the research community. Some of the newer devices are also able to transmit data electronically. The use of this type of device may reduce office turnaround time and staff resource requirements, as well as potentially increasing sample coverage.

Finally, there are methods other than a wearable research accelerometer that can be used to collect objective physical activity data. Case et al. (2015) have shown some smartphone apps can be used successfully as step counters. Other studies have used smartphone apps with some success to detect physical activity and sedentary behaviour (Bort-Roig et al., 2014), with one using the opportunity to augment the objective data with self-reported contextual information (Dunton et al. 2014).

References

- Bort-Roig, J., Gilson, N.D., Puig-Ribera, A., Contreras, R.S. and Trost, S.G. (2014) 'Measuring and influencing physical activity with smartphone technology: a systematic review.': *Sports Medicine*, 44 (5): 671-86.
- Case, M.A., Burwick, H.A., Volpp, K.G. and Patel, M.S. (2015) 'Accuracy of Smartphone Applications and Wearable Devices for Tracking Physical Activity Data': *Journal of the American Medical Association*, 313 (6): 625-626.
- Craig R, Mindell J, Hirani, V. (eds). Health Survey for England 2008. Volume 1: Physical Activity and fitness. The NHS Information Centre, Leeds, 2009. <http://content.digital.nhs.uk/catalogue/PUB00430/heal-surv-phys-acti-fitt-eng-2008-rep-v2.pdf>
- Dunton, G.F., Dzibur, E., Kawabata, K., Yanez, B., Bo, B. and Intille, S. (2014) 'Development of a smartphone application to measure physical activity using sensor-assisted self-report': *Frontiers in Public Health*, 2: 12.
- European Commission. (2004) *Guidelines on Harmonized European Time Use Surveys*. Eurostat. Luxembourg.
- Fairclough S.J., Noonan, R., Rowlands, A.V., Van Hees, V., Knowles, Z., and Boddy, L.M. (2016) 'Wear Compliance and Activity in Children Wearing Wrist- and Hip-Mounted Accelerometers.': *Medicine & Science in Sports & Exercise*, 48 (2): 245-253.
- Freedson, P. and Dinesh, J. (2013) 'Comment on "Estimating Activity and Sedentary Behavior from an Accelerometer on the Hip and Wrist"': *Medicine & Science in Sports & Exercise*, 45 (5): 962-963.

Appendix- Technical specification of the GENEActiv Original

| | |
|---------------------------|---|
| Physical Parameters | |
| Size | 43mm x 40mm x 13mm |
| Weight | 16g (without strap) |
| Main Housing Material | PC/ABS (medical device grade) |
| Light Guide Material | PC (medical device grade) |
| Data Contact Material | Gold-plated |
| Fixings | 20mm heavy duty spring bar |
| Strap | PU resin |
| Battery Type | Rechargeable lithium polymer |
| Environmental Protection | |
| Moisture Ingress | Water-resistant to 10mm (IP67 – 1m 24hrs) |
| Material Ingress | Dust tight (IP67) |
| Operating Temperature | 5 – 40 deg C |
| Mechanical Impact | 0.5m drop resistant |
| Measurement Capabilities | |
| Memory | 0.5Gb non-volatile |
| Logging Frequencies | Selectable 10-100Hz (10Hz) |
| Maximum Logging Periods | 45 days @ 10Hz; 7 days @ 100Hz |
| Internal Clock | |
| Type | Quartz Real Time Clock |
| Frequency | 32.7768kHz |
| Accuracy | +/- 20ppm (+/- 1.7s per day) |
| Acceleration Measurements | |
| Sensor Type | MEMS |

| | |
|--------------------------|---|
| Range | +/- 8g |
| Resolution | 12 bit (3.9 mg) |
| Light Measurements | |
| Sensor Type | Silicon photodiode |
| Wavelength | 400 to 1100 nm |
| Range | 0 – 3000 Lux typical |
| Resolution | 5 Lux typical |
| Accuracy | +/- 10% @ 1000 Lux calibration |
| Event Logger | |
| Sensor Type | Mechanical membrane switch |
| Temperature Measurements | |
| Sensor Type | Linear active thermister |
| Range | 0 to 60 deg C |
| Resolution | 0.25 deg C |
| Accuracy | +/- 1 deg C |
| Measurement Frequency | Every 30s minimum |
| USB Connection | |
| Device | USB 2.0 Full Speed |
| Charge Cradle | Format 4 unit cradle USB 2.0 High Speed |
| Charge Time | 90% @ 2 hours; 100% @ 3 hours |
| Data Download Time | Maximum 15 minutes for 4 concurrent units |