Travel Surveys: Measuring compliance over an eight week GPS survey

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ABSTRACT
Data on people's travel behaviour is typically collected using travel questionnaires, travel diaries or Computer Assisted Telephone Interviewing (CATI). These methods are time consuming for the participant and involve the participant recalling their travel information. This creates problems because human recall is often less than perfect. If the data recall element of a survey could be eliminated it could reduce human error and the burden placed on the participant to remember what they did. Global Positioning System (GPS) technology offers a possible solution as the participants' movements are automatically recorded. This paper aims to explore the burden experienced by participants of a GPS-survey, of 8 weeks duration and to examine the compliance rates of those participants over the duration of the survey time. A better understanding of burden and compliance is important for survey design. These will affect our recruitment strategies, choice of sample size and sampling strategy and survey protocols.

INTRODUCTION

Data on people's travel behaviour is typically collected using travel questionnaires, travel diaries or Computer Assisted Telephone Interviewing (CATI). These methods are time consuming for the participant and involve the participant recalling their travel information. This creates problems because human recall is often less than perfect. If the data recall element of a survey could be eliminated it could reduce human error and the burden placed on the participant to remember what they did. Global Positioning System (GPS) technology offers a possible solution as the participants' movements are automatically recorded. Owing to its passive nature, an additional advantage of GPS is the reduction in burden experienced by the participant. This makes it feasible to collect data on an individual's travel behaviour over many days; traditionally, due to the high burden they place on participants, diary surveys have largely been limited to one day (Stopher & Greaves 2007) and rarely cover more than one week. The lowered burden of a GPS-based survey also provides an opportunity to ameliorate some of the problems that exist in traditional travel surveys, such as non-response rates. Non-response rates are linked, to some extent, to survey burden. If, having agreed to participate, they find completing the survey relatively easy their compliance rate is likely to be increased. As yet, our understanding of how GPS-based survey design will affect perceptions of burden and compliance rates is limited, particularly with regards to longer duration surveys where limitations of the technology relating to battery life and memory capacity come into play and may place alternative burdens on the participants.

This paper aims to explore the burden experienced by participants of a GPS-survey, of 8 weeks duration and to examine the compliance rates of those

participants over the duration of the survey time. A better understanding of burden and compliance is important for survey design. These will affect our recruitment strategies, choice of sample size and sampling strategy and survey protocols.

BACKGROUND

Transport planners need information on people's travel patterns and behaviour and an essential part of this is knowing *who* is travelling by *what* mode, *where* and *when*. This information is usually collected through travel surveys, which come in many forms. The most common survey tool used for these purposes is the travel diary. Travel diaries have been the dominant method of collecting this information for over 30 years. They enable collection of rich qualitative data from participants including reasons for choices of mode, route and other aspects of their journey (Stopher & Greaves 2007). The most common form of travel diaries are trip diaries, which were first established in the late 1970s (Brög et al 1983), although other forms of travel diaries exist such as activity diaries (Stopher 1992) and placed-based travel diaries (Batellino & Peachman 2003). Given the open design of travel diaries, they can be tailored to focus on those aspects of travel the researcher is most interested in. Despite the many advantages travel diaries offer, there are a number of issues which affect the quality of the data including non-response, human error, trip omission and drop-off, all of which can be partially attributed to burden of participation.

Richardson & Meyburg (2001) differentiated between two types of non-response; unit non-response referring to where non response is received from the sampling unit e.g. the household; and item non-response, where a response is received but there is data missing within that response. The distinction between unit non-response and item non-response made by Richardson & Meyburg (2001) both refer directly to burden; the former is related to the perceived burden of the survey whilst the latter is related to the burden of undertaking the survey.

There are a variety of reasons for item non-response. Brög et al (1982) categorised these into three distinct types:

- first trips that were not reported by the respondent due to increasing lack of care in case of survey periods of several days' length (drop-off);
- second trips that were not reported by the respondents because they forgot or considered them irrelevant (human error);
- third trips that the respondent did not want to report on the basis of their own deliberate decisions (trip omission).

Drop-off is the fall in compliance with a travel survey once it has commenced (Stopher & Greaves 2007); a form of non-response after the participant has accepted the invitation to partake in the survey and can lead to travel being not recorded as the burden of completing the survey is greater than the participant expected. Drop-off is often accounted for in surveys, for example the UK National Travel Survey (NTS) has a weighting applied to account for this factor (Department for Transport 2005; 2008; 2009). Human error is the result of surveys relying on the ability of participants to accurately recall a wide range of

information such as the number of trips made, the time and duration of each trip yet people are poor at providing accurate reports of any of this information (Adler 2003; Rietveld 2001; Rietveld 2002; Stopher 2004; Stopher et al 2007). Trip omission is defined here as trips which are deliberately not recorded by the participant. The participant may feel that the trip was of a sensitive nature and not wish others to know about it, for example certain medical trips or a trip made when the participant was should have been fulfilling other obligations. Alternatively, the participant may choose not to record a trip because it is too complicated or too burdensome to do this.

GPS survey methods have been shown to substantially reduce human error. For example, work by the UK Department for Transport (2009) found that travel diaries in the National Travel Survey (NTS) captured a higher number of walking trips over one mile in length, compared to when participants were measured simultaneously by GPS methods. A possible explanation offered by the Department of Transport (2009) for this was that respondents were including ineligible short walks by rounding up the distance travelled to meet the threshold for reporting.

GPS records the participant's location at set intervals in time (typically 1s to 1 minute intervals). By examining their location over time and the rate at which the location changes, it is possible to determine the number of trips a participant makes. The raw data does not include data on the mode of travel or the journey purpose. In the early days of GPS surveys, additional information on purpose and mode had to be collected through other means such as a follow up telephone interview. However, an increasing number of algorithms are available that can infer the travel mode from GPS data (Bricka & Bhat 2004; Schuessler & Axhausen 2008) and by combining the location of trip ends with land use data, it is possible to make some inferences about the purpose of the trips. Thus the need for any information about respondents (Liao et al 2008) is reducing, which can only reduce the participant's burden further.

GPS's primary advantage is the rich spatial and temporal data one is able to capture whilst its passive measurement nature results in a lowering of participation burden for the participants as all that is required is for the device to remain charged and to be carried. Despite these advantages, there are a number of problems including processing errors, technical errors from equipment and human error (which is only partially eliminated from the methodology). The passive nature of the methodology partially reduces human error as the data no longer relies on participants recalling their trips although it does rely on participants charging the device and carrying it with them as well as requiring knowledge of how the device itself works. It is possible that technical errors, processing errors and participant's knowledge of the technology will improve over time with increased familiarisation.

A frequent assumption in travel behaviour research is that travel behaviour consists mainly of routines as travellers prefer to repeat those activity patterns with which they were satisfied in the past, based on utility maximisation theory (Schlich & Axhausen 2003). It is reasonable to assume humans perform a high

proportion of actions regularly because their constraints and obligations do not change every day. However, the activities an individual chooses to participate in on different days are not necessarily identical, because people do not have the same needs every day. Whilst we would expect work trips to be systematic throughout an individual's travel pattern we would expect variability to occur from unexpected events such as variations in weather. The question of how repetitious travel actually is has been the subject of investigation for many years however intrapersonal variability (different behaviour of one person from day to day) has played a minor role in travel behaviour research in comparison with research on interpersonal variability (differences in the behaviour of different persons). This is surprising, since the question of intrapersonal variability is of great interest to transport planning. For example, an attempt to reorganise the traffic system in a way that produces less environmental impact can only succeed if the supply is organised corresponding to the needs and desires of the traveller. The more variable and complex the traveller's behaviour is, the more flexible the supply needs to be.

In order to study intrapersonal variability properly, we need access to information on people's travel behaviour over a substantial period – weeks if not more. However, it is unusual for travel surveys to be more than seven days in length with most surveys being a single day surveys. The limiting factor for the survey duration has traditionally been burden, given the significant amount of time a participant must take to complete a survey each day when recalling the information required for the study. In theory, by using GPS methodology, the time burden on participants is the time taken for the participant to pick up the device from its charger and place it in their bag or pocket and this burden reduction allows for survey durations of a greater length.

Figure 1 shows compliance rates for the first 11919 participants of a large-scale GPS survey being conducted by the international media research firm Ipsos MORI (2010). They ultimately aim to collect travel data from 30K participants over a five year rolling survey across the UK. Participants are asked to carry a small GPS device for a 10 day period. Participants are also asked to complete a short questionnaire to capture socio-demographic data and key locations that the participants regularly visit including their home, work, shopping and leisure locations. Computer Assisted Telephone Interview (CATI) techniques are employed to contact the respondents every third evening to check their compliance rates. When asked whether they complied with the survey requirements and carried the device, there are three possible responses:

- the respondent did not take the device;
- the respondent took the device but not for all the journeys they made that day;
- the respondent took the device for all journeys they made that day.

Figure 1 clearly shows that there is an overall drop-off from the first day of the survey (Saturday 1) to the final day of the survey (Sunday 2). However, there are some interesting aspects to the graph. Compliance over the four weekend days are lower than the five weekdays with an increase in compliance seen between days two and three (Sunday 1 and Monday 1). This warrants further study: is

the lower compliance rate towards the end of the period a symptom of drop off or is this simply a result of a weekend affect. The low compliance at the start of the week may be a "warming-up" period, where it takes participants a few days to get used to carrying the device.

In order to understand the extent to which the compliance patterns seen in the Ipsos MORI survey are related to a weekend affect as opposed to being due to drop off, we need to over a survey period of a greater duration is necessary in order. In addition, for surveys of longer duration conducted using a GPS methodology, there may be other burdens such as the need to charge the battery or upload data from the device which may affect compliance rates which also need investigating.

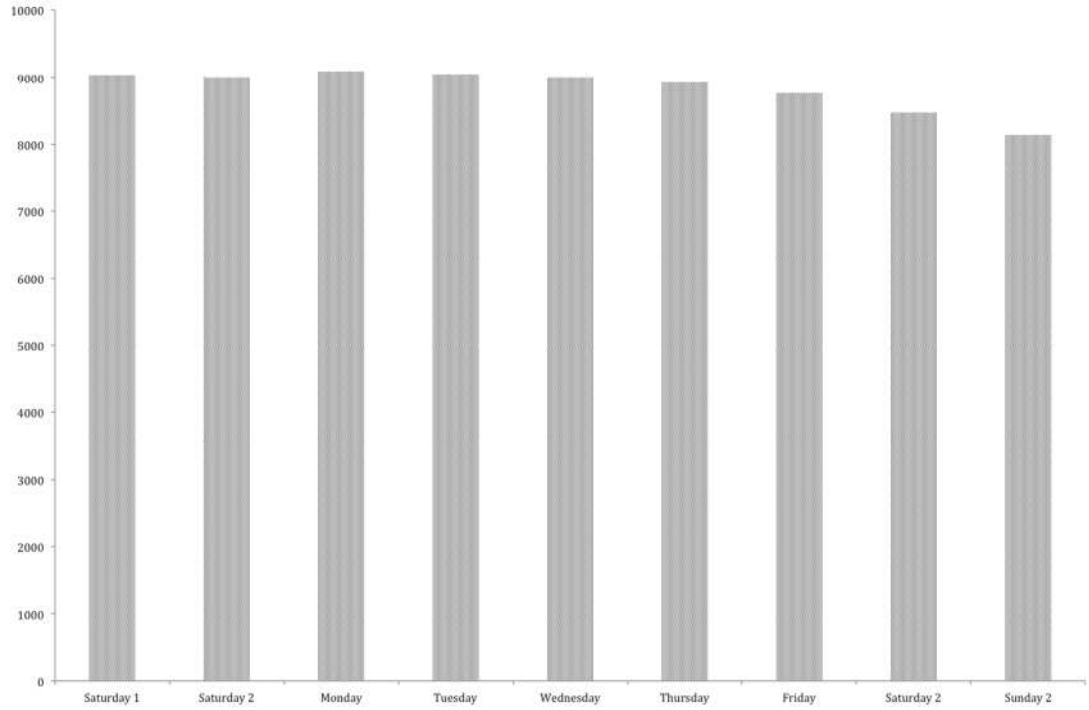

Figure 1: Compliance rates from Ipsos MORI

This paper seeks to shed light on the level of burden and patterns of compliance from longer duration GPS travel surveys, by examining reported burden and measured compliance from a GPS survey currently being deployed in London. Each participant is survey for a minimum period of eight weeks.

METHODOLOGY

Data on travel behaviour is being collected from 100 participants in London using GPS. Each participant is asked to carry the GPS device for a period of eight weeks. Additional data is collected through from participants through questionnaires. At the time of writing this paper, the survey is still ongoing with 21 complete participants. All graphs and tables in this paper contain the data from 21 participants unless otherwise stated. The devices the used were produced by GTrek (2011) that allow for custom epoch rates to be selected. The battery life was stated as 30 hours and they are smaller and lighter than a mobile phone.

Participants were recruited via an online eligibility survey, publicized by email sent to all students, researchers and staff within UCL. The key question determining eligibility was that the potential survey participant resided in London. Once they were deemed eligible, random selection took place within four distinct quotas including participants:

- under twenty five,
- over sixty,
- who work long hours (in excess of 36 hour per week) or shift work and
- with children in their household.

These quotas were selected as these groups were found to display different forms of travel behaviour and thus may be expected to experience burden differently (Simpson 2011).

Table 1 displays the current progress of measuring the survey quotas and Table 2 displays the age distribution of the completed surveys of the 21 respondents.

	Under 25	Over 60	Shift/30+ hours	Children
Aim	25	25	25	25
Received to date*	3	2	15	6

Table 1: Participants who have completed the survey split into quotas (NB: participants can fall into more than one quota).

Age Range	18-24	25-39	40-59	60+
Received to date*	4	8	7	2

Table 2: Age distribution of the initial 21 respondents

As participants start the GPS survey, they undertake an entrance survey to give details about themselves, the types of transport modes they have used over the past two months (as an indicator of what they may use over the next month) as well as the reasons they repeatedly travel to the same locations.

Between days 21 and 35 of the survey, the participants were met by the researcher. At this meeting data was uploaded from the device and the device memory was cleared. This was necessitated to ensure the devices didn't fill with data before the end of the survey although it provided an opportunity to check the device was functioning.

As participants complete the GPS survey an exit survey is conducted, which aims to discover how they rate the overall burden they experienced in participating. The levels of burden imposed by different elements of the survey were also explored, such as the ease of keeping the device charged. The exit survey also gathered some basic data on compliance – the frequency with which the participant forgot to carry the device and the extent to which they forgot to charge the device.

Over the survey period, 100% of participants travelled by foot, 90% by London Underground, 85% by bus, 85% by rail, 61% by car (passenger), 47% by plane, 42% by bicycle, 38% by car (driver) and no participants travelling by van. The high levels of public transport and of cycling are likely due to the pre-requisite of

living in London to be eligible to take part in the survey; a city which has higher levels of public transport usage and greater numbers of cyclists. The higher proportion of people travelling by plane over the survey period is likely owing to the first complete datasets occurred over July and August, traditionally a time of holiday in the UK although the figure of 47% is lower than the 61% of the participants who had reported travelling by plane over the previous two months at the start of the survey. 67% of the participants had a driving licence whilst only 43% of respondents reported having access to a car. 69% of participants reported having access to a bicycle. When asked if they planned to leave London over the next two months, 95% participants said they had plans to leave London.

RESULTS

SURVEY BURDEN

The participant's general experience of burden of the survey, were tackled through two key questions in the exit survey. When asked how they would rate the burden of carrying the device day-to-day and over the survey period, the results show that participants on the whole found the survey to have burden to be of an acceptable level with no participant rating the burden as high or very high (Figure 2). Despite this, participants appear to have rated the burden of carrying the device for the minimum eight weeks of the survey period slightly higher than the burden of carrying the device each day, with a slight shift to rating the burden as low and OK as opposed to very low.

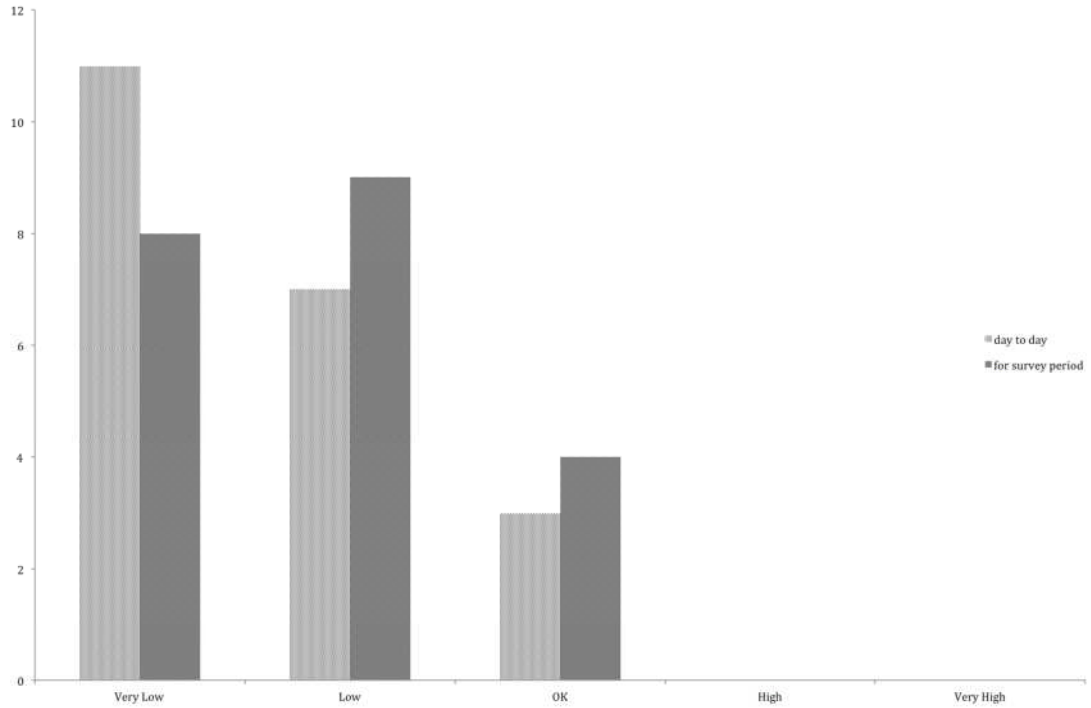

Figure 2: Participant ratings of the burden of carrying the device both day to day and over the survey period.

Many comments indicated the charging of the device was a burden: "*no burden carrying it but problem with keeping it charged.*" Perceptions of the easy of keeping the device charged were mixed, responses were spread across the scale from very easy to very difficult. A third of participants stating the task of

keeping the GPS device charged as either difficult or very difficult (Figure 3). In addition the participants were asked to rate the difficulty of remembering to carry the device. Only one participant rated the task of carrying the device as difficult with nobody rating the device very difficult (Figure 4).

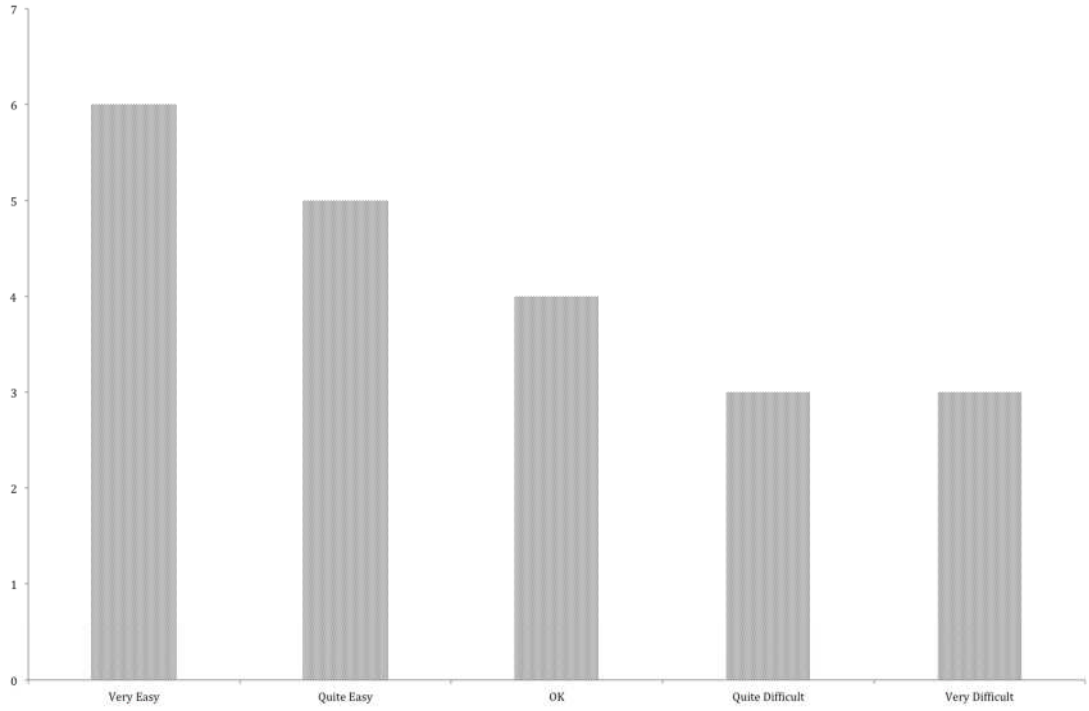

Figure 3: Participant ratings of the difficulty of keeping the device charged

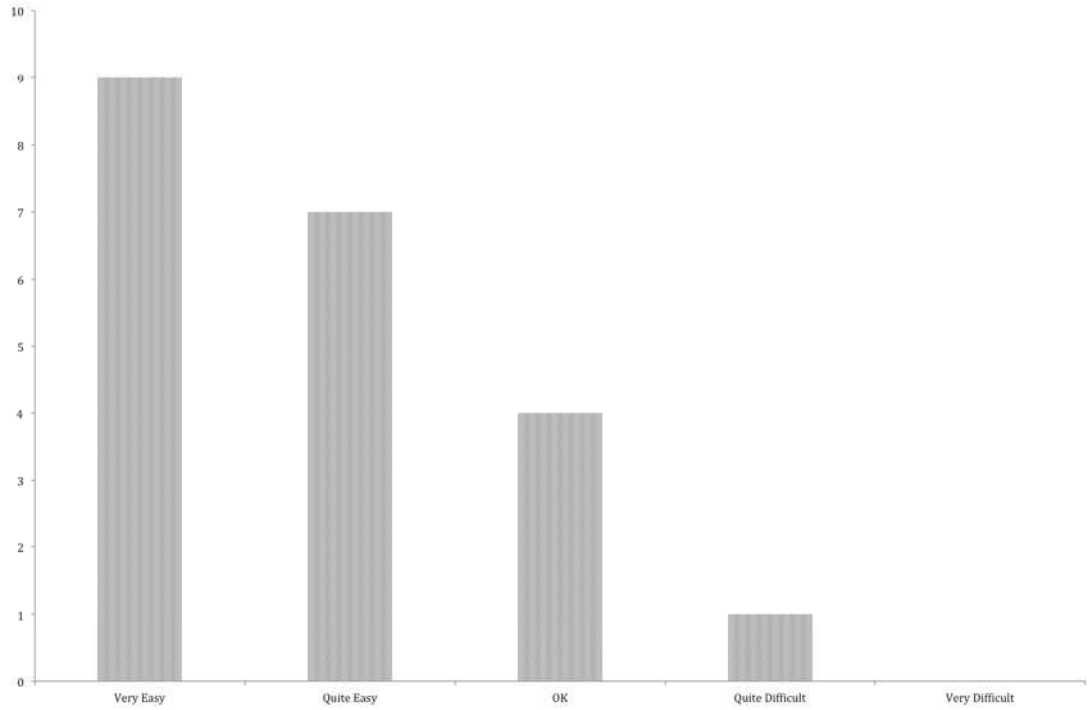

Figure 4: Participant ratings of the difficulty of remembering to carry the device.

The burden of the survey design was measured with a further three questions asking the participant to rate whether they found the initial and placement

meetings easy or difficult to arrange and whether they found their halfway meeting required for data collection as helpful or a burden. Of the 63 responses, only three responses were rated as quite difficult (2) or difficult (1) (Figure 5). The initial meeting did was not rated as difficult or very difficult which may be due to the benefits the participant gets from attending the initial meeting; a full explanation of the study, an explanation of the device and the reward for taking part in the study.

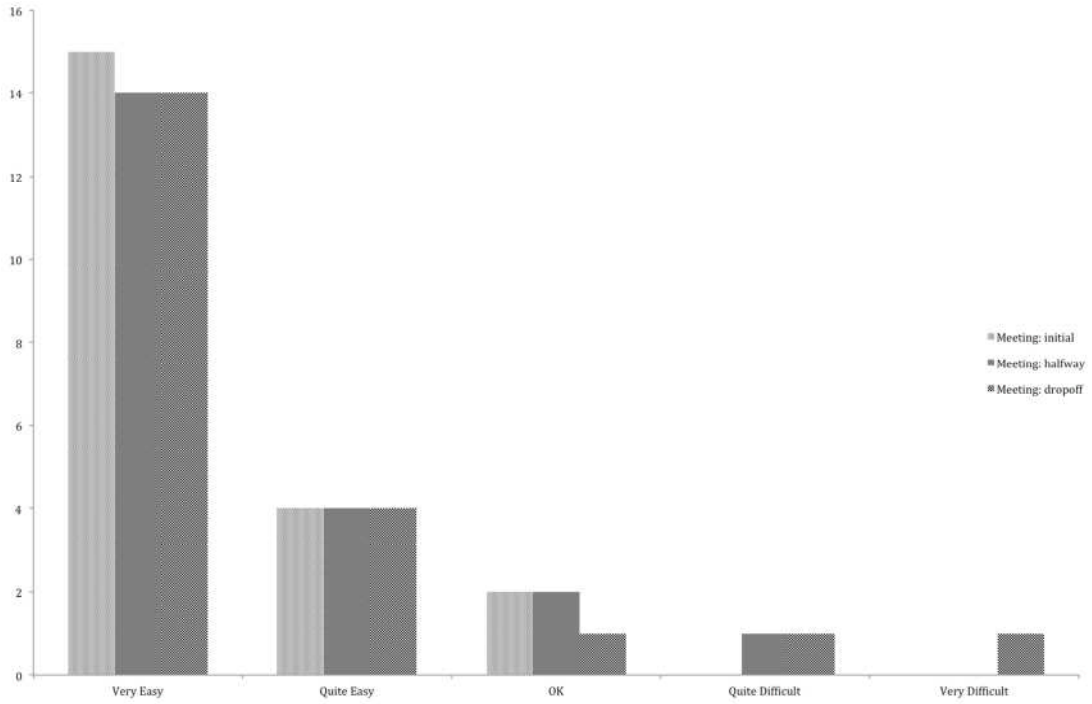

Figure 5: Participant ratings of the meetings with the researcher.

The GPS technology offers a low burden methodology option for travel surveys, indicated with 75% of the participants willing to continue the methodology for longer without further reward (Table 3). Furthermore, the fact that nobody rated the burden of the eight week survey period as high or very high is somewhat surprising given the long-term nature of carrying the device. When considering the ratings of burden for the different aspects of the survey design, remembering to carry the device saw low burden values given (Figure 4), carrying the device around with the participant each day and for the overall survey period was deemed to be low burden (Figure 2) and 87% of respondents stating it was either very easy or easy to meet with the participant (Figure 5). Indeed the burden of the researcher meeting with the participant may even lower in a future study if the memory storage on the device was sufficient not to necessitate a halfway meeting for data collection purposes. Where the burden is slightly higher is the effort involved in keeping the battery charged (Figure 3). The devices come with batteries that last for 30 hours when fully charged meaning they must be recharged daily. There were many reports of "*left it in my jacket pocket*" or *"left it in my handbag*" with some participants complaining that the charger used was "*not the same charger as mobile/mp3/kindle*".

Number of participants willing to continue		
without reward	with reward	not willing
16	1	4

Table 3: Number of participants willing to continue with the survey.

COMPLIANCE

Whilst participants may have found the survey low burden it is worthwhile looking at their levels of compliance. The exit survey asked participants about their level of compliance with regards to two aspects – keeping the device charged and remembering to carry the device.

Only three participants responded that the device remained charged for the survey period. Reasons given in the exits interviews for not keeping the device charged included the fact the charger was "*not the same charger as mobile/mp3/kindle*" or that it was *"left at the office*" and that the charge ran out "*several times especially during weekend*". These responses are in keeping with the ratings given by the participants on the burden of keeping the device charged.

When asked about compliance with regards to carrying the device, only three participants stated they had never forgotten to carry the device. There was anecdotal evidence obtained when meeting with the participants that the types of trips that people forgot the device on were the infrequent and non-habitual aspects of their travel i.e. work trips may be over represented as a proportion of the trips measured over the survey period compared to short unplanned trips for example when travelling to the corner shop or spending an afternoon in a park.

Compliance was also examined by analyzing the GPS data collected. In the following graphs, a participant has been deemed to be complying with the survey demands if there is GPS data on a given day, as this means they are remembering to charge, carry and switch their device on for at least part of the day. Figure 6 shows the percentage of participants for whom no data was recorded on each of the survey days, where 1 is the first day on which the participant was asked carrying the device and 56 is the 56th day of the survey period. Note: some devices were defective and retrieving devices from some participants proved difficult thus a sizable proportion of participants continued past the initial eight week survey period with one participant continuing to carry the device for over 100 days thus the number of participants have been displayed in the graph. This should not be mistaken with drop-off.

The percentage of days without any data over the survey period seems to contain three distinct phases:

1. An initial rise over the first week
2. A greater variation in the percentage of participants for who no data was recorded between days 15 and 35
3. After day 35 a slight rise and then leveling of the participants without data.

The sharp rise over the first phase could be the participant acclimatising to the survey demands as the novelty of using a GPS device wears off. The second phase of a greater variation in the number of participants could be affected by

halfway data collection meeting whilst the third more settled phase after day 35 could hint that compliance settles once the participants settle into the demands of the survey.

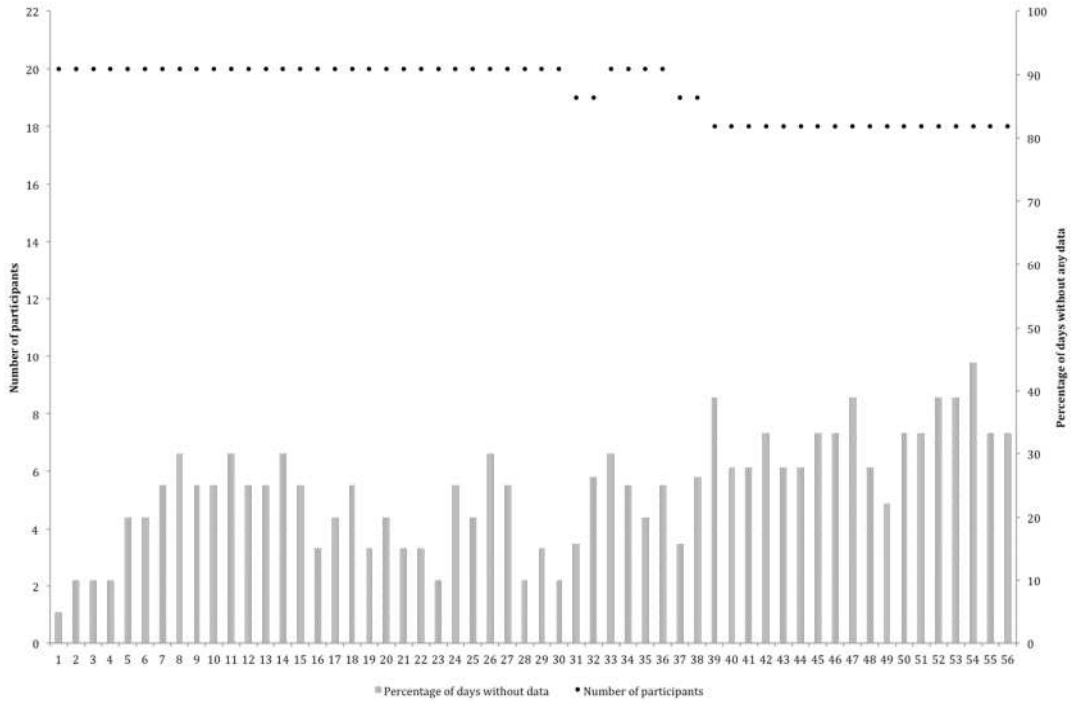

Figure 6: Percentage of days without any data over two months survey period. Note the number of participants displays the number of GPS devices that were in use and functioning for any given day and should not be confused with participant drop-off.

The second phase includes a period in the survey design when the participant and researcher meet to transfer data from the device to ensure the memory does not fill up over the survey period. When placing this halfway data collection date as zero and showing the number of days with no data for the two weeks before and after (Figure 7), it is clear that the data collection aspect of the survey method has an effect; with no participants having days without any data the day after the collection and a marked reduction for some days afterwards.

When exploring the compliance by measuring the number of days without any data by day of week, the results clearly show that Sundays have a higher proportion of days without any data, with Tuesday Wednesday and Thursdays seeing the lowest proportion of days without any data (Figure 8). Interestingly, Friday and Monday although slightly lower than the weekend average are level with the proportion of days with no data on Saturday. Saturday could be artificially higher given this measure would include respondents who unplugged a device from charge on Friday morning and didn't charge it over the weekend (some data points would still be recorded on Saturday). Given most people's work habits impose systematic variations on weekdays, respondents may have more variation in the types and destinations they travel to. This greater variation in trips undertaken over a weekend may result in the participant experiencing a higher burden with regards to charging the device as greater thought must be given as to where, when and how the device can be charged thus weekend activities impact compliance.

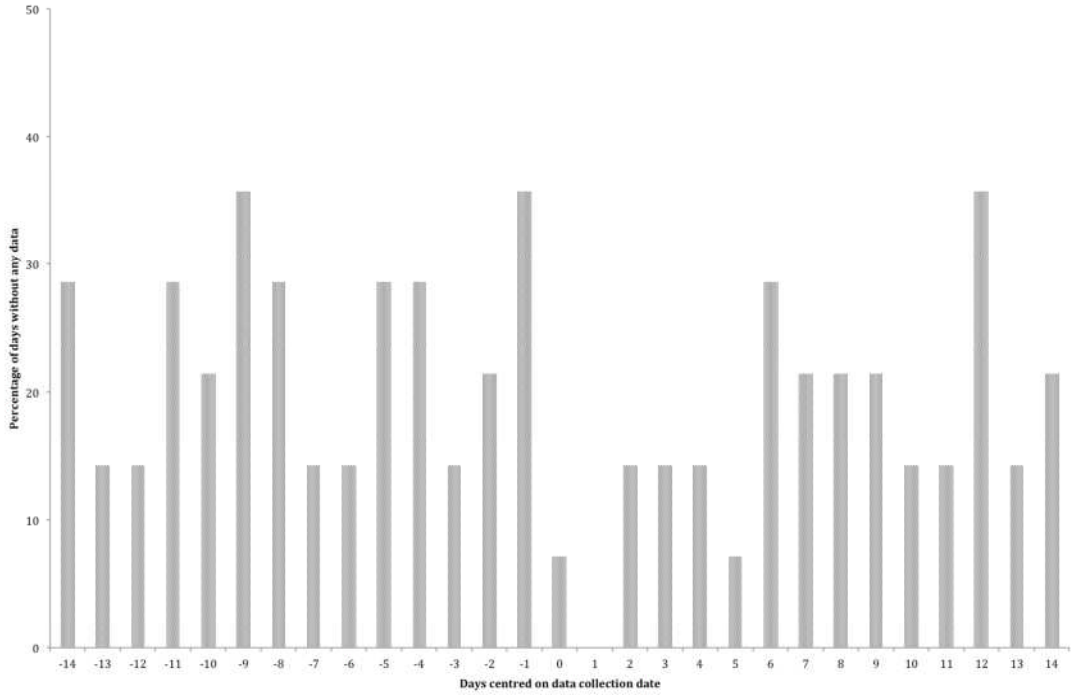

Figure 7: Percentage of days without any data centred on the data collection point of the GPS survey design (day 0). This graph consists of 15 participants data owing to five cases of broken devices (incomplete data) and one case of a participant not meeting with the researcher for data collection.

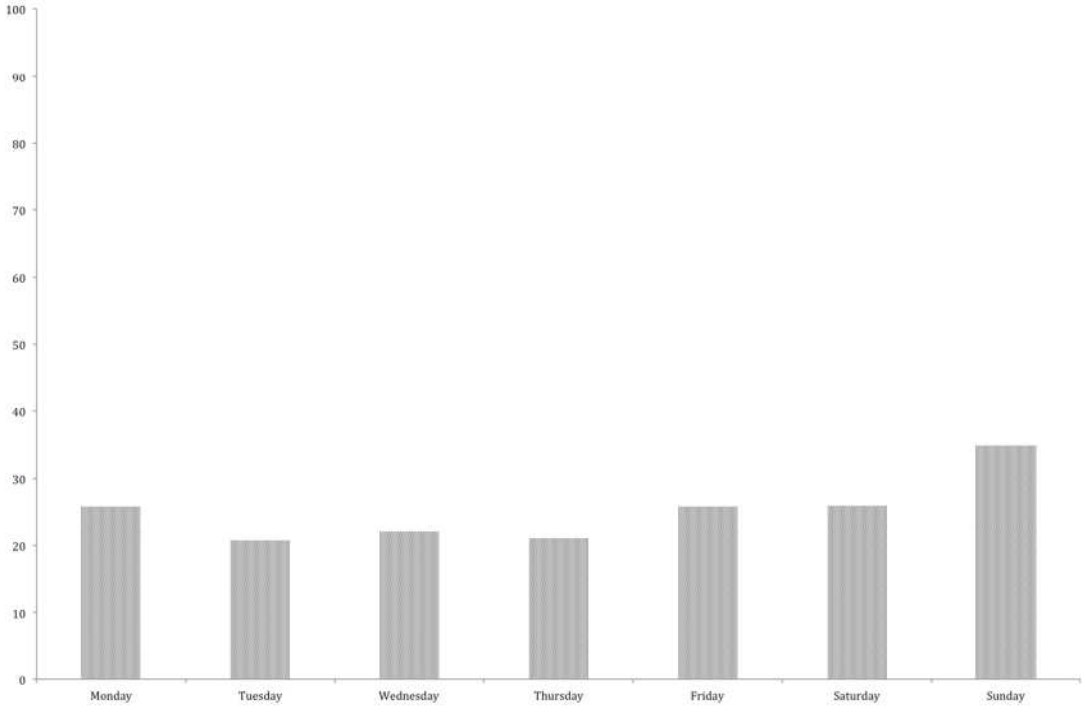

Figure 8: Average percentage of days without any data sorted by day of week.

Figure 9 displays the distribution of the number of points on days with data. This analysis shows 60% of the days included data for more than 12 hours in a given day, 80% included more than five hours and just short of 90% contained more than three hours of data. Just over 10% of days contained less than three hours of data suggesting that when participants were complying with the

demands of the survey, the devices are collecting lots of data. When exploring the differences between participants regarding compliance, Figure 10 shows that ten of the 21 participants had fewer than 10% of days surveyed without any data whilst eight participants had greater than 30% of day without data. Given 18 of the respondents reported the battery running out during the survey period it would appear that the battery life is an issue with the device used and any future studies should ensure battery life carefully when choosing which device to use.

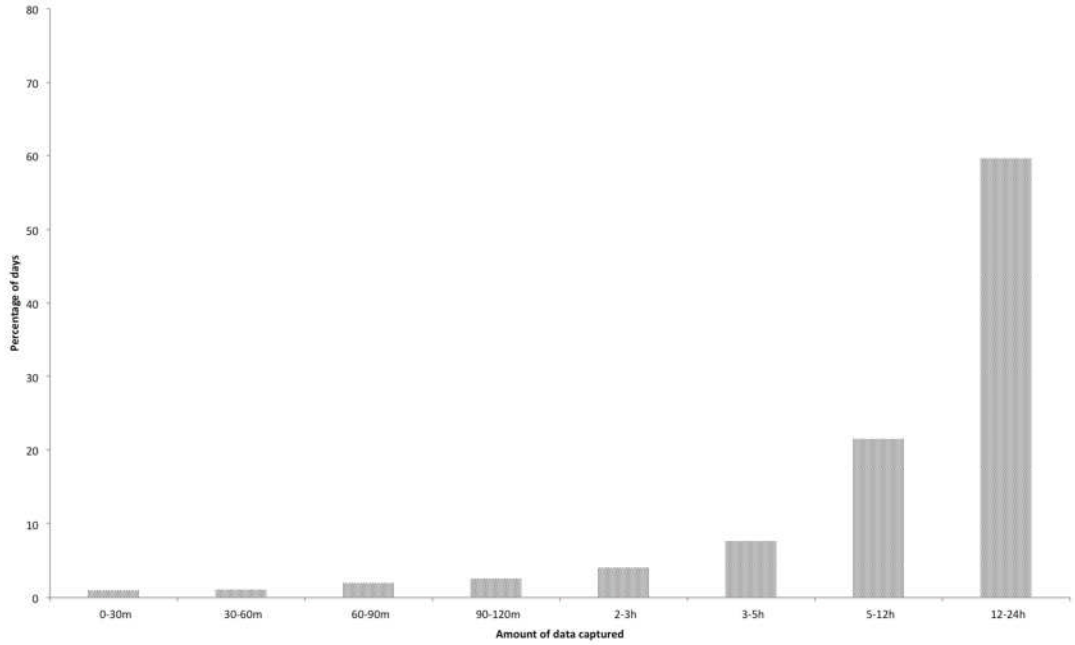

Figure 9: Distribution of the number of points on days with data, displayed in times i.e. with an epoch rate of 30s, 60 data points provide 30 minutes of data. Non-compliant days (i.e. days where no data was received) have been excluded from this graph.

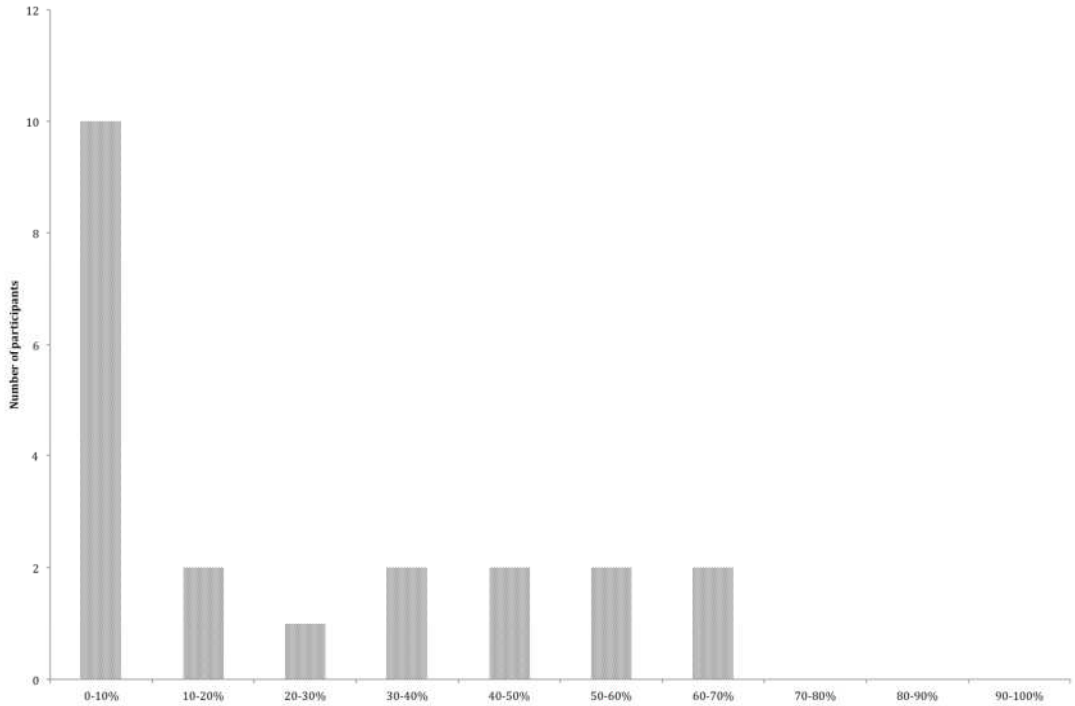

Figure 10: Number of participants sorted by the percentage of days where no data is recorded by the GPS device.

CONCLUSIONS

The participants rated the burden of participating in the survey as relatively low. The biggest burden seems to be related to that of keeping the battery charged. Surprisingly, no participants have so far rated the survey as high or very high burden when relating to carrying the device each day or over the eight-week survey period. With regards to the survey design necessitating the participant and researcher to meet three times over the survey, 95% of the participants rated the process as acceptable (very easy, easy or OK) with three quarters willing to continue the survey without a reward. The initial respondents indicate Sunday as having the lowest compliance with Monday, Friday and Saturday appearing about equal in compliance. This is different from the initial survey results from Ipsos MORI (2010) which showed both weekend days to have a lower compliance than weekdays, and may be a result of the value of non-compliance for Saturday being artificially lower given the method used within this paper for reporting non-compliance. The weekend for many participants sees a greater variation in trip destinations and activities. This variation may result in a higher burden with regards to charging the device as greater thought must be given as to where, when and how the device can be charged thus weekend activities impact compliance.

With regards to compliance, when looking at the percentage of days without any data over the survey period, there appears to be three distinct phases within the dataset; first an initial rise over the first week which may be a result of the burden of complying with the demands of the study rising as the novelty of participating (quickly) wears off. The second phase involves a greater variation in the percentage of participants for whom no data was recorded between days 15 and 35 and appears to be a result of the survey design's data collection point in the middle of the survey period. The third and final phase after day 35 sees a leveling in the percentage of participants for who no data was recorded and may be a result of the settling of burden; whereby participants who find the survey high burden and difficult to comply with the demands of the survey settle into higher levels on low compliance whilst those who find the survey low burden and find it easy to comply settle into rates of high compliance.

Due to the small number of responses received at the time of writing this paper, it has not been possible to complete all the analysis desired on compliance rates and how these relate to perceptions of burden amongst the participants. Once the data set is complete the following will also be investigated:

The analysis done to date has concentrated on assessing burden and investigating days of complete non-compliance. Further analysis will be done to investigate partial compliance on any particular day and to attempt to identify reasons for partial compliance. Reasons for partial compliance might include, for example:

- The device runs out of battery
- The device accidentally gets switched off whilst being carried

- Participant travelled by tube and on exit no signal was received until they reached their charging location
- Bad weather or other factors caused bad signal quality through the day
- The participant may have chosen to omit a trip by switching off the device and only remembering to turn it back on when they charged the device.

By examining where and when the signal is lost and then returns, it may be possible to identify possible reasons for missing data and therefore draw inferences about rates of partial compliance.

Finally, it should be noted that another type of non-compliance is trip omission; given the hugely personal and spatial nature of the data being captured, participants were instructed how to conceal trips they consider being private. Although this is permitted in the survey design, it is still a form of non-compliance and as such may be encountered in the GPS trace by the device losing signal and regaining signal in a non-charging location.

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