The benefits of measuring driving exposure using objective GPS-based methods and subjective self-report methods concurrently

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Abstract

Measurement of individuals' driving exposure has traditionally relied on subjective self-report methods, which tend to be inaccurate and require substantial effort for the individuals volunteering for the study. The development of Global Positioning System (GPS) technology has provided a new option for accurately and objectively measuring exposure. However, some exposure information (trip purpose and driver identification) can most easily be obtained with self-report methods. Therefore, the purpose of this study was to evaluate the concurrent use of GPS data loggers and telephone-based travel diaries for measuring driving exposure. The driving of 54 participants (aged ≥ 75) was monitored for a period of one week. The GPS data loggers provided standard exposure measures (distance driven, time spent driving, number of trips), as well as measures that cannot be obtained through self-report (travelling speed, driving route) for all participants. The distance measured by GPS corresponded with distances obtained from the odometers in the vehicles, which indicated that the GPS measurements were accurate. Furthermore, the trips that were recorded by GPS were matched to the information reported in the travel diaries and, therefore, the purpose and driver of a majority (95.2%) of the trips could be identified. Also, a subset of the participants who were interviewed (n = 16) provided favourable feedback regarding the data collection process. The findings indicate that GPS technology will advance the measurement of driving exposure but that self-report methods are still useful for obtaining certain exposure information. Therefore, GPS technology may not replace traditional methods but complement them.

Introduction

The most common methods for measuring individuals' driving exposure have traditionally been self-reported in nature. However, these methods can produce inaccurate data (Blanchard, Myers, & Porter, 2010; Huebner, Porter, & Marshall, 2006; Staplin, Gish, & Joyce, 2008; Staplin, Gish, & Wagner, 2003). Self-report questionnaires, in particular, usually involve retrospective estimation of how much driving an individual has done, which is likely to be quite divergent from the true amount due to inaccurate recall (Blanchard, et al., 2010; Huebner, et al., 2006; Staplin, et al., 2008; Staplin, et al., 2003). The difficulty of recalling exposure can make participants reluctant to even attempt it (Blanchard, et al., 2010).

This problem of recall bias is reduced with the use of self-administered travel diaries, as the participant is required to actively fill out daily logs of their driving. Such methods may include a daily record of the distance travelled as measured by the car's odometer. Travel diaries also provide a greater level of information (Blanchard, et al., 2010), such as the purpose, start/stop times and origin/destination of trips, as well as the amount of trips that a driver makes. They require, however, substantial effort for the individuals volunteering for the study, which introduces the possibility that the participant may forget to fill in the diary or fill it in at the last minute with incorrect information, and it also increases the likelihood of fatigue and non-compliance, all of which result in a loss of data (Marshall et al., 2007). The demands of this method are also likely to be particularly arduous for older participants.

The development of Global Positioning System (GPS) technology has provided a new option for measuring exposure. Devices that receive GPS signals from satellites are used to provide time-stamped location information from anywhere on the earth. The information is accurate to within a few metres for location and to the nearest second or less for time (Stopher, FitzGerald, & Zhang, 2008). When a receiver is placed in a motor vehicle, it uses the location and time information to provide an accurate measurement of the distance the car travels between two points, as well as the start/stop time of the trip and the time it took the car to travel the distance. It does not rely on recall estimations or daily completion of detailed travel logs. Thus, the level of involvement of the participant, as well as the burden on them, is minimal. Consequently, it provides data that is considerably more accurate and objective (Inbakaran & Kroen, 2011; Shoval et al., 2010). It has also been demonstrated in earlier studies that participants preferred this method to questionnaires and travel diaries (Blanchard, et al., 2010; Marshall, et al., 2007). GPS receivers that record location and time information have also proven to be small, unobtrusive, inexpensive and reliable (Duncan, Badland, & Mummery, 2009; Shoval, et al., 2010; Stopher, et al., 2008). Recent research (Blanchard, et al., 2010; Shoval, et al., 2010) has espoused the advantages of using this technology and shown that there are substantial discrepancies between the accurate measurements made through this method and those based on subjective self-report methods.

The application of GPS technology to measuring driving exposure further advances the detail of the exposure information obtainable (Marshall, et al., 2007). The combination of exact location and time information results in the ability to determine how fast a vehicle has travelled between two points, which is particularly useful for road safety research for assessing the speeds at which people drive and whether they abide by road speed limits. Furthermore, when the location and time information is imported into geographic information system (GIS) software (e.g., Google Maps or similar software), it provides a way of visualising where the driving took place. This allows examination of the characteristics of the roads on which the driving occurred (e.g., number of intersections, lanes, etc.), as well as the routes that people have taken to reach their destinations (Marshall, et al., 2007).

The reduced involvement of the participants in data collection using GPS does result in an inability, however, to obtain some important information from the GPS receivers alone. This includes determining the purposes behind individual driving trips made by the participants (e.g., shopping) and identifying the driver of the vehicle (necessary when the participant's vehicle is also driven by one or more other drivers).

As preparation for a study using GPS-based measurements of driving exposure and travel patterns to compare older drivers (aged 75 years and older) from rural and urban areas of South Australia in terms of their driving mobility and safety, it was first necessary to evaluate the process of using GPS receivers for data measurement with older road users. It has been argued that more traditional travel survey methods work best for older travellers while GPS methods are more suited to younger study participants (Bricka, Sen, Paleti, & Bhat, 2012). A sample of 54 older drivers were recruited for the study and had a GPS device installed in their vehicle for a week to measure their driving.

To obtain information about trip purpose and who was driving the vehicle for each trip, participants were called on the telephone by a researcher on a daily basis during the one week testing period and asked to report these to the researcher, who recorded them. The intention was that this would work in a similar way to a conventional travel diary but would be less strenuous for the participant because the researcher would record the information, which would also result in decreased data loss. It was hoped that, through the combination of calling the participants daily and using GPS receivers, all necessary information could be measured and the limitations of each separate method could be overcome.

The aim of the present study was not to test any specific hypotheses regarding the driving exposure or travel patterns of older adults, but rather to determine whether data collection with GPS receivers (also referred to as GPS data loggers) and the process of calling the participants was achievable, accurate and undemanding. In terms of achievability, the intention was to determine whether any problems with data collection as noted by the researcher could be overcome. For accuracy, the intention was to determine whether there was a high level of correspondence between the distance travelled by each participant over the week as measured by the odometers in their vehicles and that measured by GPS. A further intention was to determine whether the trips reported daily by the participants corresponded with those recorded by GPS. The final intention was to examine whether the feedback from the participants was favourable, in order to determine whether using GPS data loggers and being called daily by a researcher was acceptable to older adults.

Method

Participants

Participants for both the present study and the subsequent study were recruited at the South Australian Royal Automobile Association's (RAA) "Years Ahead" presentations. The RAA is an independent automobile club in SA that provides services such as 24-hour emergency breakdown assistance, insurance and road safety information to the approximately 560,000 members. The "Years Ahead" presentations are held at senior citizens clubs and churches throughout SA and provide information on road safety specifically focusing on older adults. One of the researchers (JPT) spoke about the study at these presentations and invited attendees to participate.

Participants were required to be aged 75 years or older, hold a valid driver's licence for a car (class C licence, entitling a person to drive non-commercial motor vehicles not exceeding 4,500kg), have driven at least once in the previous month and speak fluent English. The total sample consisted of 54 older drivers (23 females, 31 males), with 27 participants from metropolitan Adelaide (13 females, 14 males) and 27 from rural areas beyond metropolitan Adelaide (10 females, 17 males). Participants ranged in age from 75 to 90 years, with a mean of 80.3 (SD = 3.7). Urban participants had a mean age of 80.6 years (SD = 3.6) and rural participants 79.9 years (SD = 3.8). Participants were entered into a draw to win one of five $50 gift-vouchers to thank them for their assistance.

Materials

The cognitive functioning of each participant was assessed prior to their involvement in the study in order to screen for cognitive decline and ensure that they had the ability to recall specific information about their driving. The standard version of the Mini-Mental State Examination, 2nd edition (MMSE-2) (Folstein, Folstein, White, & Messer, 2010) was used for this purpose. Scores range from 0 to 30, with higher scores indicating higher levels of cognitive functioning. Participants were to be excluded if they scored 24 or less, as this cut-off is thought to be suggestive of cognitive impairment (Lezak, Howieson, Bigler, & Tranel, 2012). However, no participant scored $\leq$ 24 on this measure (mean = 28.56, SD = 1.27) and so no-one was excluded from the research.

The GPS data logger that was used was the 747ProS GPS Trip Recorder (TranSystem Inc., Hsinchu, Taiwan). Figure 1 displays a digital photograph of the device (hereafter referred to as Trip Recorder). This data logger was selected for several reasons. Firstly, it is small (width = 47mm, length = 72 mm, height = 20 mm, weight = 65gm) and can be mounted onto the vehicle's dashboard. It has 64Mb of internal memory and can be set to record location and time information by specified time intervals, distances or speeds. For this study, it was set to record data every second. Depending on the strength of the satellite reception (which can be affected by overhanging trees, tall buildings, inclement weather, tunnels, etc.), the accuracy of the information that the Trip Recorder records is within 3 metres for location and to the nearest second or less for time. This level of accuracy corresponds with other contemporary GPS data loggers (Stopher, et al., 2008).

Figure 1. Digital photograph of the 747ProS GPS Trip Recorder shown with the car charger.

The Trip Recorder has a rechargeable battery, which provides 30 hours operation time and 300 hours standby time. When attached to the vehicle's AC power using a car charger, however, it has a setting that synchronises its operation with the vehicle's ignition. Thus, it only records data when the ignition is on and the device is receiving power; when the ignition is off, it goes into standby mode. This reduces the consumption of the internal battery power, as well as continually recharging it. It also groups the data into separate 'trips' (i.e., a section of driving in which the vehicle was started at a certain location, driven and then stopped at a particular destination) because it starts recording when the vehicle is started and driven, and then stops when the vehicle is turned off. Moreover, by not operating continuously, it eliminates needless data. It also has a built-in motion sensor. When it is set to use this sensor, it will start recording data when motion is detected (i.e., when the car is in motion) and will enter standby mode when it is static for two minutes. This was useful for vehicles in which the AC connection was not working or was used for another purpose (e.g., charging a mobile phone). Use of this sensor prolongs the life of the internal battery and, as with the car charger, eliminates needless data and separates trips.

The Trip Recorder obtains and records data independently of the vehicle it is placed in. This differs from other data loggers which connect to the vehicle's on-board computer and only work in cars manufactured after 1996 (Blanchard, et al., 2010; Huebner, et al., 2006; Marshall, et al., 2007). Unlike these loggers, the Trip Recorder also works in hybrid cars that switch between power sources.

A common problem with the use of GPS data loggers relates to 'cold starts' (Blanchard, et al., 2010; Stopher, et al., 2008). These occur at the beginning of trips when the device is delayed in acquiring adequate satellite reception. The vehicle may travel a distance before a signal is acquired. This can result in the device not logging the start of a trip or, if the trip is short, the entire trip. If the device is stationary during this process it may obtain reception relatively quickly, if it is already in motion, however, it may take longer. The time in which data recording is delayed by cold starts is continually being reduced as the reception acquisition rates of newer GPS receivers improve. The Trip Recorder has an average acquisition rate of 35 seconds for cold starts where the device is switched on for the first time, which is similar to other contemporary devices. It has several advantages, however. Firstly, when the vehicle is stopped the Trip Recorder does not turn off but goes into standby mode. When started from standby, it reacquires reception faster (up to less than one 1 second). It also has the ability to use assisted GPS (A-GPS) information that is downloaded from the satellite network. This information relates to the orbital location of satellites and helps the device locate satellites faster and reduce the time that it takes to receive data.

A computer program that was supplied with the Trip Recorder, called GPS Photo Tagger, was used to change the settings on the device, import the A-GPS information and retrieve the recorded GPS data. The retrieved data was then imported into a program that was developed by the researchers at the Centre for Automotive Safety Research (University of Adelaide) for analysis. The program organises the data for each participant into a list of separate trips. The information that is presented for each trip includes the date and time when it started, its length in distance (kilometres) and duration (minutes), and the average, minimum and maximum speeds (km/hour). The total kilometres and minutes, as well as the average speed, over all of the combined trips are also displayed. Each trip can be viewed on a map, with a line represented the trip from start to finish. Along the line are dots for each instance where location and time information were recorded, which occur every second. The dots and line are coloured differently according to the speed at which the vehicle was travelling at the time, with different colours representing 0 to 59 km/h, 60 to 79 km/h, 80 to 99 km/h and 100 km/h and over. The user can select a segment of a trip by clicking on any two dots on a line, which then displays the distance (metres) between the two points and the time (seconds) that the vehicle took to travel between them. This option allows the user to highlight a segment where, for example, the participant was travelling over 100km/h.

A ‘Travel Diary’ sheet was used by the researcher when contacting the participants daily to record the details of all of the driving that occurred in the vehicle(s) in which a Trip Recorder had been installed. For each trip, the Travel Diary recorded the date, the driver, start location and destination, trip purpose (e.g. shopping), and approximate start and end times. Odometer readings for the participants’ vehicles were also recorded at the beginning and end of the week.

Feedback was also sought from a subset of the participants (n = 16) in terms of whether they found taking part in the study easy, whether they were bothered by being called each day and asked about their driving, whether they were bothered by having a GPS device in their car, and whether the GPS affected their normal process of driving. Four point scales were used for these items. They were also asked whether they changed their normal driving routines because they had a GPS in the car and whether they forgot about the presence of the GPS. Three point scales were used for these items.

Procedure

Following recruitment, the researcher visited the home of each participant to obtain written consent for participation, to administer the MMSE-2 and install the Trip Recorder into the participant’s vehicle. If they drove more than one vehicle, a device was placed in each. If the AC power connection in the vehicle was not working, or if it was needed for another purpose, the device was set to use the motion sensor. The researcher also recorded the vehicle’s odometer reading.

The researcher telephoned participants on a daily basis during the week to record the Travel Diary information, and returned to their residence at the completion of the seven day period. On this second visit, the researcher recorded the final information for the Travel Diary, removed the Trip Recorder and took a final odometer reading. Also, 16 participants provided feedback on the study.

The GPS data for each participant was imported to the computer program that was developed specifically for analysing the data recorded on the Trip Recorder. Trips were excluded where the motion sensor was activated and the distance travelled was 0.00, 0.01 or 0.02 km. These recordings resulted from the sensor being highly sensitive to movement, such that a car would be turned off and stationary but something (e.g. passing truck) would cause the Trip Recorder to sense motion and start recording for at least two minutes until it returned to standby mode. The trips with a recorded distance of 0.01 and 0.02 km (i.e., 10 and 20 metres) resulted from longer periods of motion-induced data recording, where random minor errors in the GPS location were erroneously recorded as distance travelled by the vehicle.

Results

The evaluation of the Trip Recorder as a means of measuring driving exposure among a sample of older adults can be summarised in terms of any problems with data collection that were noted by the researcher, the correspondence between distances measured by the GPS and vehicle odometer, correspondence between individual driving trips recorded by GPS and those reported by the participants, and participant feedback.

Problems with data collection

Several problems were noted by the researcher when using the Trip Recorder to measure driving exposure. Firstly, the AC power was not working in several vehicles and, consequently, the motion sensor was used. However, although the motion sensor prolongs the life of the internal battery (by returning to standby when no motion is detected), it does not have enough power to run the Trip Recorder for an entire week. Therefore, the researcher had to return to the residence of each of these participants mid-week to exchange the first device with a fully charged device in order to address this issue.

Secondly, there were several instances where the Trip Recorder was delayed in acquiring satellite reception at the start of a trip. This was evident when the trip was viewed on the map and there were scattered data points at the start which were a distance away from where the previous trip ended. In these cases, adequate reception was quickly obtained and the remainder of the trip was recorded, but the data for the beginning of the trip was not useable. It was unclear what caused this. It was not a cold start because the vehicle was stationary for a short period and the device was in standby and using A-GPS information. There may have been buildings or trees that were blocking adequate reception. There were also three instances where a trip was not recorded at all. These instances were evident when the GPS data was matched to the information reported in the Travel Diaries. In two instances, the participants reported making a trip to a particular destination and then returning home, however, the trip to the destination was not recorded by the Trip Recorder in one instance and the return trip home was not recorded in the other instance. In the third instance, two consecutive trips were missing (i.e., the participant reported driving to the hairdresser and home again, however, neither trip was recorded). It was unclear why these instances occurred. It is possible that the Trip Recorder was unable to acquire adequate reception at any point during the trips. In the case of the two consecutive missing trips, it is possible that the participant mistakenly reported an outing that did not occur rather than an error by the Trip Recorder (though all participants were initially assessed using the MMSE-2 in order to screen for cognitive impairment and ensure that they had the ability to recall details of their daily driving). However, these were only four trips relative to 1,218 trips successfully recorded by the Trip Recorder for all of the participants.

Correspondence between distance measured by vehicle odometers and GPS

The difference between the vehicle odometer and Trip Recorder measurements of total distance (km) travelled over the week was calculated for each participant. The Trip Recorder obtained a smaller measurement than the odometer for 38 of the 54 participants (70.4%) and a larger measurement for the other 16 (29.6%). The difference was less than one kilometre for 24 (44.4%)

participants, which is small and may be accounted for by the fact that the odometer measurements were recorded in whole kilometres. However, 23 participants (42.6%) had differences that were between 1 and 5 kilometres and 7 (13.0%) were between 5 and 9 kilometres. It should be noted though that some participants travelled much further over the week than others (odometer measurements ranged from 5 to 554 km). Thus, a difference between 5 and 9 kilometres is relatively small if the participant travelled a large total distance. Consequently, the difference between the odometer and GPS measurements as a proportion of total distance (measured by odometer) was calculated for each participant (displayed in Figure 2). The differences represented less than four per cent of the total distances of 47 (87.0%) of the participants, but were larger for the others. The highest proportional difference was 14.6%, where the odometer measurement was 45 km and the GPS was 38.43 km. It was in this case, however, that the Trip Recorder failed to record the participant's trips to the hairdresser and home again, which may explain the large difference. Also, the third largest proportional difference (9.1%), was one of the other two participants for whom a trip was not recorded.

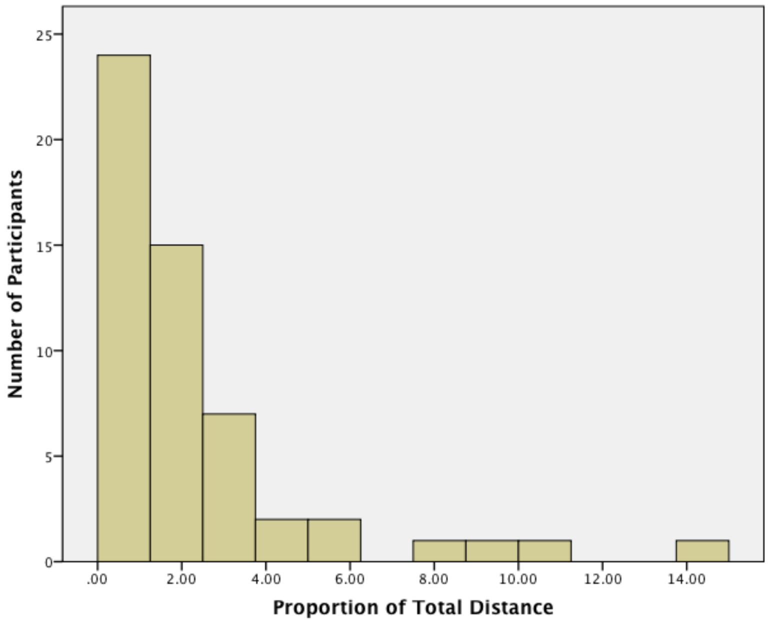

Figure 2. The proportional difference between odometer and Trip Recorder measurements of total distance travelled over one week for each participant.

Correspondence between individual driving trips recorded by GPS and those reported by the participants

Of the 1,218 trips recorded by the Trip Recorder for all of the participants, 1,005 (82.5%) were reported by the participants in their Travel Diaries. Thus, the purposes for these trips could be identified. The purposes of a further 154 (12.6%) were identified by the researcher in several ways. Firstly, a vehicle may have been re-parked or moved in/out of the garage, which could be identified on the map display. Sometimes a participant would forget to report that they made an extra stop at home before their next trip - this, too, could be detected on the map. An unreported trip often had the same destination (and purpose) as other trips made during the week (e.g., supermarket), which could also be detected on the map. The location where a trip ended could additionally be viewed through Street View in the Google Maps internet site (http://maps.google.com/). By doing so, the researcher could often determine the most likely purpose of the trip (e.g., library, shopping centre), although it is possible that the true purpose would not be identified using this method (e.g., driving to a shopping centre to go to the bank). Of the total 1,218 trips, there were 59 (4.8%) which were not reported and for which their purpose could not be identified.

A total of 13 participants shared the driving of the vehicle in which the Trip Recorder was installed with another driver. This other driver was often a spouse who only occasionally drove. The participant's driving could easily be differentiated from the other driver's through the Travel Diary information. The driver of any unreported trips was also identifiable because such trips usually occurred as one in a group of trips made by a particular driver. For example, the participant might travel from home to the bank, to the petrol station, to the supermarket, and then home again, but would forget to report their stop at the petrol station. It would be assumed, however, that the same driver made all of these trips.

Participant feedback

The participants' responses to the four feedback statements are displayed in Table 1. All either "strongly agreed" or "agreed" that they found that taking part in this study was easy, they were not bothered by being called up each day and having to report their driving, they were not bothered by having the GPS device in their cars, and the GPS device did not affect the normal process of driving their cars. This indicates that the participants viewed the data collection process favourably.

Table 1. Participants' responses (number of participants) to the feedback statements

	Strongly agree	Agree	Disagree	Strongly disagree
I found that taking part in this study was easy.	11	5	0	0
I was not bothered by being called up each day and having to report my driving.	13	3	0	0
I was not bothered by having the GPS device in my car.	13	3	0	0
The GPS device did not affect the normal process of driving my car.	14	2	0	0

The responses to the two feedback questions are displayed in Table 2. All of the participants reported that they did not change their normal driving routines in any way because they knew that the GPS device was in their cars. The responses to the second question were more varied but most participants reported that they "greatly" or "somewhat" tended to forget that the GPS device was in their cars while they were driving. These responses suggest that the participants and their driving routines were not affected by an awareness of the Trip Recorder in their vehicles.

Table 2. Participants' responses (number of participants) to the feedback questions

	Not at all	Somewhat	Greatly
Did you change your normal driving routines in any way because you knew that the GPS device was in your car?	16	0	0
While you were driving, did you tend to forget that the GPS device was in your car?	3	8	5

Discussion

The purpose of this study was to evaluate the use of a particular GPS data logger, called a Trip Recorder, as a means of measuring driving exposure for a subsequent study focusing on the driving mobility and safety of persons aged 75 years and older. The Trip Recorder was able to provide standard exposure measures such as distance driven, time spent driving and number of trips, as well as the start and stop times and dates of trips, for all participants. It also provided more complex measures such as travelling speed and, when the data was examined with mapping software that was developed for this research, the origin and destination of trips and information relating to the roads and routes on which the driving occurred.

Information relating to trip purpose and driver identification was also necessary but is not obtainable through the use of GPS data loggers alone (Blanchard, et al., 2010). It can be obtained using travel diaries, but their use has limitations related to the burden on the participant and the likelihood that they will forget to fill in the diary, or fill it in with incorrect information. Consequently, a further objective was to develop and test a process of contacting the participants daily during the testing period to record this information. It was hoped that this process could overcome the limitations of conventional travel diaries, but retain their ability to provide trip purpose and driver information. The necessary information was easily obtained with this method. Furthermore, the information was easily matched to the trips recorded on the Trip Recorder. Thus, a combination of using the Trip Recorder and contacting the participants provided the data that was necessary to undertake the intended analyses for the subsequent study. Blanchard et al. (2010) and Bricka et al. (2012) also argue that a combination of electronic and self-report methods are necessary to obtain the full range of exposure data. Moreover, an additional benefit of the Travel Diary in the present study was that the information that was reported by the participants was used to identify instances where the GPS device may have failed to record data. This demonstrates that GPS may not completely replace traditional methods of measuring driving exposure but complement them.

Other driver identification methods have been proposed, including key fobs or entry codes (Blanchard, et al., 2010; Marshall, et al., 2007) that are required when starting the car and which inform the data logger as to whom the driver is. These may work with research where only data loggers are used, but for research such as the present study where some form of participant self-report is necessary to determine trip purpose, an extra question on driver identification would be the simplest option. Another option is to use wearable devices (Stopher, et al., 2008) or applications downloaded onto mobile phones (Inbakaran & Kroen, 2011), where the participant carries the device on them instead of it being installed in their vehicle. Thus, only the participant's travel is recorded. However, wearable GPS devices rely on battery power, which limits the period of data collection. Also, both of these alternatives require the participant to remember to carry the device or phone, which means increased involvement and awareness of the process from the participant. There is also the additional difficulty of differentiating different modes of travel (e.g. pubic transport) and when the participant is a passenger in a car rather than its driver.

In the present study, the involvement required of the participants in the process of telephoning them daily and the resulting burden on them was minimal because it was the researcher who filled out the Travel Diary. The participant was only required to recall what driving they had done the previous day. In addition, the participants reported that they were not bothered by being called up each day and having to report their driving. This suggests that this method does not inconvenience the participants and is favourable to them.

As the demands and inconvenience of the Travel Diary are minimal, it was expected that there would be a high level of compliance by the participants and minimal missing data. All of the participants reported their daily driving. When the trips that they reported were matched to those recorded by the Trip Recorder, it was found that a majority were reported and the purpose and driver of a majority of those that were not could be identified by the researcher using the map display. The regularity of the daily prompting by the contact with the researcher would have reduced the data loss because it is likely to have encouraged diligence by the participants and they could not leave it to the end of the week to report all of their driving. Therefore, this process appears to overcome the limitations of conventional travel diaries where the participant records the necessary information.

The accuracy of the GPS measurements of distance were also demonstrated. The measurements were found to correspond with the distances recorded by the participants' vehicle odometers. Indeed, for a majority (87%) of the participants, the difference between the measurements represented less than four per cent of their total travel distance over the week. This is consistent with research by Huebner et al. (2006) who compared GPS measurements over a 26 km road course to those made by a CarChip device (which plugs into the vehicle's on-board computer to obtain exposure information) and found that the mean difference between measurements was less than 1%.

Furthermore, the process of using the Trip Recorder was found to be favourable and undemanding of the participants, as they reported that they were not bothered by having it in their cars, it did not affect the normal process of their driving, they tended to forget that it was present, and they did not change their normal driving routines in any way because of the GPS. This corresponds with similar research by Blanchard et al. (2010) who found that their participants reported that the GPS devices were barely noticeable and did not affect their driving behaviour.

Several problems with the Trip Recorder were noted but were able to be addressed so that they did not impede the data collection. The were some problems relating to delayed reception and power supply but these are not unique to the Trip Recorder and have been noted in research using other GPS devices (Blanchard, et al., 2010; Marshall, et al., 2007; Stopher, et al., 2008). The use of GPS data loggers to measure driving exposure is still in the early stages but does have a number of advantages. Furthermore, there is likely to be continual improvement as the techniques, technology and general understanding develop. Also, the process of daily contact with the participants developed in this study seems to hold potential for providing useful information without being intrusive. It should be noted, however, that the process of calling each participant daily was feasible with a sample of 54 participants, but would be more difficult to manage if the sample size was considerably larger. It may also be more difficult with other age groups for various reasons (e.g., work/social commitments).

In the subsequent study, the measurements of driving exposure are used to compare the rural and urban older participants in terms of their everyday driving mobility (i.e., number of trips for discretionary/non-discretionary purposes) and safety (i.e., amount of driving on roads with speed limits of 100 km/h or higher, and at GPS-measured speeds of 100 km/h or faster). However, many other examinations can be undertaken using the present data collection methods. Blanchard et al. (2010) compared GPS and travel diary measurements of the driving exposure and travel patterns of older adults to demonstrate that they avoid challenging driving situations (i.e., self-regulate their driving) less than they report. Research by Marshall et al. (2007) demonstrated that the braking and acceleration patterns of older adults can be examined using GPS. Also, research by Meredith et al. (2013) used GPS devices with in-built accelerometers to identify rapid deceleration events in the driving of older adults and obtain information about the context of these events (i.e., location, time of day, speeds before and after, duration of deceleration). Additionally, other information could be obtained through the telephone-based Travel Diary, such as participant self-reports of the number of passengers in their vehicle or the weather conditions at the time of their driving. Such examinations will build on what is understood about the driving exposure of older adults.

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