

# Adding maps (GPS) to accelerometry data to improve study participants' recall of physical activity: a methodological advance in physical activity research

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Accepted 18 April 2014

## ABSTRACT

**Objective** Obtaining the 'when, where and why' of healthy bouts of moderate-to-vigorous physical activity (MVPA) provides insights into natural PA.

**Design** In Salt Lake City, Utah, adults wore accelerometer and Global Positioning System (GPS) loggers for a week in a cross-sectional study to establish baseline travel and activity patterns near a planned Complete Street intervention involving a new rail line, new sidewalks and a bike path.

**Results** At the end of the week, research assistants met with the 918 participants who had at least three 10 h days of good accelerometer readings.

Accelerometer and GPS data were uploaded and integrated within a custom application, and participants were provided with maps and time information for past MVPA bouts of  $\geq 3$  min to help them recall bout details. Participants said that 'getting someplace' was, on average, a more important motivation for their bouts than leisure or exercise. A series of recall tests showed that participants recalled most bouts they were asked about, regardless of the duration of the bout, suggesting that participant perceptions of their shorter lifestyle bouts can be studied with this methodology. Visual prompting with a map depicting where each bout took place yielded more accurate recall than prompting with time cues alone.

**Conclusions** These techniques provide a novel way to understand participant memories of the context and subjective assessments associated with healthy bouts of PA. Prompts with time-stamped maps that illustrate places of MVPA offer an effective method to improve understanding of activity and its supportive sociophysical contexts.

## INTRODUCTION

Researchers, designers and policymakers need to know how everyday settings can encourage 'active living'.<sup>1,2</sup> However, everyday bouts of activity may be difficult to track, given that many of them are short and not intended or thought of as 'exercise'. To understand the natural ecology of physical activity (PA), technological improvements can help address the when, where and why of healthy activities. Understanding where people achieve bouts of moderate-to-vigorous physical activity (MVPA) will enable policymakers and designers to understand how everyday settings might be designed or altered to support healthy PA.

Accelerometers, providing objective measures of PA intensity, and Global Positioning System (GPS) data loggers, locating activities in space, have significantly improved research on PA.<sup>3</sup> In a national study, 51% of participants reported sufficient MVPA (30 min/day, most days of the week, in  $\geq 10$  min bouts) but accelerometer measurements indicated that <5% of participants met those guidelines.<sup>4</sup> Furthermore, the recall of PA may be biased by health conditions, such as when obese individuals overestimate and healthy individuals underestimate their MVPA bouts.<sup>5</sup> Similarly, surveys provide undercounts of biking/walking trips compared with GPS/accelerometry identification.<sup>6</sup> When used in tandem, GPS/accelerometry measures can track PA episodes or bouts within parks<sup>7</sup> or along bike paths.<sup>8</sup> Maps displaying GPS-measured travel help participants recall more trips than unaided surveys.<sup>9,10</sup> GPS and accelerometry are costly and add to participant burden, but merit examination to see if they yield more accurate recall and valuable contextual and experiential data.

When contextual or subjective information can be provided about why, with whom or where the MVPA is occurring, researchers can better understand settings that promote activity. Although many contextual/experiential aspects of MVPA exist, we illustrate our novel technique for one fundamental example. In debates about how to increase walking, there has been controversy about whether environmental designs that support walkability might be more important for leisure walks compared with instrumental walks undertaken to get someplace.<sup>11</sup> Complicating this topic further, some researchers suggest that walks often result from multiple motivations.<sup>12</sup> However, we know very little about how people endorse these various motives for single bouts of activity. Thus, we employed exit interviews after approximately week-long data collection periods to test whether the past week's MVPA bouts were motivated to achieve leisure/recreation, exercise or 'getting someplace' or some combination of these three.

Currently, it is not clear whether maps and time cues can effectively prompt recall of MVPA bouts from the past week, especially short lifestyle MVPA bouts. PA recall is often better over shorter<sup>13</sup> than longer intervals, such as is found with past day versus 1-week recalls.<sup>14</sup> Past research has used accelerometer feedback alone to prompt recall of particular destinations for past MVPA walking

**To cite:** Brown BB, Wilson L, Tribby CP, et al. *Br J Sports Med* Published Online First: [please include Day Month Year] doi:10.1136/bjsports-2014-093530

bouts.<sup>5</sup> Adding location information via the novel procedure of providing participants with end-of-week maps of their recent MVPA bouts merits testing to see whether it enhances participant recall.

In sum, we ask: What motivates MVPA bouts? How does recall of bouts decline across days, bouts and bout frequencies and durations and for obese and non-obese participants? How valid is bout recall? Do end-of-week map prompts yield more accurate recalls than simply providing days/times of bouts as prompts?

## METHOD

### Procedures

The data are from the *Moving Across Places Study* (MAPS)—an evaluation of a Complete Street intervention in which a street is renovated to serve more than cars. Specifically, this street received light rail, a bike path and improved sidewalks in early 2013. The prebuild data were collected from March–December 2012. Adults living within 2 km of the planned transportation improvements were recruited to wear accelerometers (Actigraph GT3X+) and GPS loggers (GlobalSat DG-100 data loggers) for approximately 1 week. During in-home visits, participants completed surveys and were fitted with the devices.

At the exit interview, approximately 1 week later, participants described their bouts of MVPA. Research assistants (RAs) equipped with laptops and internet connectivity devices uploaded accelerometer and GPS files to a secure website. The website application, developed and hosted by GeoStats, merged GPS to accelerometer data, producing a report of past week bouts of MVPA. To reduce participant burden, this report first identified all 10 min or longer bouts, using the National Health and Nutrition Examination Survey (NHANES) specifications for wear time and MVPA detection ( $\geq 2020$  counts/min<sup>4</sup>). If the participant still did not have 10 10 min bouts,  $\geq 3$  min bouts were listed. The online survey then presented a Google Maps display depicting locations of bouts that had associated GPS points (see [figure 1](#)), starting with most recent activities. RAs asked participants about their motivations (getting exercise; getting someplace; and/or getting leisure/recreation). Map controls included zoom and pan features to achieve the desired resolution. Participants were asked to describe up to 10 bouts, but were invited to describe more bouts if willing, able and time permitted.

When internet connectivity was not possible at the exit interview due to poor signal reception, the RAs could not download the maps of past week bouts, so they prompted participants to recall their bouts without maps, using time-of-day and day-of-week prompts from accelerometer feedback. These connectivity failures enabled us to test whether bouts with and without map prompting are equally likely to be remembered. For these validity checks, we focused on the subset of home-based bouts because home addresses were geocoded and represented common locations for MVPA bouts. Most home-based leisure walks<sup>15</sup> or active transportation walks<sup>16</sup> occur within about half a mile from home; short MVPA bouts might occur anywhere along the half-mile route. Therefore, when the participant said that the bout originated or ended at home and the GPS point for the bout beginning or ending was within 800 m (approximately  $\frac{1}{2}$  a mile) of the geocoded home address, we considered the bout location to be accurate. To explore sensitivity, we also tested other distances: 100, 200, 400 and 1600 m. Connectivity failed more often for residents who were randomly selected within-household participants (see explanations below), so we also tested whether maps improved recall after controlling for this variable.

### Participants

Eligible participants were Spanish or English speakers, aged  $\geq 18$ , not pregnant, expected to reside within the neighbourhood for another year, and able to walk a few blocks and complete surveys and wear the devices. To be retained, participants needed to complete surveys and register  $\geq 3$  days of  $\geq 10$  h accelerometer wear.<sup>17 18</sup> An initial mail invitation was followed by door-to-door recruitment visits at varied times of the day and week. Among the 1015 participants who provided some initial survey information, 41 dropped out without wearing the accelerometers and 62 finished the first survey but had insufficient accelerometer wear time; 2 more were withdrawn due to technical problems or becoming ineligible during the week. The resulting 910 completions yielded a 28.93% response rate based on the universe of all addresses that could be recruited (using the American Association of Public Opinion Researchers response rate formula 3, this improves to 30.9% if all survey completers are included). In addition, for a subset of 29 addresses, a second person living at the same address also participated. For 21 cases, the epoch length saved on the accelerometer file did not mesh with GPS data, so those cases were dropped. The remaining analyses include 918 respondents.

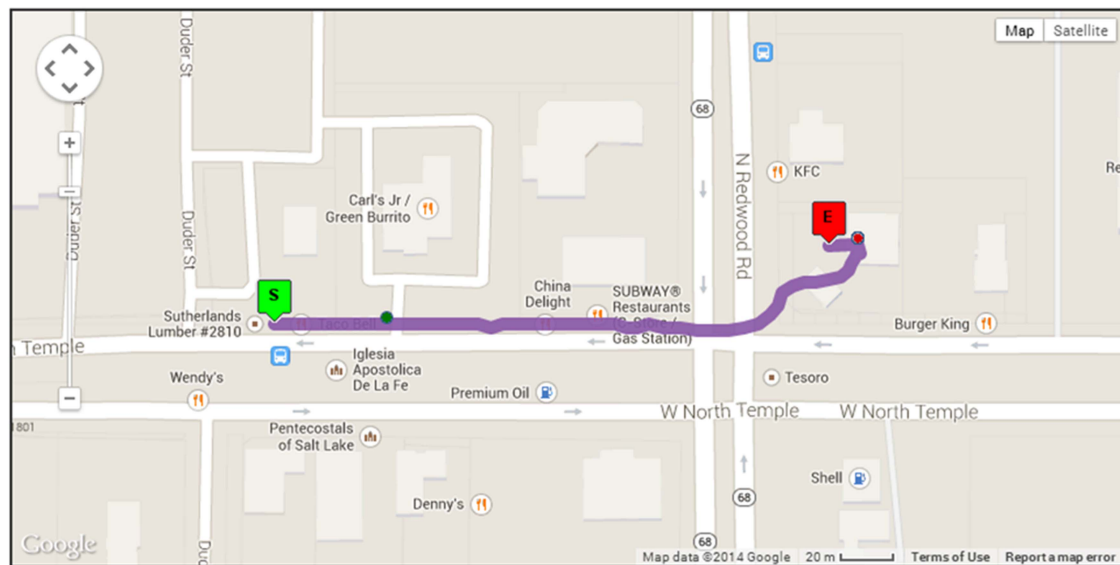
Those who dropped out or had insufficient accelerometer wear times were compared with study completers on multiple variables: sex, Hispanic ethnicity, white race, marital and student status, employment, education (up to high school graduate, college graduate+ education), number of rooms in the home, parenting status, household income, car availability, years of residence, renter status and single family detached housing. According to logistic regression, non-completers had lower education levels. Specifically, 43.1% of non-completers (from N=102 reporting) had education levels up to high school completion versus 32.9% of completers,  $\chi^2$  (1, N=1027)=4.32,  $p=0.04$ . Thus, completers and non-completers were comparable on many qualities.

For within-household selection, the youngest male/oldest female selection procedure was used to avoid intrusive household enumeration.<sup>19</sup> This method randomly selects an eligible adult unless the household has  $\geq 3$  eligible adults, in which case RAs recruit the youngest eligible male (to reduce the gender/age bias); if he is unavailable, the oldest eligible female is recruited. Part-way through the study, adults who were otherwise eligible but not the randomly designated individual within the household were allowed to participate as alternates, in keeping with practices in similar studies.<sup>20</sup> Of the 939 with sufficient wear, 200 (21.3%) were alternates, who were tested against randomly selected household members. Randomly selected participants, compared with alternates, were less likely to be female (51.90% vs 61.50% for alternates), were older (40.45-years-old vs 37.64), and less likely to be married (38.13% vs 53.57%; logistic regression Nagelkerke  $R^2=0.045$ ).

## RESULTS

### Descriptives

Of the 939 total participants, 856 or 91.16% registered one or more bouts in their  $\geq 3$  days of 10 h accelerometer wear. Participants averaged 5.43 days where GPS trips were detected (SD=2.28) and 5.57 valid days of accelerometer wear (SD=1.36). In combination, participants averaged 4.36 days with GPS trips and complete accelerometer wear (SD=2.11). Bouts of  $\geq 3$  min of MVPA averaged 10.19 min duration (SD=11.33; median=5.0 MVPA minutes) and ranged from 3 to



Please fill in **START** location name and address for activity on Friday,

at 5:05 PM:

Name	Sutherlands Lumber (Burrito stand)
Address	e.g. Home, Library, Neighborworks, Red Iguana North Temple St @ 1758 W, Salt Lake City, UT 84116, USA

Please fill in **END** location address.

Name	7-Eleven
Address	e.g. Home, Library, Neighborworks, Red Iguana 1692 West North Temple, Salt Lake City, UT 84116, USA

**Figure 1** Example of bout activity map and location details provided by participant. Note that date cue was covered in the figure to preserve anonymity. Google and the Google logo are registered trademarks of Google Inc, used with permission.

161 min. Across the 939 participants, between 0 and 63 bouts were detected, using reporting rules described earlier.

### Motivations for bouts

'Getting someplace' was rated stronger than either exercise (paired  $t(825)=-12.08$ ,  $p<0.001$ ) or leisure/recreation motives (paired  $t(825)=12.42$ ,  $p<0.001$ ). Exercise and leisure/recreation motives were strongly correlated and the other correlations were modest but significant (see [table 1](#)).

### Recall of bouts

During the exit interview, participants were asked if they could recall the MVPA bouts when the RA showed them their time, date and duration of bouts as well as map information if GPS points or traces were available. If participants recalled the bout, they were questioned about their motivations and other details.

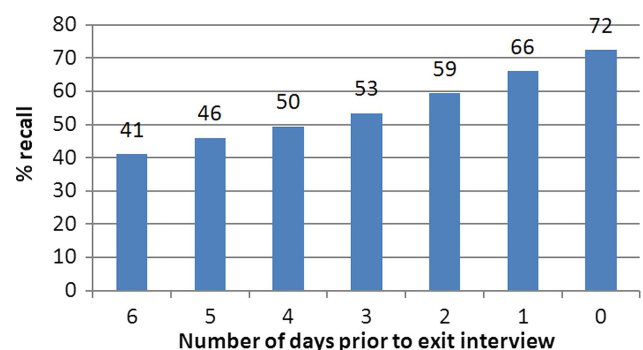
**Table 1** Activity motivations: means and correlations (N=826)

How important were the following goals to this activity? (1–5 scale, 5=very important)	Mean	SD	Pearson correlations	
			1	2
1. Getting exercise	2.89	1.40	1.00	
2. Getting someplace	3.65	1.23	0.08*	1.00
3. Getting leisure or recreation	2.93	1.30	0.60**	0.14**

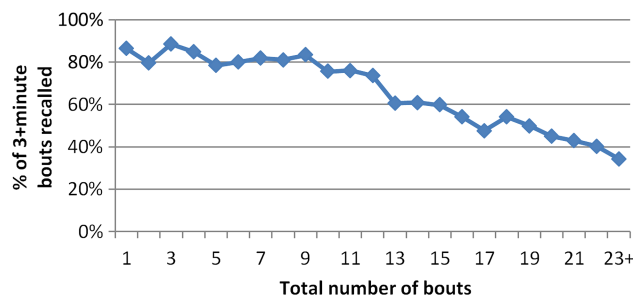
\* $p<0.05$ , \*\* $p<0.01$ .

The following analyses demonstrate the recall pattern across days, all bouts, recent bouts and for total numbers of bouts.

[Figure 2](#), based on the past 7 days of wear, shows that the bouts from the most recent days are the most easily recalled ones. Overall, 56% of the 7896 total bouts detected across 7 days were recalled by participants; instructions were to recall up to 10 bouts and 29% of the 7.896 bouts involved 11 or more bouts. The linear trend of recall across days was significant,  $\chi^2(1, n=7896)=284.31$ ,  $p<0.001$ . Specifically, the fourth day prior to the final day had a 50% recall, with lower percentages prior to that.



**Figure 2** Recall declines as number of days prior to recall day increases.



**Figure 3** Recall by total number of bouts achieved.

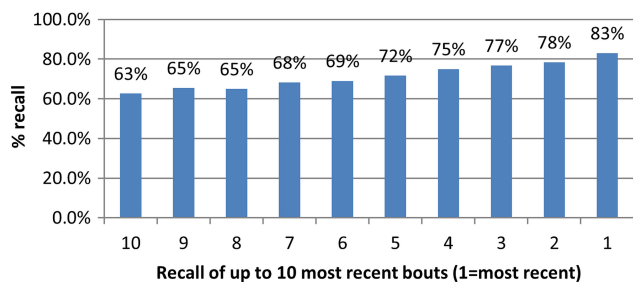
Figure 3 shows recall by total number of bouts achieved. As expected, given the goal of 10 recalls, the total percentage of recall diminished after a participant had achieved around 10 bouts; linear trend  $\chi^2(1, n=9092)=1073.63, p<0.001$ . Those with  $\leq 9$  MVPA bouts recalled about 80% of them; it was only when an individual achieved  $\geq 17$  bouts that recall declined to  $<50\%$  of total bouts.

Figure 4 demonstrates recall for a participant's most recent 10 bouts, regardless of the total number of bouts achieved or time since the bout. Participants were able to recall between 63% and 83% of their 10 most recent bouts; linear trend  $\chi^2(1, n=6068) = 120.78, p<0.001$ .

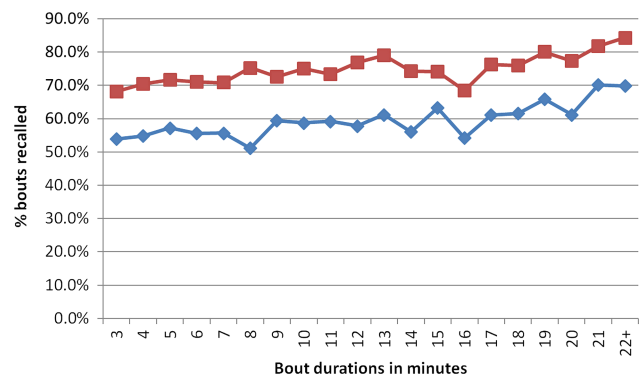
Figure 5 shows that longer bouts were more likely to be recalled; linear  $\chi^2(1, n=9113)=89.61, p<0.001$ . However,  $\geq 50\%$  of all bouts presented to participants were recalled, regardless of the duration. These percentages increase to 68% or better recall for the 10 most recent bouts,  $\chi^2(1, n=6068) = 65.00, p<0.001$ . Finally, bout recall was unrelated to measured obesity once bout duration was controlled, Wald  $\chi^2<1.4, n.s.$

To test whether having a map helped with activity recall and to verify the accuracy of these recalls, the subgroup of participants who had no maps because internet connectivity was poor provides a useful group to compare with the map-prompted sample. Those with connectivity were shown a map with time cues; those without connectivity were shown only the time cues (day, time and duration of bout). Bouts might be short bursts of activity contained within longer trips to/from home. Therefore, we tested participants' recalls of bouts involving home as an origin or destination against GPS points within 800 m of home, which should encompass most home-based walks.<sup>15 16</sup> At 800 m lengths, recall was corroborated by GPS points for 94.71% of 850 bouts with maps and 81.91% of 94 bouts without maps,  $\chi^2(1, n=944)=22.57, p<0.001$ .

Similar results held across other distances used to define home-based bouts from GPS points. At four different distances, recalls with and without maps were: 66.82% vs 50% at 100 m ( $p<0.002$ ); 82.82% vs 64.89% at 200 m, 91.76% vs 76.60% at



**Figure 4** Recall of the 10 most recent bouts.



**Figure 5** Recall of all (bottom line) and 10 most recent bouts (top line) by bout duration.

400 m, 97.06% vs 88.30% at 1600 m ( $ps<0.001$ ). In addition, maps improved recall accuracy when controlling for participants who were randomly chosen within households (not alternatives), who were more likely to be participants with connectivity failures. Those without maps were less likely to recall bouts within 800 m of home as home-based (odds=0.29 (CI 0.14 to 0.59)).

## DISCUSSION

Prompting individuals to recall details of their MVPA bouts, when those bouts are measured objectively and recall is aided by the provision of place and time cues, allows more bout-specific information than many self-reports. By asking participants to describe their bout motives, we illustrate how this technique can clarify contextual and experiential qualities of healthy bouts of activity. Most MVPA bouts were described by participants as done to 'get someplace', highlighting the importance of instrumental travel when studying the ecology of everyday activity. The same technique can be used to understand social and physical contexts, or other questions about psychological states, such as fear or happiness.

This paper focused on aspects of bout recall accuracy, an essential step prior to considering contextual/experiential aspects of bouts. This recall is different from many self-report forms, which require individuals to average their MVPA bout durations over the past week<sup>21</sup>; the current procedure retains bout-specific durations. At the same time, this procedure provides the challenge that recall has to be about a specific date, time and place. Although in some cases it may be easier to provide answers about general PA patterns than to recall motives for specific bouts, our procedure also showed that most bouts of any duration presented to residents were recalled. This finding is encouraging for researchers who want to study short bouts and past bouts. Recent research shows that short bouts are as strongly related to obesity as longer bouts of 10 min, which are the ones traditionally studied.<sup>22</sup> Short lifestyle activities—the walk to a restaurant or transit stop—can be better understood with this procedure. Future research might compare specific bout recalls with more typical across-week recalls to understand how the different techniques might yield substantive differences. Future research is also needed to understand how bout lengths may differ by personal qualities of people, their places of activity and their bout motivational and contextual qualities.

The majority of bouts were recalled by participants regardless of which recall parameter was investigated—days since the bout, total bouts retrieved (up to about 17 bouts), 10 most recent bouts or bouts of varied durations. If a researcher wants to

assess bouts efficiently, limiting recall to the 10 most recent bouts may be useful; this yielded between 63% and 83% recall for each of those 10 bouts. A simple analysis, based on two GPS points, indicated that when maps were shown to participants, corroboration of self-reports of home-based bouts improved by about 8–17%, depending on the distance definition used to determine accuracy; future testing is needed to determine whether additional GPS route assessments can refine these estimates better than the use of two GPS points alone. Although we reduced participant burden by asking for recall of up to 10 bouts, we did not test the limits of recall comprehensively. Whether one should attempt to ask for participants to describe all their bouts without harming rapport or imposing excessive time and burden is a question for future research.

Important decisions for GPS/accelerometry researchers involve the choice of techniques to query participants and ways to collect complementary experiential data. Our technique is one of several options researchers can choose that vary according to targeted time intervals for behaviours of interest and participant burden. Ecological momentary assessment (EMA) methods, in which a smart phone provides a frequent short survey, offers the greatest immediacy between experience and self-report.<sup>23</sup> However, the requests for surveys are not tied to PA bouts; thus, only 16% of the surveys in an EMA study of children included PAs.<sup>24</sup> Transportation survey techniques that leverage GPS-based prompted recall methods collect more comprehensive and more accurate travel details by having participants visit a website that shows maps depicting their GPS traces, a method that enhances recall better than traditional surveys without maps; however, these surveys have not traditionally collected information about PAs.<sup>25</sup> More recent transportation surveys, such as the 2011 Jerusalem Travel Habits Survey and three ongoing regional surveys in Israel, are entirely based on GPS-based prompted recall methods<sup>26</sup>; PA researchers may find that collaboration with transportation researchers will enhance an understanding of all forms of travel.

Our procedures worked well for our circumstances. The exit interviews focused on MVPA bouts without sensitising residents to these issues throughout the week. Many in our sample did not have experience with smartphones or computers, so home visits reduced barriers to participation. Face-to-face meetings enabled the RAs to retrieve equipment and provide the interactive map survey of MVPA bouts in the same visit. The RAs also provided friendly motivation for completion, typed in addresses for bout origins/destinations and provided the needed technical expertise for the data uploads and online surveys. Nevertheless, limitations include that the recruited sample

### How might it impact on clinical practice in the near future?

- ▶ Researchers have struggled to understand the daily context of healthy physical activity bouts.
- ▶ With this method involving prompting recalls by maps of healthy bouts, researchers will gain access to important social, psychological and physical concomitants of bouts.
- ▶ This method should become more popular with advances in accelerometry and Global Positioning System measurements.

underrepresented low-education individuals and participants must devote time and effort to remembering to recharge and wear the equipment and do the surveys and prompted recalls. Future technological improvements may ease data collection tasks, but for now, RAs conducting home visits, especially when the sample is unfamiliar with the novel technology, were crucial to the success of the study.

**Acknowledgements** The authors are grateful to Kristi Flick, project manager, and Victor Solis, field supervisor, for assistance with the study and to Anthony Fucci, Derek Jaworski and Wyatt Jensen for technical support.

**Contributors** BBB drafted the article and conducted the data analyses. LW and CPT provided statistical and geographic information systems support and commented on the draft. BBB, LW, CMW, KRS and JW helped with development of the interactive bout reviewer for substantive or technical aspects. CMW, JW, HJM and KRS commented on drafts of the manuscript.

**Funding** The project described was supported (in part) by grant number CA157509 from the National Cancer Institute at the National Institutes of Health and the Robert Wood Johnson Foundation.

**Competing interests** None.

**Patient consent** Obtained.

**Ethics approval** University of Utah Institutional Review Board (IRB).

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data sharing statement** This data set cannot be de-identified so that special privacy rules restrict access to parts of this data set.

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### What are the new findings?

- ▶ A novel method of providing participants with maps of their past week bouts of moderate-to-vigorous physical activity is presented.
- ▶ Participants were able to recall most of their past week bouts, even those of only 3 min duration.
- ▶ The provision of a map to prompt participants about their past week bouts yielded more accurate recalls of the location.
- ▶ The method can be useful for researchers who wish to get participant reports on the social, physical and psychological aspects of recent bouts of activity.

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*Br J Sports Med* published online May 9, 2014

doi: 10.1136/bjsports-2014-093530

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