

## Pilot 1 – Working paper

### Measuring and mapping activity outdoors: GIS, GPS and related methods

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### 1 Introduction

GPS, GIS, and activity measurement technology, such as accelerometers, lend themselves well to study of behaviour and activity patterns in the outdoor environment. This brief review is not intended as a literature review or a discussion of research findings, but a discussion of the technology and methods available, with some examples of relevant studies.

### 2 GIS/GISc

Geographical Information Systems/Science (GIS/GISc) have a relatively long history of application to ecology and environmental science, and a somewhat shorter history of use in health and social research. GIS provides a methodology to link environmental features/characteristics - which are inherently geographical - to health and wellbeing data, at individual and population levels.

GIS has frequently been applied in investigations of the association between greenspace (and other environmental characteristics) and health/health related behaviour. For example, a 2006 study using the Norfolk Cohort of the European Prospective Investigation into Cancer and Nutrition (EPIC) allocated each of the cohort members with greenspace accessibility, size and quality measures based on the distance from their home to the nearest greenspace (Hillsdon et al. 2006). In this study, boundaries of local greenspaces were geographically captured (digitised) and assessed for quality by the investigators. This greenspace spatial dataset was then analysed in conjunction with the cohort data based on each individual's home location. A US study used satellite image data to measure neighbourhood 'greenness' around children's residences, and associated this greenness variable with the participants' Body Mass Index (BMI) and change in BMI over time (Bell et al. 2008). A Dutch study used a national land cover database to investigate associations between neighbourhood greenspace and morbidity from a general practice database (Maas et al. 2009). Ecological small-area studies can also use GIS to combine routine, aggregate datasets for analysis,

such as one that related greenspace in a English national land use database to the standardised rate of 'not good' health from the 2001 census (Mitchell & Popham 2007).

This type of study, investigating residential proximity to (or neighbourhood density of) environmental characteristics is useful in describing how the characteristics of where people live, work, go to school etc. are associated with their health and wellbeing. This is an important consideration in determining what makes a healthy neighbourhood, which in turn may inform planning policy and other decision making processes. However, these methods alone do not allow us to measure how much time people actually spend outdoors, in different outdoor environments, or in proximity to environmental risk factors. Global Positioning System (GPS) technology provides the opportunity to obtain this kind of detailed location data.

### 3 GPS

Self-reported time-activity diaries can be used to generate data regarding where study participants spend their time (e.g. Biddle et al. 2009), but these data suffer from validity and recall issues, and lack location precision. Recent developments in the precision and affordability of Global Positioning System receivers (GPSr) (Rodriguez et al. 2005) mean that objective, accurate, location-based estimation of 'exposure' to outdoors environments is now possible, even for studies with fairly large samples. For example, a UCL study asked 200 participating children to wear GPS receivers and to keep travel and activity diaries in order to assess associations between location and self-reported transport-related physical activity (Mackett & Paskins 2008). A GPSr can typically record location, altitude and speed up to every few seconds, and can store data in a format that is relatively straightforward to import to GIS and statistical analysis packages.

Techniques for using GPS receivers to collect data on exactly where study participants spend their time are rapidly developing, as are methods for analysing the resulting datasets. The Global Positioning Systems in Health Research Network ([www.gps-hrn.org](http://www.gps-hrn.org)) was launched in mid-2009, and provides a useful international forum for sharing methodological developments, and opinions on different GPS technology. Commercial GPS receivers (e.g. Garmin Forerunner) have been frequently used, but units designed as simple 'dataloggers' are now available with significant benefits for research purposes (longer battery life due to lack of screen; no buttons, preventing study participants changing settings, and so on). Tools developed for spatial analysis of GPS data in other disciplines can be readily applied to human health and wellbeing studies. For example, the 'Geospatial Modelling Environment' ([www.spatial ecology.com/gme](http://www.spatial ecology.com/gme)) extension to ArcGIS was designed for ecological studies, particularly animal tracking, but the tools are equally useful for human GPS studies.

To provide context for GPS datapoints, high-resolution, national and international environmental datasets are readily available to the research community, along with other contextual geographical data. For example, the Ordnance Survey MasterMap dataset provides a very detailed topographical spatial data layer for Britain, and is available through the Edina Digimap service ([www.edina.ac.uk/digimap](http://www.edina.ac.uk/digimap)). MasterMap land parcels are categorised by the OS using a variety of classifications useful for defining the nature of environmental features, and can also be attributed with Generalised Land Use Database categories, including greenspace (England only). Socio-economic and health data from sources such as the Census and ONS mortality records can be readily mapped for small areas across the UK (see [www.edina.ac.uk/ukborders](http://www.edina.ac.uk/ukborders)). A directory of available spatial datasets exists at the Go-Geo portal ([www.gogeo.ac.uk](http://www.gogeo.ac.uk)), and a useful resource for small-area socio-economic data is ONS Neighbourhood Statistics ([www.neighbourhood.statistics.gov.uk](http://www.neighbourhood.statistics.gov.uk)).

### 4 Accelerometers

Accelerometers are a well-established and validated means of objectively quantifying physical activity, and are capable of capturing data at high temporal resolution for sustained periods. They measure 'accelerations' ('counts'), and counts per time period can be used as an objective measure of physical activity. Threshold values relating counts per minute to established physical activity classifications (such as 'sedentary', 'moderate' or 'vigorous') are a subject of debate, but are a useful way to understand the

somewhat arbitrary-seeming numbers produced by accelerometry. For example, values above a threshold of 3200 counts per minute have been validated as indicating moderate-vigorous physical activity (MVPA) in children (Puyau et al. 2002). The validity of accelerometers is sufficiently accepted that they have been used for validation of self-report/diary activity metrics such as the International and Global Physical Activity Questionnaires (IPAQ/GPAQ, see for example, Bull et al. 2009).

First generation accelerometers measure accelerations on a single axis (e.g. Actigraph GT1M, [www.theactigraph.com](http://www.theactigraph.com)), while more recent versions can measure on 3 axes (dimensions) simultaneously, and use these to produce an estimated count of 'steps' (e.g. Actigraph GT3X). There are some issues with using accelerometers during specific activities – for example they tend to underestimate activity through cycling, given the smoothness of movement, and watersports present similar issues along with potential water damage to the devices. There is a body of research on the methods of use of accelerometers, comparing placement on different parts of the body, and validity for monitoring different activities (see for example Parkka et al. 2007).

Datasets produced by accelerometers can be readily imported and analysed using standard database/statistical packages. Software designed specifically to analyse accelerometer data is also available. The MRC Epidemiology Unit at Cambridge has produced a free package allowing aggregation and analysis of accelerometer datasets (Mahuffe, [www.mrc-epid.cam.ac.uk/Research/PA/Downloads.html](http://www.mrc-epid.cam.ac.uk/Research/PA/Downloads.html)). Commercial packages are also available, providing a variety of analytical tools. Actigraph produce their own software (ActiLife) to download and analyse data from their accelerometers. Kinesoft ([www.kinesoft.org](http://www.kinesoft.org)) has an extensive range of tools for importing, checking and processing accelerometer data, with the ability to create summary variables for activity volume, intensity, bouts and so on.

## 5 GPS & Accelerometers

GPS and accelerometry data can be combined to relate activity levels to specific location, and can in turn be integrated with environmental and other geographical data in a GIS (Oliver et al. 2010). With GPS resolution down to a few metres, and the possibility of both instruments recording data at high frequency, the combination can produce a very high resolution space-time dataset. One example is the PEACH (Personal and Environmental Associations with Children's Health) cohort ([www.bris.ac.uk/enhs/peach](http://www.bris.ac.uk/enhs/peach)), which involved around 1,300 children in final year of primary school, with a follow-up in first year of secondary school (further waves may be possible). At both waves, participants were asked to wear an accelerometer for a week, and a GPSr for four of those days, to complement data collected through anthropometry, self-administered questionnaires and activity diaries. The GPS and accelerometer recorded location/physical activity at 10-second intervals, and data were merged using the date-time stamp recorded by both devices. The GPS receivers used for this study do not receive a signal indoors, meaning that a comparison of time outdoors/indoors is possible (Cooper et al. 2010). GIS-based analysis of the association between activity and greenspace has been carried out using the OS MasterMap/Generalised Land Use Database (paper submitted).

In another example, a subsample of 100 children from the Norfolk SPEEDY (Sport, Physical activity and Eating behaviour: Environmental Determinants in Young people) cohort also wore GPS receivers and accelerometers for four days. Data were overlaid with a landcover dataset in a GIS to assess how activity varied in different environments (Jones et al. 2009).

Combining datasets from accelerometers and GPS receivers using date/time is relatively straightforward conceptually, but can pose challenges in terms of dataset sizes, formats and aggregation. Data from the PEACH and SPEEDY studies have been analysed using bespoke solutions (the Stata statistical package has been used for PEACH, and a custom Java programme for SPEEDY). Commercial products are being developed, such as Actigraph's GPS Correlator, although this only works with a specific range of Garmin GPS receivers, and has very basic functionality given its cost.

## 6 Related methodologies

In addition to GPS and accelerometers, other technological and methodological developments may prove applicable to studies of the outdoors and health. A New Zealand study combined GPS with heart rate monitors, rather than accelerometers, to measure activity (Duncan et al. 2009). With GPS capability being added to many devices (especially mobile phones/smartphones), there is increasing potential for novel data collection methods such as 'crowd-sourcing' (e.g. see CASA working paper 143 <http://www.casa.ucl.ac.uk/publications/workingPaperDetail.asp?ID=143>).

GPS can be integrated with other 'sensors' to produce a wide variety of georeferenced data. Cycle couriers in Cambridge have carried GPS receivers and air pollution monitors, allowing high resolution mapping of air quality (<http://bioinf.ncl.ac.uk/message/>), and providing the potential for individual pollution exposure estimation. Digital cameras can be linked to GPS receivers, allowing the collection of georeferenced digital photographs (see for example, GeoPlace article at [tinyurl.com/yewaap9](http://tinyurl.com/yewaap9)). These can serve to record qualitative/visual environmental data linked to precise locations, permitting subsequent assessment and mapping of environmental quality indicators.

Much of the relevant research applying GIS to environment-health issues has been quantitative, but qualitative, participatory and mixed-method GIS are emerging methodologies with great scope for application here (Cope & Elwood 2009;Dunn 2007).

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