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Using whole body technologies to map the mobility of older adults

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Abstract

In this paper we describe the preliminary findings of two-year study that attempted to map the mobility of our oldest citizens using activity monitoring and location-aware technologies. We recruited a group of 100 adults aged between 72 and 92 years old, drawn from a 25 year longitudinal cohort, and collected lifestyle, nutrition, health and social engagement data. We also fitted a subset of the group with accelerometers and location-based tracking devices and asked them to wear these for a week in order that we could generate accurate, live mobility data and assess these data against self-reports. We are now using this data to describe the relationship between mobility, activity and physical and mental well-being, but in this preliminary paper, we outline some of the main challenges we encountered when trying to use these 'whole body' technologies to determine mobility.

Keywords

Accelerometry, location-based systems, wellbeing, mobility, elders, ageing.

ACM Classification Keywords

K4.1 Public policy issues; K4.2 Social issues

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Introduction

Ageing is generally associated with a decrease in mobility and social interaction (Morris et al. 2004) and this decrease is dependent on various health and social factors (Chen et al. 2004). A recent government report on the scientific aspects of ageing noted that 43% of people over the age of 50 report problems with their mobility and reported a deterioration in walking speed that is more marked in women than in men (Select Committee on Science and Technology 2002). The report cited The Royal College of Physicians of Edinburgh as stating that: "Physical activity is the major modifiable influence on health in old age," citing loss of bone density as one of the problems associated with restricted activity. Mobility loss is not inevitable – although clearly a function of age, it is also linked to income and educational attainment (Guralnik et al, 1993; Melzer et al, 2001) and simple interventions can help to alleviate the problem: For example, those older adults who keep a dog reported much greater levels of activity than those who did not, with many associated benefits (Serpell, 1991). Adults for whom mobility is a problem suffer in a variety of ways. Not only are their social lives restricted but they are also more limited in terms of their access to good nutrition, leisure and other activities. For example people with restricted mobility have fewer choices in terms of where and when they can shop, and they have been found to experience problems in maintaining a balanced diet (Wylie et al, 1999).

Clearly, mobility is an issue for the ageing agenda, but at present there are two major gaps in our knowledge: firstly we know relatively little about mobility in the oldest old and secondly there are methodological problems in the literature. Specifically, methods of

determining the extent to which older adults are active in the community and are able to move around their environment have, until very recently, been limited largely to self-report studies. Two new technology-based methods for assessing mobility are useful in this regard: accelerometry and location-based tracking.

Accelerometry and location-based tracking

Activity monitors are small accelerometers, typically worn around the ankle or thigh where they register the stepping movements of the legs but can also register changes in body position indicative of the transition from lying to sitting or from sitting to standing. This kind of activity monitoring provides an objective method of quantifying activity unobtrusively for extended periods of time in the home and community. Accelerometry has been used for the assessment of activity levels in different subjects and also as an outcome in intervention studies (Rochester et al., 2006; Bussman et al., 1998a&b; Busse et al., 2004). For example, Busse et al., 2004, demonstrated that activity monitoring was a reliable and valid measure of activity in people with neurological conditions who were living independently in the community. They found that neurological patients, including those with Parkinsons Disease, had lower levels of walking activity than an age-matched control group without the disease.

Location-based technologies have grown in recent years. Services such as OnStar's *Driving Directions*, MModes's *Find Things or People Nearby* help others to keep track of our movements, but they also remove certain privacy privileges (Consolvo et al., 2005). These new location-based technologies tend to fall into

two camps: *Location-tracking* services collate information from third parties (such as mobile telephony service providers) in order to track individuals, while *position-aware* services depend upon devices which have knowledge of their own position (Snekkenes, 2001). Several of these systems have been specifically developed to monitor people for homecare purposes e.g. Telemonitoring (Rialle et al 2003). Maciuszek et al (2005) argue such systems can make a decisive contribution to coping and quality of life particularly for vulnerable adults, as they promote independent living rather than hospitalised care. Location-aware systems may help the ageing population live independently but we need to understand more about the opportunities and problems associated with such monitoring.

Until recently, use of self-report measures have been identified as the most practical ways to categorise and quantify physical activity in typically sedentary adult populations, such as that under study (Tudor-Locke et al., 2001). Activity monitoring using accelerometry is an objective means of capturing the level of activity an individual shows at any particular time, however activity monitors provide no information on the context in which activity is being undertaken, or its purpose (Masse et al., 1998). In order to compensate for this, activity diaries have been used to provide contextual information on activity in long term conditions such as rheumatoid arthritis (Goodacre et al., 2004), and have been shown to be a valid and reliable instrument for the assessment of daily activity patterns in chronic pain patients when compared to activity monitoring in the home (Follick et al., 1984). While activity diaries are important, they provide subjective data that may show response bias (reporting of idealized patterns of

behaviour). In this study we have used the diary method in combination with (i) location-based tracking as an objective measure of the context in which activity takes place and (ii) activity monitoring as a means of objectively quantifying intensity and type of activity. We have further used this data to calculate a range of mobility indices such as distance to nearest shops etc. and an assessment of transport methods available to each volunteer.

Methodology

Participants

The participants (N=100) were drawn from a unique 20 year longitudinal study of cognitive ageing in healthy, community resident older people in the North East and North West of England. In the North Eastern sample, 3384 individuals were recruited in waves and screened at 2 –3 year intervals on batteries of cognitive tests. In addition extensive information on health, socio-economic status, mobility, activities undertaken, alcohol consumption, tobacco use, diet and other lifestyle factors were gathered at 3-5 year intervals (details in Rabbitt et al. 1993; Rabbitt et al. 2004).

The database includes a number of measures which may be used as predictors of mobility and successful ageing. Such measures include functional ability which assesses ease and difficulty with activities of daily living (see McInnes and Rabbitt, 1998); hobbies and activities; depression; socio-economic status; indices of volunteers' social networks, their degree of dependency, and the amount of help and social support obtained, required and desired; information about the number of people living in a household, marital status,

and living location (see Pendleton et al, 2004; Rabbitt, Bent and McInnes, 1997).

Activity Monitoring

Activity data was collected using the activPAL™ monitor taped to the thigh. An internal real-time clock contained inside the monitor provided recordings of the onset, duration, and frequency of physical activity and other important events. Each participant wore the activPAL™ physical monitor, stuck to the thigh, for a seven day period (The monitor is easily removed and replaced for purposes of showering, bathing or sleeping). In addition, all participants kept a simple record (diary) of events such as falls or near falls and general activities, will aid data evaluation. Data generated included: number of steps taken (primary outcome measure), step cadence (steps per minute), time spent seated/lying, time spent standing, time spent walking, number of transition between sedentary and upright postures.

Location-monitoring

A UK company, specialising in location-based services provided advice and support for (i) location tracing (i.e. plotting an individuals geographical movements over both space and time, and allowing analyses of inter-alia shopping and leisure activities) and (ii) mobility measures that logged the extent and variability of activity across days and weeks. The company supplied small tracking devices that were strapped to the arm and a service (the 'people locator') that mapped the daily journeys of our participants as seen in figure 1.

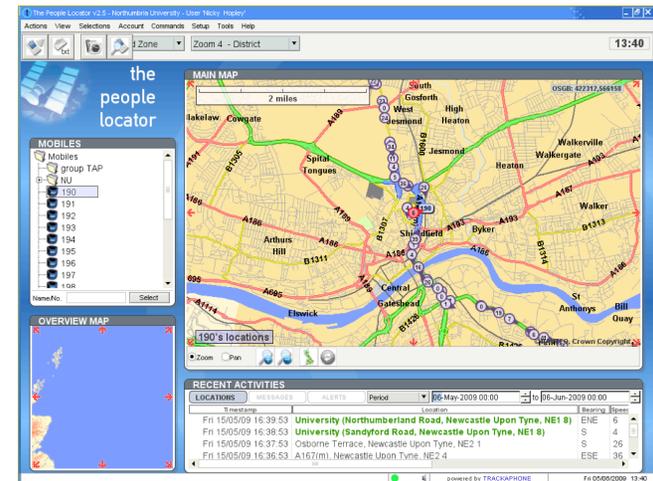


Figure 1: Location monitoring displays for individual participants.

One hundred participants (drawn from our cohort of oldest-old) were invited to take part in our studies, each wore the activity monitor and tracking device for a period of 7 days (with ten individuals tested in any one week). In addition, all participants completed activity diaries. A researcher visited each participant, in order to apply the monitor, explain the use of the tracking device and battery charging procedures and administer nutrition and activity diaries. The researcher returned 7 days later to remove the monitor (which is quite comfortable to wear) and collect the activity diaries. All participants had an emergency telephone number in case they experienced any problems.

Following a week of mobility monitoring, each participant was asked to engage in a second week of assessment, involving activities in the laboratory.

Interviews and assessments of health, wellbeing, lifestyle, balance and gait were conducted. Laboratory assessments were also made, to measure sensory acuity, cognitive performance, balance and gait.

Results

Three sources of mobility data have already been analysed (accelerometry, location-aware technology and time use diaries). Accelerometer activity profiles are comparable to earlier reports of pedometer-based estimates of 6,000 to 8,500 steps per day for healthy older adults and within recommended physical activity guidelines, despite 70% of the day being spent sitting or lying down, 22% of the day spent standing and only 7% of the day spent walking. The time use diary data reveals that older people spend much of their time doing indoor activities with the majority being static indoor activities and, on average, only 3 hours per day are spent outside. The location-aware technology data supports this as it reveals that older people on the whole do not travel far. The furthest distance travelled away from home is 6.79 km /4.22 miles; the total number of km /miles travelled per week is 36.64 km / 22.77 miles and on average people travel 5.23km / 3.25 miles per day and make 5.63 journeys outside of the home per week.

Regression analyses conducted thus far shows that the most consistent predictor of mobility as measured by accelerometry and time use diaries is the person's balancing ability, and for mobility as measured by the location-aware devices, it is their health, functional mobility and gait speed. However more analyses are required here to more fully understand these relationships. Longitudinal data suggests that health

status from 10 years previously, a measure of personality and number of friends six years previously can predict current mobility. Such knowledge has the potential to be very useful to built environment planners for it reveals that services need to continue to be located within communities for older people to be able to take advantage of them. Further analyses will reveal transport used by older people and the types of activities they do.

Finally, we were interested in attitudes to location-based services (LBS), particularly regarding trust and privacy issues. Our older adults considered their location information to be sensitive and were concerned with the potential misuse of personal information. Our 'healthy' older adults did not immediately see the benefits of LBS and expressed fears that such systems would limit their control and portray them as 'unhealthy'. This is of great importance for product development for it reveals that, potentially, one of the biggest challenges for LBS adoption within the older adult population is concerns the unhealthy stigma associated with such systems. Other issues surrounding accuracy of such devices (see below) will also have great impact for product developers.

Data Challenges

Although an initial 100 volunteers were recruited, there were a number of issues involved in data collection. Firstly, fourteen participants withdrew at some point throughout the study, leaving 86 enrolled participants. For these, mobility data was collected via three methods – (i) time use diaries, (ii) accelerometry devices and (iii) a location based service device based on GPS technology.

(i) The time use diaries were paper and pencil records of when participants did certain activities throughout the day. Participants were generally diligent about completing these and we were able to obtain baseline measures of activity pre testing with devices and also measures obtained while the other two devices were being worn. In total 79 pre-test diaries were completed and 78 concurrent test diaries were completed. The main problem with the diaries initially was finding a format that participants could easily understand and therefore complete.

(ii) The accelerometry devices were meant to be worn by participants for seven consecutive days. Eight participants did not wear the device for the full seven days, no data was recorded for four participants, and data was missing for a further 9 participants so the resulting accelerometry data set captured data for 65 participants.

(iii) There have been problems with some of the LBS data. Of the 80 participants who completed the trial only 27 sets of data were deemed usable in the first instance due to problems in establishing the HOME address. We are able to retrieve some of the data by establishing a HOME location in a post-hoc fashion and recalibrating data, but, for future studies, two devices would be recommended - one to operate in the home and one to operate outside.

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