Behavioural Nutrition & Big Data: How Geodata, Register Data & GPS, Mobile Positioning, Wi-Fi, Bluetooth & Thermal Cameras Can Contribute to the study of human food behaviour

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Introduction

Place has traditionally been providing the conceptual and analytic platform for the studying physical environment and its relation to food behaviour [1, 2]. Where human activities previously were closely attached to the locations of home or work perspective of human activities has shifted towards a people-based view [3, 4]. Complexity and heterogeneity of human mobility no longer appear to correspond the use of residential neighbourhoods, but stress the need for methods and measures of individual activity and exposure, along with a change in awareness of researchers that human behaviour and activity is individual/people-based and not place-based [2, 4]. Portable intelligent devices has created a series of new opportunities for convenient assessment of food choice and as a result, food and lifestyle related behaviour is increasingly becoming the subject of measurement through application of such mobile devices [5, 6]. Intelligent devices such as smartphones, touch pads, etc. increasingly becomes used by consumers not only to get online using different wireless technologies but also for self-monitoring of lifestyle. For the research community this development also offers new opportunities since the devices can also be used in a reverse mode to track the behaviour of individuals applying GPS, mobile positioning, Wi-Fi and Bluetooth. Furthermore, thermal cameras offer new possibilities to track human behaviour, contrary to regular RGB-cameras where individuals are recognisable and subject for ethical issues. Application of GPS tracking within behavioural nutrition research [7] has been limited, but other research areas has embraced the technology and used it for task such as measuring travel patterns [8, 9], wildlife movement and habitats [10], exposure to toxics, pesticides or air pollution [11], following elderly with Alzheimer's and other dementia [12], and within health research to measure physical activity [13]. Use of mobile positioning, Wi-Fi and Bluetooth signals for tracking is more novel technologies in terms of tracking and less used in research for tracking than GPS. Application potentials of Bluetooth and Wi-Fi are comparable and has been used for measuring travel time through airport security [14], travel time on freeways [15] or mapping large crowds at mass events [16]. GSM has been sparsely used in for tracking with the exception of Ahas et al. [17], who used it for GSM tracking of tourists.

Use of the smartphones available in a study sample are believed to have large potential within social science, due to the use of apps and the large population penetration [18]. The penetration of smartphones worldwide has gone from 35% to 56% in two years and for cell phones in general to 91% [19] making the population basis for passive tracking with Wi-Fi, Bluetooth or mobile positioning profound. Normal RGB-cameras has long been used for surveillance but the ability to recognize people often poses a problem. Thermal cameras can replace RGB-cameras for tracking, as it is anonymized data. Traditionally nutritional research has used food diaries, questionnaires and interviews to analysis of food behaviour [20]. This is not uniquely to food studies, also transport research has previously frequently applied travel diaries, but implementation of GPS has reduced some of the shortcomings such as poor data quality, lack of reporting short trips, total trip times and destination locations [4, 8]. Functionalities related to Geographical Information Systems (GIS) offers simple representations of the physical environment including its opportunities for physical activity and food. The collection of behaviour information leads to the creation of very huge dataset, which induce problems for analysis. Hence, changing from place-based polygon features to people based point features requires different analysis and an increased focus on data administration and cleaning.

The contribution of this paper is on monitoring activity to improve the comprehension of food behaviour, which has numerous examples of placed-based studies [21, 22] and only a few people-based [7, 20]. This paper aims at giving an overview of the options available through these new technologies. The paper aims at an assessment of pros and cons for different type of tracking technologies and application setups. It gives examples of combinations of the technologies, and finally discusses the reach of these new opportunities along with a discussion of the ethical dimensions of such tracking.

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Comparison of technologies – strengths and weaknesses

Deciding on which technology to use for a given research problem can be a straining problem, but very crucial to get right the first time. Knowing and understanding the strengths and weaknesses of the tracking technologies are the keys to selecting one or more technologies fitting the scale and environment of the research. The best fit of a technology in a study is influence by the environment, the extent of the study area, the required accuracy in the positioning, the need for respondents (active tracking) or for a only the movement (passive tracking) and the availability and pricing of the hardware and data. The environment for a study is often indoor, outdoor, or a combination. The GNSS and A-GPS technologies are only suitable for outdoor tracking. The thermal cameras require the environment to have open spaces with limited objects that block the view, whereas BT, Wi-Fi and mobile positioning copes with both outdoor and indoor tracking, regardless of the building layout and design. Only exception to this is, if the walls inside the buildings are blocking the short-wavelength radio waves and microwaves in for example BT and Wi-Fi, which is solved by adding additional BT sensors or Wi-Fi hotspots. The accuracy in estimated positions of the devices spans widely from approximately 1 metre to 20 kilometres dependent on the environment, hardware and signals. The accuracy of GNSS depends heavily on the environment of the study. With high buildings and narrow streets, the accuracy can easily be as bad as 20-30 meters dependent on the equipment, time of day and whether the equipment can use satellites from more than one system. In a bare field the accuracy can be as good as 1-5 meters again influenced by the same elements. The accuracy of BT and Wi-Fi can vary greatly based on two parameters, the range of the sensors and the possibility to triangulate between several sensors. The accuracy with no overlapping sensors will never be better than the scanning range of the sensors and due to the nature of the signals; the range of the sensors is a bit fuzzy making the exact precision of the positioning a bit uncertain. The accuracy of mobile positioning is the worst among the technologies mentioned in this paper. As mentioned in Ahas [17] there are several methods and network standards to base the tracking upon, of which A-GPS is the most accurate with 3 meters or better in open spaces and 20 meters in urban high-rise environments. Tracking solely on the cellular network would yield accuracies from under 100 meters to 20 kilometres, very much dependent on the environment and the density of the cellular network. Thermal cameras have proven to have a high position accuracy of 1-2 meters.

The size of the study area combined with the environment and the needed accuracy has a large impact on choosing the technology, the amount of devices needed and thereby the cost of the tracking. GNSS, A-GPS and mobile positioning are generally best suited for large areas as the individuals are carrying the technology necessary for tracking, while using BT, Wi-Fi and thermal cameras stationary sensors are needed. BT, Wi-Fi and thermal cameras are in theory plausible to use for large scale tracking at a very high price for equipment proportional to the amount needed or a low density of sensors only covering certain zones in the study area. Only covering all the supermarkets in an area could be an option if only the presence in a shop is relevant for the aim of the study. GNSS and A-GPS are the most accurate technologies to capture movement over a large area, but both requires respondents acceptance, while mobile positioning covers over 90% of the population worldwide without their permission is required. Choosing a passive or an active tracking technology both has consequences. Passive tracking technologies such as thermal cameras and mobile positioning have the potential for following close too every person. However, if BT and Wi-Fi are used for passive tracking, only a proportion of the population is registered, as only some of the customers will have either or both of the signals turned on. There are methods to bypass this and get a larger part of the customers tracked through inserting tags in shopping baskets and trolleys, encourage customers to turn on the signals with prizes or other benefits for the customer or combine BT and Wi-Fi to track on both signal types. If the goal of the study is to count the customers or measure the time spent at the shop, one or two sensors might be enough dependent on the amount of entrances and exits. With passive tracking only the movement patterns of individuals are the output, whereas with active tracking is it possible to join additional information about each person's health status, socioeconomic status, etc. However, active tracking requires the consent of each respondent. Willingness to participate in tracking varies across the population and the proportion that completes the study satisfactory are often in the range of 50-60%. GNNS and A-GPS are active tracking technologies only, whereas thermal cameras are unsuited for active tracking.

The technical knowledge needed to apply the technologies for tracking differ as GNSS have a huge amount of off-the-shelf solutions and delivers an output that needs little or no processing to be implemented in GIS. Mobile positioning, BT and Wi-Fi are all based on a cell structure, from which a processing is needed to change the data to point features with coordinates. A-GPS requires an app to handle the tracking, which needs development or buying and existing that fits the purpose and hardware. Thermal cameras require the most processing as movement detection is still far from commercial use. The technologies are in theory applicable worldwide, but in reality are GNSS, A-GPS and mobile positioning the

only technologies, as the rest requires power supply or changing of batteries at regular basis. Mobile positioning is limited by the goodwill of the operating companies and the legal clauses in each country.nThe prize of a complete tracking setup is influenced by the amount of devices, the type of technology and the accuracy. In many cases, A-GPS probably is the cheapest option, as a large segment of populations already owns a smartphone and the technology is well suited for combination with BT and Wi-Fi tracking inside selected shops. Combination of the technologies is preferred, to utilize the strengths of each technology in different environment settings.

Discussion

Developments in wearable positioning technologies and GIS provide an opportunity for understanding and controlling many phenomena occurring in urban areas. The position technologies offer quantifiable measures of individual's movement and exposure as they make decisions in real-time. The degrees autonomy of people varies when making decisions about residence and work, who to socialize with and where to do that, as neither the individuals nor the living environment is static. It is unrealistic to assume that the majority of people spend all or most of their time in pre-defined geographical areas. The high levels of mobility in a population requires methods to measure this without limitations, as the residential or administrative boundaries, and the residential and working addresses not necessarily are the best identifier for our dietary behaviour. Residential and administrative boundaries may not provide the most adequate basis for analysis of the impact of place on health. Determination of the most appropriate scale for analysis of places influence on dietary behaviour or preferably, to apply flexible scales to fit the patterns of every person, would increase the understanding of individual and group behaviour. Potentially tracking technologies could help loosening the dependency of residential and administrative boundaries for representing place, by an individual measure of behaviour.

Traditionally dietary research has focused on questionnaires and interviews for analysis, but it is known that people have a tendency to embellish the reality about information on food intake. Likewise have self-reported information about trips and whereabouts been incomplete in especially short trips, start and end time of trips, and the addresses visited. The development of wearable positioning provides a more objective measure for the behaviour in terms of space-time information. The potential of the tracking technologies for research on dietary behaviour are great for measurement of exposure to example healthy and unhealthy food options. GIS provides the tools for combining the individual behaviour patterns with personal information on health and socioeconomic status and conduct statistical and spatial analysis. The purpose of implementing the tracking technologies in dietary research is not to replace the questionnaires and interviews on dietary behaviour, but perceived to add to a growing toolbox for researchers. Combining the data from questionnaires and interviews with tracking data increases the potential analysis potential.

Questionnaires, interviews and tracking are all invasive on the persons followed as the question presented by researchers and knowledge of being followed possibly affects the person's behaviour. Researchers ask for information that is often regarded personal or confidential as the whereabouts or food intake. This is active tracking and often requires a lot effort from the respondents, which also have a great influence on which segments of the population that are willing to participate. Passive tracking, on the contrary, removes the demands on the respondents and provides a measure of human movement and behaviour in a non-invasive manner. Passive tracking often have the ability to capture the behaviour of large groups of the populations i.e. because of the high cell phone penetration in the population, but at the cost of losing the supplementary information of individuals. Both active and passive tracking offers great possibilities for research in term of tracking the general populations' movement patterns and shopping patterns or smaller samples of the populations' behaviour and its impact on health.

The choice of technology should not necessarily be limited to selecting one, as several of the technologies combined would enable tracking at several scales and accuracies to serve the objective of the study. Example, use of GNNS or A-GPS to track the overall movement of individuals in a city and then in all the supermarket and grocery shops set up Wi-Fi and BT tracking to track the movement inside the buildings. Then the tracking provides information of both the person's choice in food retailer and the choices made inside each individual food shop.

Use of wearable position technologies to follow the behaviour of individuals is an intrusion into people's privacy and violates many people's boundaries. Surveillance is in many countries frowned upon and raises a whole host of ethical issues for many people and governments. Privacy is a public concern, which causes debate about personal freedom and scientific ethics. Privacy, surveillance and data security are key aspects in both passive and active tracking. In active tracking, the person's identity is known to the researchers, who have the key responsibility, when storing, analysing and publishing results of tracking, to ensure the confidentiality of the participating persons. European and national legal

regulations for data collection must be followed to ensure the persons and their locations are not identifiable. Privacy and ethical concerns influences the type of people willing to participate in studies involving tracking. Some of the concerns revolve around the fear of being subject to surveillance, and followed and listened to everywhere one goes. The growing ICT generation may be more open to the technologies, and the accustoming of positioning technologies may lower the concerns. Explanation of the aspects and demonstration of the results of tracking could decrease the concerns of privacy violations and data security. Private tracking have to treat the people in way that ensures their complete confidentiality also in the data. Thermal cameras ensure this compared to RGB-cameras, while application of other methods are needed for BT, Wi-Fi and mobile positioning. There are several methods [4] i.e. assigning 'dummy' variables to ID a device instead of using the MAC-address.

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