Tracking People Network
Briefing Paper 3
Designing Systems for Tracking People

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Introduction

Technologies for tracking the locations of objects have developed significantly in recent years, particularly as a result of developments in the fields of robotics and autonomous systems, data science and the internet of things. As a result, the technologies available for tracking locations, behaviours and other information about individuals are becoming increasingly sophisticated and a wider array of systems, applications and organisations are making use of these technologies.

The costs of developing bespoke tracking schemes and the commercial conditions under which they are produced creates financial pressure to find new groups to track in order to recover development costs and generate economies of scale. As a result, the design and use of tracking systems has generally been on the basis of 'technology push' - where tracking capabilities are developed and then applications are found – rather than 'user pull' - where systems are designed around the unmet needs of users with the specific intention of addressing those needs. As a result, there is a mismatch between the devices which have been developed and the needs of the individuals being tracked, potentially resulting in rejection, non-use and non-compliance.

Similar challenges are faced in the design of assistive technologies, where user-centred design methods are increasingly being adopted to address this problem. A user-centred design approach – putting the various users of a system at the heart of its development – could also usefully be applied to the design of tracking devices and the systems they operate within to ensure that they better meet the needs of those being tracked and organisations/individuals tracking them, thereby reducing the potential for non-use and non-compliance.

It is important to note that tracking does not simply refer to identifying the location of individuals or objects. Firstly, location is not the only thing that can be tracked – behaviours and browsing patterns are routinely tracked online for advertising purposes and technologies exist for tracking body functioning such as blood alcohol levels, pulse rate or activity levels. Secondly, a single measure of any property – be it location, blood alcohol level, or pulse rate – does not constitute tracking. Tracking requires that such measures are captured and monitored over a period of time. This means that tracking technologies extend beyond the underpinning technology used to measure a property, to the systems being used to capture, communicate, analyse, store and respond to this information (Potter, 2017). Designing tracking systems therefore amounts to more than the development or selection of fundamental measurement technologies and encompasses the design of wider communications and organisational systems whose interaction must be considered along with the goals, culture and environment of individuals being tracked and the people around them. The issues considered in this paper therefore apply not only to those who are designing tracking devices, but to anyone who is creating or operating tracking systems and/or deploying tracking devices.

Tracking as a socio-technical system

Designing any system to track people involves, as a minimum, the individuals being tracked and the individuals or organisations doing the tracking. Both are influenced by the social, physical and organisational environment around them. Thus, tracking systems are always socio-technical and how such systems function in practice – their intended and unintended consequences and whether they are accepted, rejected, compromised or adapted by users is influenced by the complex interaction of technical and social elements (Greenhalgh et al. 2017).

The technologies deployed will depend upon what is being tracked: invariably this will involve a

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measurement technology to determine location, blood alcohol level, behaviour and so forth. The measurements must then be recorded and stored in some way, and - since tracking is generally undertaken for a purpose - these data must be transmitted, analysed and appropriate responses formulated. Exactly what each of these steps involves, whether they can be undertaken on a single device and whether they require broader infrastructure and/or other organisations will depend upon what is being tracked and for what purpose. This, in turn, influences which technologies are most appropriate and the other physical and organisational elements which must be designed to fit around those technologies.

The following sections will examine some of the key technical and socio-technical issues which should be considered when designing tracking systems and some of the methods available to support designers when doing this.

Infrastructure

All tracking technologies require infrastructure over and above the devices themselves and the availability and suitability of this infrastructure is critical to the correct functioning of the system (Potter, 2017). All positioning or locating technologies need to triangulate their position relative to a set of known anchor points (Kemp, 2017). These may be set up independently of the tracking system, for instance GPS satellites can be used by any GPS receiver, specifically for the tracking system in question such as the readers used to detect the presence of a given tag in RFID-based applications. Even methods that are not based on positioning systems, such as face- or number plate- recognition using computer vision techniques, rely on the presence of a network of cameras and a searchable database.

Tracking systems depend upon infrastructure for communication networks and storage to transmit and record data. Attention must be paid to where data are to be stored and processed, where and how often they must be communicated to others and access arrangements. These factors depend upon the purpose of tracking: if real time alerts are necessary when someone enters an exclusion zone then tracking data must be gathered continuously, requiring a constant connection to the internet and mobile data connection if devices are to move freely. A wired connection is only feasible if devices use fixed anchor points (such as RFID, where receivers are attached to the internet). A wireless connection relies on devices staying in range of wireless networks and introduces risks because information is necessarily broadcast to any receiver capable of picking it up. This makes security measures such as encryption essential.

Storage likewise requires infrastructure – for all that data are described as residing in ‘the cloud’, in practice they must be stored on physical servers in one or more datacentres and thought must be given to practical, as well as legal ownership if subsequent access is required.

The design of any system for tracking must therefore consider the likely availability and potential maintenance of any required infrastructure. This raises important questions such as will it continue to be available for the lifetime of the tracking process and afterwards; who is responsible for its upkeep; and what are the consequences if it becomes temporarily or permanently unavailable?

Processes and procedures

When designing a tracking system, it is not simply the tracking technology and the infrastructure required to operate it which needs to be considered, but also the organisational system and procedures that surround it. An important concern is how frequently tracking data needs to be communicated. If urgent responses are required, for example to breaches of inclusion/exclusion zones, then real time communication of data is required, but this has implications for battery life and the processing power required on devices. A second consideration is what happens when alarms are activated, how are false alarms identified and what happens if excessive alarms are triggered which exhausts response capacity and/or leads to genuine alarms being ignored.

A third consideration is charging devices – all GPS devices require frequent charging whereas the batteries on RFID devices are long-lasting. However, having mechanisms in place to manage battery life and charging is important. Some wearers will be sufficiently capable and/or responsible to charge devices but others will not. Thought needs to be given to: i) the likely consequences if devices run out of charge; ii) who is responsible for keeping devices charged; and iii) what remainders/nudges should be put in place to remind wearers to charge devices. The costs and so on of these measures need to be assessed against the battery life of devices, which in turn is restricted by their weight and what data processing is required. Frequent reporting of data requires a lot of processing power and power for communication and will consequently run batteries down faster than less frequent reporting. Equally, doing all the processing on devices and not just transmitting all raw position data improves security and reduces storage and communication requirements, but increases processing demands.

In addition, legal and ethical frameworks must be taken into account. What is technically feasible is not always legal or ethically desirable and designers must consider compliance with relevant standards. For example, the UK Engineering Council’s statement of ethical principles

(www.engc.org.uk/professional-ethics) requires engineers to respect life, law and the public good, including the need to abide by relevant laws and consider the social impacts of the uses and misuses of the technologies they develop.

Ergonomics, usability and stigma

The comfort and wearability of devices also needs to be thought through: devices that fit the 'average man' are unlikely to fit women and devices designed for adults will not fit children well (Holdsworth and Hucklesby, 2014). Equally, devices which are comfortable when worn briefly may cease to be comfortable when worn for extended periods of time. Any device that is uncomfortable to wear, too heavy, too bulky – or too easily damaged – may be rejected by users and/or reduce their quality of life. The intended and unintended consequences will effect both wearers and those around them. For example, devices may need to be childproof if wearers live with young family members.

The usability of a system will also depend upon the lifestyle and desires of wearers, which vary a great deal. The need for frequent charging may not be difficult if wearers are able to stay at home and can respond to alerts to charge their devices. In other cases, this may be impossible, for instance, if wearers do not have a permanent address or regularly stay away from home. Such problems may lead to devices being abandoned if users have this option and/or have unintended consequences for their quality of life – reluctance to go out or persistent anxiety about malfunction or potential damage to the equipment.

Finally, there is the consideration of visibility and stigma. Making devices visible may be regarded as part of the punishment in criminal justice settings, but if other groups – such as those with dementia – are being tracked, then this may create problems, particularly if they are wrongly identified as criminals. Equally, devices may be rejected if they are felt to be demeaning or impair wearers' sense of identity.

In order to make tracking systems effective and acceptable to their intended users, it is important to take account of their needs in the design process. It is also necessary to recognise that human beings vary greatly and different individuals have different body sizes and shapes, lifestyles, backgrounds, expectations and experiences. It is not possible to apply a 'one-size fits all' approach to the design of tracking devices. Minor adaptations to styling or colour do not address these differences: tracking systems must be fundamentally designed from the ground up around the individuals who will be using them.

Considering user needs

While some attention has been given to the technical challenges of tracking position and other properties and to legal and procedural issues associated with their use, there has been less consideration of the needs of wearers as end users. One of the challenges in applying user-centred design thinking to tracking systems is that there are at least two 'users': wearers and the individuals or organisations doing the tracking. As it is generally the latter who pay for the system, they are the customers and it is their concerns, if any, that are taken into account by designers and manufacturers. As those being tracked are rarely - if ever - given an option about the devices they wear, their needs are not prioritised.

An objection to considering the needs of wearers is that they may conflict with, or outright contradict, the needs and preferences of those paying for the system. After all, the preference of wearers may well be that they are not tracked at all; or that the system reports with less precision and frequency than those requiring the tracking are happy with; or they may request features that are more expensive than the funders are willing to pay for. Such objections miss the point of user-centred design, where the goal is to establish an understanding of user needs and make informed trade-offs, rather than simply asking users for a wish list of features to include. As noted in Briefing Paper 1, tracking devices ultimately rely on some level of wearers' consent and failing to consider their needs reduces the likelihood that consent will be given and compliance will be forthcoming (Hucklesby et al. 2019).

It is not only wearers who must be considered: all actors whose participation is required for the tracking system to work effectively should be involved. This includes individuals who fit equipment and work in monitoring centres, families and friends and other organisations who might have to respond to alerts or deal with the equipment, for example the police, care workers, hospital staff and so on. In addressing issues such as stigma, it may be necessary to gather views from those not directly involved in the tracking process in order to identify what is acceptable and how the wider population are likely to respond to wearers of tracking devices.

Another challenge in undertaking user-centred design is that in the very situations which create the desire to track certain groups, such as children and individuals with dementia, makes it difficult to engage them in the design process. Similar problems are faced in many domains of design, particularly in relation to medical and assistive technologies where those prescribing and paying for devices are different from those who ultimately wear them. Nevertheless, increasing attention has been paid to identifying and addressing user needs in these areas and a range of methods are available for supporting this process, which designers of tracking systems may find useful.

User-centred design methods

It is worth noting that efforts are being made to engage end-users in the evaluation of tracking devices, such as patients with dementia and their carers (McCabe, 2017). Various methods have been proposed to support the design of human-focussed systems. ISO9241-210: *Ergonomics of Human-System Interaction* (ISO, 2010) recommends an iterative process starting from understanding the context of use, determining requirements and then refining designs against these user requirements, ideally by reviewing performance with users themselves or by engaging users in the design of systems. The challenges noted above in terms of which users to engage and how to reconcile the differing or conflicting needs of different groups still exist, but they can be identified and considered before the system is actually deployed by engaging with users and identifying their needs and preferences and the contexts in which systems will be used. Resources such as IDEO'S DesignKit website (http://designkit.org) provides an excellent introduction to user or human-centred design methods.

While there are challenges in engaging some groups in user-centred design processes, there are some good examples with children (Markopoulos et al., 2008) and individuals with dementia (Smeenk *et al.,* 2018; Harrison Dening *et al.*, 2019).

Concluding comments

To improve take-up and compliance, tracking systems need to stop being driven by new technologies and instead focus on recognising and addressing the needs of those being tracked by adopting a user-centred approach to the development and deployment of these systems. This requires actively engaging (potential) wearers in the design process, empathising with their needs and understanding how the tracking system fits into their lives and the lives of those around them. Systems should recognise the extent to which these needs vary and be developed for the specific needs of the individuals in question, rather than simply adapting systems from other domains to benefit from recovering costs and economies of scale.

Designers of tracking devices and those responsible for their deployment should consider the following questions in choosing approaches to tracking: who are the individuals being tracked? What are their needs and aspirations? What are the contexts and environments in which they will be tracked? Who else will be effected by the tracking? To what extent do these groups vary between wearers? Is the system compatible with the needs of wearers or does it unnecessarily restrict them through its function, size or appearance? Does it interfere with basic activities of daily life, such as taking a shower or undertaking exercise? Finally, is the system compatible with relevant legal and ethical frameworks? Designers must think carefully about what they are designing and why if they are to produce useable tracking systems that address problems, rather than creating new ones.

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*All reports and presentations from Tracking People events are available from http://trackingpeople.leeds.ac.uk

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More information about the network is available at: http://trackingpeople.leeds.ac.uk or contact the Network Chair, Professor Anthea Hucklesby (A.L.Hucklesby@leeds.ac.uk).