Smart Wearable and Portable Technologies that Have Immediate and Low-cost Applications in Community and Self-Care

Dr Kevin Doughty

e-mail: dr.k.doughty@btinternet.com

Introduction

Many of the criticisms of Assistive Technology (AT) and Telecare devices and systems is that they are designed to operate only within the home. Indeed, many of the most popular and useful examples of AT are designed as adaptations of the home that make life simpler or easier for individuals and/or their carers. Stair lifts and bathing hoists overcome practical issues associated with poor mobility and frailty enabling people to get upstairs or to have a bath. Similarly, telecare sensors and the dispersed alarm units that connect them to monitoring and coordination centres are mainly fixed in place, and simply wont operate away from the home. Thus, the use of the first three waves of Technology Enabled Community Care (TECC) or Technology Enabled Care at Home (TEC@Home), has the potential to keep people in their own homes i.e. in a place of safety. Unfortunately, this might prevent them from going out as much as they might like, resulting in:

- a loss of exercise opportunities and future mobility concerns,
- a reduction in the benefits to their well-being afforded by fresh air and open spaces; and
- a risk of social isolation and loneliness if they become house-bound.

Portable electronic devices, and especially those that are worn on or carried about the body, overcome many of the concerns described above. They are being introduced as the 4th wave of TECC, but their use in social care is restricted in many areas due to a lack of clarity of their benefits, and a number of concerns about their reliability and application for specific user groups. Some of the major benefits and concerns are described in Table 1.

Table 1: Some Benefits and Concerns in Introducing Wearable Social Care Technologies

Benefits	Concerns
Continuously available	Many have significant power needs
Programmable to satisfy individual needs	User interfaces may not be simple and intuitive
Multiple functions within the same device	Need discrete personalisation to avoid stigma
Can be worn in the bath or in the shower	Designs may not be robust and waterproof
Allow direct feedback to individual	Information may be accidentally shared
Can manage some risks associated with cognitive or intellectual disability	May be used as an electronic tag and for tracking and surveillance
Avoids the user becoming lost	Incomplete mobile phone coverage
Can synch with smartphones for remote monitoring and alerts	Many older and vulnerable people are unable to use and manage smartphones
May detect falls and convulsive seizures	Lots of false alarms
Unique identification	Exploitation by criminals
Reminders for tasks and medication	Users need training in their features
Attractive designs can increase utility	Devices may be stolen

Table 1 does not attempt to include opportunities within the medical sphere, and therefore overcomes concerns regarding medical device classification and testing. It also implies that the cost of providing such devices may be relatively low, especially if they are produced at scale and incorporate standard sensing and communication techniques. Some applications are discussed below focusing on devices that may be worn on the wrist, the location that appears to be most attractive to most users because of the similarity to a watch.

Tracking and Location using GPS

There are now over 30 devices on the UK market that are suitable for managing the risk of a vulnerable individual becoming lost. The majority are small enough to be attached to a key-ring or kept in a pocket or a hand-bag, but may be left behind if the individual has short-term memory problems or simply chooses to wear different clothing. This has resulted in new designs that integrate the electronics and the GPS technology into small devices that can be worn with different sets of clothing. A GPS belt and a smart shoe insole are perhaps the most interesting examples because both use an inductive charging mat that simplifies and speeds up the process of charging. This helps to overcome the need to use charging cradles or replaceable batteries but, in these cases, offer aesthetically acceptable solutions that enhance usability.

Figure 1: A Range of Wrist-Worn Location Tracking Devices that Use GPS

Several studies have concluded that GPS watches are more likely to be accepted by men than any other form factor, while women are happy to wear devices on their wrists provided that there are both choices of colour and style and that the devices have smaller profiles. Most, but not all, of the wrist-worn devices shown in Figure 1 cost under £100 and are designed mainly for children and for their tracking by concerned parents. They have a range of functions which are, in many cases, too complex for people with limited cognition and dexterity to operate successfully. Most can be used with a user-defined safe zone, which allows alerts to be generated if the wearer leaves this area. A mobile phone connection is required to enable location information to be transmitted and, usually, to allow a conversation to be had with the wearer. There is therefore a need for a SIM card to be provided which is suitable for the country in which it is to be used, and with good coverage around the area of interest. When supplied by the manufacturer or distributor, they often require a monthly contract. Roaming SIMS offer the most reliable approaches but can also lead to additional charges. The importance of providing these devices within a professional support service cannot be over-emphasised. The possibility of investing in a low-cost product without considering set-up, training and maintenance needs can cause considerable frustration and distress. These feelings can be amplified if no thought has been given to how an alert can lead to an appropriate response, especially during the night, and if family members are many miles away.

Sleep Analysis

Good quality sleep plays a key role in promoting and maintaining good health and well-being at all stages of life. It's needed to protect physical health, mental health, emotional health, as well as the quality of life and factors relating to safety. Sleep is about more than rest and freedom from disturbance; it also relates to the length of sleep and when periods of sleep might occur. Sleep deficiency affects the level of tiredness, concentration and the ability to think, remember, react, learn, make sensible decisions, and interact with others. It can increase the risk of depression and self-harm or other dangerous behaviour.

A lack of sleep restricts the body's ability to repair itself and has a long term impact on several conditions including heart disease, kidney disease, high blood pressure, stroke, obesity and Type 2 diabetes which all tend to be age-related. The lack of sleep affects how the body reacts to insulin, leading to higher than normal blood glucose levels, and the onset of diabetes. It follows that tracking sleep can provide an insight into changing patterns of activity, and help to identify remedies such as a need for medication review. In extreme cases, it might indicate a physiological problem such as obstructive sleep apnoea (OSA) which is a fairly common medical disorder where the upper airway repeatedly collapses during sleep.

Figure 2: Jawbone Up3, Misfit Shine2, Basis Peak, Fitbit Charge2 & Fitbit Blaze Wrist-Worn Sleep Trackers

Worn sleep analysing devices can also be used more routinely to identify periods of rest during the day, and confirm when an individual goes to bed, and gets up during the night or in the morning. This is possible because they have sensitive accelerometers that are capable of detecting micromovements at the wrist and relating them to other physiological parameters such as heart rate and breathing rate, that vary according to the stage of sleep. The analysis opens up access to key information of relevance to assessment, especially for people who may have mild cognitive impairment and who may be unable to provide accurate information on activities and time spent in bed. This approach is fundamentally more satisfactory for people who live with a partner or with their family as it is individual and enables the actions of individuals to be uniquely identified. The devices shown in Figure 2 all have powerful sleep analysis capabilities

Tracking Activity Levels

Devices that can monitor sleep and disturbance levels can also monitor more general activity levels. Most have been optimised to correlate the frequency and amplitude of the signals received to the type of activity, the speed of motion, and the number of calories consumed. Such information is ideal for fitness tracking, and is regularly used by sportsmen and women, to track performance and often include GPS for location tracking. Their role in improving health by encouraging more activity, often as part of a weight reduction programme, is well recognised though the evidence for weight reduction is surprisingly weak.

The potential of these devices for monitoring activity to demonstrate both total activity and hour by hour action profiles has yet to used in assessment nor to support programmes of reablement or rehabilitation following accident, surgery or illness. However, the devices shown in Figure 2 are packed full of additional sensors which could enable analysis to support goal-setting in an unobtrusive manner.

Detecting Epileptic Seizures

About 5% of all people will experience an epileptic seizure at some time in their lives. Not all will have epilepsy but over 30,000 people in the UK will receive a diagnosis every year. The two most common types of seizure are absence seizures, where the mind goes blank for a few seconds, putting them at risk of an accident if they are operating machinery, and convulsive seizures which are the most common. But there are many other types of seizure, and these can affect people irrespective of age both during the day and during sleep at night.

Fortunately, once diagnosed and treated with appropriate medication, nearly three-quarters of sufferers can manage or control the symptoms and their conditions. However, they, and their families and loved ones, may remain anxious about the risk of future incidents occurring, especially when alone and away from their homes.

Because convulsive seizures usually involve shaking of the whole body, they can be monitored by wristband devices of the type described above and used for sleep and activity tracking. However, to provide reassurance, they need also to reliably detect all incidents, and then provide an alert so that help can be summoned. This detection needs to be achieved without a high level of false alarms (often caused by oversensitivity or a lack of local device intelligence) which could lead to more distress and a waste of emergency services resources.

A number of new wrist-worn designs have emerged recently that are showing great potential for the reliable detection of convulsive seizures. Figure 3 shows four of the most popular devices available currently in the UK, though it is anticipated that some top of the range generic smartwatches may soon claim similar features. The Epi-Care Free, on the left of Figure 3, was featured in the TV soap Emmerdale during 2016 and is being used in some NHS services currently following extended clinical trials. The Epilepsy Solutions SmartWatch, second left in Figure 3, is an epilepsy alarm built into a wrist-watch. It automatically raises an alarm if its built-in accelerometer detects repetitive shaking movements that are characteristic of an epileptic seizure. In order to communicate with a suitable responder, the watch must be linked to a suitable smartphone (using a Bluetooth connection).

Figure 3: Four Examples of Smart Wrist-worn Devices Used to Detect Epileptic Seizures

The Embrace watch (third from left) monitors Electrodermal activity (EDA), sometimes known as Galvanic Skin Response (GSR), which is related to emotions such as fear, anxiety, and excitement. It can therefore detect many seizures (as well as tracking activities and sleep levels). It also works with an accompanying app which allows a smartphone to send alerts as appropriate. Finally, the PulseGuard technology (fourth from left in Figure 3) monitors an individual's heartbeat, looking for any sudden increase that might indicate a seizure is about to occur. This device can detect absence seizures in some people. These devices have the potential to transform the lives of many people with epilepsy as well as those of their carers, giving them the confidence to live more independently. However, none of them can be considered low-cost purchases, and might also need to be supported by monthly monitoring charges, and for some people, by a telecare support service that can offer maintenance and physical response.

For low-cost solutions, there is a need to rely on more general fall or impact detection, and an assumption that a seizure may result in a collapse or violent convulsions involving the arms that may trigger an alarm. Examples are provided in Figure 4. These include popular, and relatively low-cost components in telecare services; however, they also require wireless connection to a dispersed alarm unit that provides connectivity to a monitoring centre through a fixed telephone line. The exception is the Acticheck Azure that needs a wi-fi connection to the base telephone unit. It follows that low-cost options are restricted to use within the home.

Figure 4: Examples of Popular Wrist-worn Fall Detectors

Identification of People With Special Needs or Responsibilities

It is recognised that the well-being of most people can be improved by spending time in the open air, appreciating the benefits of nature and of meeting people. This does, of course, increase the risk of them suffering an accident or exacerbation of illness while they are away from their home and, potentially, alone. The risks of an adverse outcome may be further increased if they are unable to communicate with those people, including the emergency services and hospital staff, who may be on hand to help them. To support appropriate responses (including medical treatment) it may be necessary for them to be quickly identified, along with clarity on their condition and needs. This was the origin of *In Case of Emergency* (ICE) and *S.O.S. Talisman* tags, which have since given way to a range of bracelets such as those shown in Figure 5.

Figure 5: A Range of Emergency Identification Bracelets

The simplest approach is to provide all relevant information on the tag, thus enabling any responder to recognise any issues and to act appropriately. This does, unfortunately, emphasise vulnerabilities and offers only limited opportunities for providing sufficient information. The responder must therefore use the listed contact telephone numbers in order to ensure that actions are timely and correct. So increasingly, responders are invited to use web resources in order to provide relevant information. This can be limiting, so a number of more innovative approaches are available that all have the benefit of being low cost and capable of reducing access to information so that confidentiality can be maintained.

A range of silicone wrist-bands is shown in Figure 6. The Welbeing OneCall is on the extreme left as the worn component in a life-saving identification service for individuals and their carers. Each member receives a silicone wristband printed with a unique reference number and the phone number for Welbeing's 24 hour 365 days emergency telephone service. The number allows emergency and medical professionals to access vital medical information details when required, for example, if the individual is lost or disoriented and is found by a member of the public or if they are involved in an accident. Personal information is not given to the caller but to the person's pre arranged contact when they are notified and informed of the person's whereabouts. If no responders are available then the Emergency Services will be called to attend.

Figure 6: Examples of Identification Wrist-band Devices

The electronic version of the printed wrist-band contains a NFC (Near Field Communication) device which combines a passive digital communication method (Radio Frequency Identification) with advanced human engineering enabling it to be easy to wear and used for identification in all sorts of environments from hospitals through to theme parks and point of sale. They can be read only by readers in close proximity to the device, ensuring that information isn't accidentally intercepted by fraudsters. The security offered is sufficient to enable such devices to be used in payment systems such as the Barclay BPay bands. The device that is third from the left

in Figure 6 is the Tap2Tag which is being used by the emergency services in the South West of England to identify people who require ambulance or paramedic services, to identify relevant personal details of people wearing the tags using an app that they have on their smartphones. These simple tags are used extensively in Ireland by people who suffer from epilepsy.

The final device in Figure 6 is the Guardian Angel or Dementia Buddy device being used in Wigan. It supports dementia-friendly town and city initiatives. These devices are issued free of charge to residents who have dementia, and the accompanying app enabling a smartphone to directly phone the person whose number has been included on the NFC chip. Other councils, in partnership with third sector organisations, are considering the use of similar devices that could enable trained people, and especially those employed by local authorities, the NHS and the police, to identify vulnerable individuals so that they can be taken to a place of safety if they are found to be unsafe, lost or distressed.

Other Applications and Technologies

Several local authorities have recognised the importance of family carers in ensuring the safety and well-being of children, disabled people and older adults in their charge. These carers are relied on to provide dozens of hours of support every week. Without their efforts, many people would be at risk of accidents, malnutrition, lack of medication and ill-health. If their carer was suddenly taken ill or involved in an accident while away from home, the health and well-being of the person that they cared for would be compromised. The carers are therefore issued with Carer Cards of the type shown in Figure 7. These identify them as carers and also show some limited identity details. More significantly, they have information on what should be done in the event of an emergency. This is usually a telephone number that can be called to enable a monitoring centre to follow a response protocol that will enable the immediate needs of a cared for person to be addressed. Some national charities also issue such cards that can be used to obtain a discount on certain purchases.

Figure 7: Examples of Carer Cards

The main problem associated with such cards is that they are kept in the carer's purse or wallet. In the event of an accident, someone needs to search for the card, which can be difficult if they are injured. It is often found when the person is already in hospital and if details of their identification are being sought. These carer cards could be easily replaced with a wrist-worn silicone bracelet on which is stamped their name, an identification number and an emergency telephone number. More practically, bracelets with an NFC chip could be deployed, enabling all information to be efficiently obtained using a smartphone, an app, and a direct line to a 24 hour monitoring centre.

An alternative to the use of NFC technology, is an extended use of QR codes of the type shown in Figure 8. These can be generated without cost, and printed on a carers card, or as sticky labels that can be applied to a telephone, a key-ring or any personal item that might be carried on the person. They can also appear on someone's smartphone if it receives an impact caused by an accident for example. Each code could be unique to the individual, giving information on how to contact their family members or emergency responders in the event of an emergency. They are also suitable for use by existing telecare monitoring centres, many of which already operate carer card schemes on behalf of local authorities or charities. QR codes can be read quickly and reliably using the phone on a smartphone, and one of many free apps that are available for all types of phone. This makes the QR approach to identifying people, products and emergency mechanisms low cost and efficient. They are

already used in many ICE applications, sometimes alongside NFC chips for contactless communication. Different application examples are appearing in different countries, including QR code rings that can be worn on the finger, and a recent innovative use of QR codes printed on the fingernails of some older people who have dementia and who may become lost.

Figure 8: Examples of QR Codes being Used for Identification of People

The use of QR codes is not restricted to the identification of people; codes can equally be applied to valuable objects and to give information on their origins. This could include any item of assistive technology or telecare hardware but might also be used on a key-safe or a front-door as an alternative means of contacting a monitoring centre to ask for details on secure access. Within the home, a QR code on the fridge could be a more effective way of allowing paramedics and other emergency services access to patient, social care or telecare alarm service records including details of medication that might be necessary to treat someone in their own home following a 999 call. It could effectively replace the "Message in a Bottle" initiatives that have been available very successfully for many years, often through Lions Clubs. A new scheme could be launched using the same arrangement of stickers but with a QR code on the outside of the fridge enabling information to be obtained more quickly than having to search in the fridge for a bottle, taking off the cap, and reading the information printed inside. Clearly, having the information available in an electronic format enables it to be updated rapidly as medication is changed, for example.

Concluding Remarks

There can be little doubt that wearable devices have the potential to overcome stigma issues associated with many other types of assistive technology, because they can be made aesthetically pleasing and, when located on the wrist, appear similar to a watch or the fitness bands used by athletes. Their value will lie in their capability of addressing the genuine concerns of older and disabled people, rather than as a fancy heart rate monitor or time-piece. The latest generation of wearable device tackle very real issues such as falls, becoming lost, epileptic seizures and poor sleep quality. Furthermore, many are not medical devices, and are therefore relatively low cost. They can communicate through mobile networks or via a smartphone, enabling remote analysis and emergency response in the event of an adverse incident.

As the devices become yet smaller, and their energy needs are reduced, they will be capable of integration, providing powerful data-sets that may benefit clinicians as well as those trying to practise self-care. Their role alongside smartphones will change the way that people can live independently, overcoming many of the obstacles that currently reduce the quality of life of people with epilepsy or dementia, as well as that of their family carers. Telecare commissioners and service providers should ensure that these devices are available to vulnerable people.