Wearable Device to Assist Independent Living

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ABSTRACT

Older people increasingly want to remain living independently in their own homes. The aim of the ENABLE project is to develop a wearable device that can be used both within and outside of the home to support older people in their daily lives and which can monitor their health status, detect potential problems, provide activity reminders and offer communication and alarm services. In order to determine the specifications and functionality required for development of the device, user surveys and focus groups were undertaken and use case analysis and scenario modeling carried out.

The project has resulted in the development of a wrist worn device and mobile phone combination that can support and assist older and vulnerable wearers with a range of activities and services both inside their homes and as they move around their local environment. The device is currently undergoing pilot trials in five European countries. The aim of this paper is to describe the ENABLE device, its features and services, and the infrastructure within which it operates.

1. INTRODUCTION – AN AGEING SOCIETY

Ageing is one of the greatest social, economic and health challenges of the 21st century. Europe is the continent with the highest percentage of people aged over 65 years (17% of the overall population), predicted to rise to 29% by 2050 (Eurostat, 2004; Börsch-Supan *et al*, 2005). The ageing phenomenon is due to a decrease in fertility coupled with increased longevity (Peace *et al*, 2007). There is an accompanying increase

in the 'oldest old'. Approximately three per cent of the EU population is currently aged 80 years or over, and the number is projected to virtually triple in the next 50 years (Peace *et al*, 2007). Life expectancy for women in the EU is currently 81.2 years and 75.1 years for men (Peace *et al*, 2007); women account for 60% of the population aged 65 years and over.

Longer lives however do not necessarily translate into healthier lives. Women's longevity makes them more likely to suffer from the chronic diseases commonly associated with old age such as osteoporosis, diabetes, hypertension, incontinence and arthritis (Fried *et al*, 1999). Men are more likely to experience heart disease, pulmonary disease and stroke (Murtagh & Hubert, 2004). Inequalities in life expectancy and overall health status are found in European countries. Specific groups of older people are also at greater risk of ill-health than others. They include older women, members of ethnic and cultural minorities, those who are socially isolated and disabled older people (WHO, 2002). Improvements in standards of living, innovations in medical care and the availability of health care over the past 50 years have led to a greater number of older people living with physical or cognitive impairment as a result of chronic illness and/or the ageing process in the extended lifespan (Mukaetova-Ladinska, 2006).

Despite the difficulties caused by chronic ill health, many older people choose to remain living at home with appropriate equipment, care and support for as long as possible (DH, 2001, 2005). Assistive technology (AT) is one important means of helping people with age-related and other forms of disability to live their lives as independently as possible in their own homes. Assistive technology covers a vast spectrum of aids and devices, from basic shower adaptations to complex computerized medical devices that support the older person in managing their disability or long-term health condition.

The aim of this paper is to describe the ENABLE assistive technology device and the features, services and infrastructure within which it operates. Development of the device has been highly user-centred and hence this paper also reports some of the perceptions, requirements and issues that older people had in relation to development of such a device.

2. ENABLE – AIMS AND OBJECTIVES

The aim of the project has been to develop a personal, user-centred system, with services, for use by an elderly person in or out of the home, to mitigate the effects of any disability and to increase quality of life: independence, autonomy, mobility, communications, care and safety. The system is based on a distributed open platform, enabling other services to be added by third parties, by "plugging" into defined interfaces. The platform includes a mobile phone, enabling the user to get out and about, for visiting, shopping, recreation, etc, whilst maintaining contact for help and services.

The system is built round a dual platform of mobile phone and wrist unit, to which are added modular capabilities for (1) alarm functions, (2) control of appliances/other devices around the home, (3) identification of the user's location, and (4) health monitoring. The project addresses mobile phone accessibility by providing an accessible user interface extension, using the wrist unit and speech guidance.

The intended benefits of the system are to:

- Improve the quality of life for an elderly person wanting to lead, or continue to lead, an independent life
- Assist in carrying out daily activities
- Monitor health and activity, especially reduce the risk of having a fall or other trauma
- Improve access in emergency, for safely and security, especially in the case of a fall
- Facilitate social contacts
- Increase the length of time that the elderly person can stay at home before moving to an institution
- Improve the quality of life and costs for their carers, especially for friends or relatives that might not be living, or want to live, in the same house, but are anxious about leaving the elderly person by themselves
- Improve the standard of care provided by local social services, and the cost of providing that care
- Reduce the amount of time that the elderly person spends in hospital before they can be safely sent home
- Improve the quality of life for the elderly person recovering from treatment, or with a terminal illness, who wants to stay at home.

3. OTHER SYSTEMS FOR ASSISTED LIVING

There are a range of systems and devices already on the market or being developed in other projects which are positioned in competing or complementary market places for the ENABLE device and which provide useful information for comparing ENABLE's approach and intended performance with that of other RTD (Research and Technology Development) projects. These products include for example the Vivago alarm watch based on measurement of physiological sensors (Vivago, 2010); the Equivatal life monitoring system (Equivital, 2010); the Tunstall's RTX telehealth home monitor (Tunstall 2010); and Movea's Motion Pod (Movea, 2010). Projects investigating assistive technology for independent living include: the i2home project (i2home, 2010); the CAALYX Complete Ambient Assisted Living Experiment (CAAlYX, 2008), Emerge (Emerge, 2010) and Soprano (Soprano, 2010) to name but a few; other projects examples may be accessed via the Foundation for Assistive Technology (FAST, 2010).

4. USER REQUIREMENTS AND CONCERNS

Design and development of the ENABLE device has been highly user-centric with older people being involved at all stages of the system lifecycle. Two such activities that influenced design of the device were the user surveys and focus groups conducted in order to explore user needs and concerns. The key findings from these are summarised in this section.

4.1 User Surveys Approach

In an initial user survey to gain a broad understanding of user needs, questionnaire data were collected from 96 older people in six European countries: UK (age rage 59-91, mean age 74.5 years), Greece (age range 68-80 years, mean age 73 years), Austria (age range 63-94 years, mean age 72 years), Czech Republic (age range 75-94 years, mean age 83 years), Belgium (age range 57-92 years, mean age 78 years) and Spain.

The sample included older people from volunteer groups and residential care with some degree of ill-health or functional difficulties. Participants were accessed via workshop days, residential and nursing homes and volunteers in six European countries. The majority (over 80 %) of participants were retired with less than 5% working full time and less than 10% working on a part time basis. We did not collect any specific data on education background as the educational systems between countries vary widely. However, the vast majority of participants (over 90%) completed secondary education, with some people being educated to degree level.

Participants' knowledge and current use of technology ranged from everyday use of communication technology devices (such as computers, internet, mobile phones) and household electrical appliances to very little or no use or previous knowledge of communication technology devices.

Questionnaires were translated into the different languages (Greek, German, Czech, Dutch and Spanish) and were predominately self- administered, although some were administered by an interviewer where the participants requested help with filling out the questionnaire.

The initial questionnaire consisted of questions relating to socio-demographic background, health status and functional difficulties, and explored areas of ownership of home entertainment and communication devices, difficulties in using such devices, safety and security, home adaptations, concerns of using ENABLE device, and importance of features of ENABLE device. A second survey with a further 98 respondents was conducted across UK, Belgium, Czech Republic and Greece in order to explore in more details the wrist unit concepts. Data were entered into SPSS and Excel and descriptive statistics were used to analyse data.

4.2 Focus Group Approach

A total of 47 participants took part in nine focus groups in the UK. The majority of participants were female and between 70 and 80 years of age. Most participants were retired. The focus groups included healthy older volunteers, older people with chronic conditions and disabilities (such as Parkinson's disease, stroke, vision impairment, respiratory and cardiac conditions) as well as some carers. The aim of these focus groups was to explore in depth end user needs and identify any issues of concern in relation to users being shown early prototype (PPT1) devices/mock-ups (Figures 1-3 and 4-5). Prior to commencing focus groups, written consent was taken from all participants. A prepared interview schedule was used to ask participants about the difficulties they faced on a daily basis. Participants were then introduced to three different space models and/ or pictures of mock up devices. The researcher explained the device and its potential functions and participants were then asked for their views on the design, functionality and potential concern regarding the use of such a device. A second researcher would take notes during the focus group on group dynamics and

any issues that were identified as important. The interview schedule was amended after each focus group after taking into account responses from participants. This allowed the research team to explore specific issues raised in more detail with subsequent focus groups. Focus groups were tape-recorded, transcribed, imported into Atlas.Ti (a software package for qualitative data) and analysed using thematic analysis.

4.3 Overall Design

The main issues arising from the user perspective with regard to overall design stemming from the questionnaires, focus groups and individual sessions with users trialling PPT1 are summarised below:

4.3.1 Wearing the device

Participants (across all participating EU countries) seem to prefer wearing a device on the wrist. This finding is supported by both survey data with over 100 participants across five EU countries (over 55% of participants preferring to wear the device on the wrist) and focus group data from the UK. This therefore led to the recommendation that the device to be developed within ENABLE should be a wrist worn device as this seems most acceptable to end users across selected EU member states, to both men and women and all age ranges. Although some concern was expressed by the participants with regard to wearing the device at all times (such as discomfort and for practical reasons), respondents also saw this as a benefit as it would eliminate the risk of forgetting to take the device with them which could be problematic in case of an emergency.

Figure1. *PPT1 Concept A*

Figure 2. *PPT1 Concept B*

Figure 3. *PPT1 Concept C*

4.3.2 Overall concept issues

Concepts A/B were the preferred versions of the WU, i.e. end users preferred the square screen with buttons on the side as opposed to buttons on the bottom of the screen. This may relate to ease of using buttons with one hand, as end users will be able to use the device much like a clock design with buttons on the side (and use their thumb for stabilising the hand that uses the buttons) whereas buttons on the bottom of the screen require a more stable hand. In addition, concept C also displays buttons with small spacing and would therefore be difficult to use for people with dexterity problems.

The main issue raised by end users in relation to the overall design was weight. Women in particular were concerned about comfort regarding the weight of the device. This issue was also of great concern to those end users who suffer from conditions that affect muscle strength in the wrist/ hand, such as arthritis, stroke and Parkinson's disease and frailty associated with old age.

Although the overall size and aesthetics of the WU was of some concern to end users, by which they preferred a slim version that would not appear too bulky, focus group data clearly indicates that functionality and ease of use of the WU would override any aesthetics concerns. This suggests that within reason end users may be willing to accept a larger size WU if this would lead to a device that was more user friendly (in terms of button size/ spacing; text size and simplicity of functions).

4.3.3 Interface and access to services

Several areas of end user needs with regard to the interface and access to services were identified:

Screen face: With regard to the clock screen options, respondents showed a clear preference for the digital clock screen over the analogue clock. However, some variance between EU countries has to be noted. Respondents from continental EU states did not like the am/pm display but would prefer the 24 hour clock display. Although the majority of respondents preferred the digital clock screen, a large number of respondents noted that they would like an analogue screen but with numbers on the clock face.

Colour scheme: End users showed a clear preference for a simple colour scheme with high contrast colours, such as black text/icons on a white background. However, such a colour scheme has high power consumption and therefore we suggested a dark/light colour scheme, such as gold on black to optimise power usage whilst providing high contrast. Busy backgrounds containing multiple colours or patterns were disliked by the vast majority of respondents across all countries.

Screen icons and text size: The vast majority of respondents preferred simple screen icons with text displayed with minimal extras, i.e. arrows, additional 'back' and 'select' buttons were disliked. Icons should be displayed on a uniform background preferably in a contrasting colour to text and icons (such as dark colour on light background). *The font size* was found to be acceptable by most respondents, however, bigger spacing between words would be preferable and some participants from Greece preferred capital letters.

4.4 Views on Specific Functions

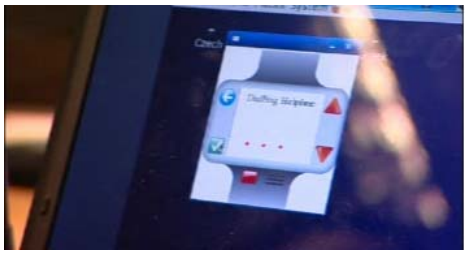
The following functions were identified as most important to older people across all countries involved.

4.4.1Emergency function:

The emergency function was seen as one of the most important functions of the device. Participants wanted a standard alarm system as well as inclusion of information of location in emergency and (to a lesser degree of importance) the possibility of pictures in an emergency. Participants liked both, activation by pressing button or voice activation, to trigger the alarm system.

4.4.2 Falls detector/prevention

These functions were mainly discussed in relation to the emergency function and respondents were mainly concerned with the range of the device (i.e. will it work outside) and risk of failure (i.e. if the person has fallen onto the arm on which the WU is worn how can the alarm be activated if the button cannot be reached). These concerns seem to be related to current fall alarms and as such indicate that these are not adequate in addressing the needs of older people who are at risk of falling. These aspects need to be considered during the development of PPT2 in order to ensure the falls functions address end user concerns. For example, the device should incorporate an alarm that would automatically be triggered when the person has fallen rather than the person having to activate the alarm manually once fallen.



Figures 4 and 5. *Syd taking part in PPT1 trials giving feedback on initial designs and mock-ups*

4.4.3 Medical device:

The use of the wrist worn device as a medical device related mainly to two aspects: the reminder function for medication and the health status monitoring.

Reminder function (medication): The majority of participants prefered an audio or vibrating alarm to a visual alarm as a reminder function. This aspect of the device is also of benefit to carers as it will alleviate them of some of their responsibility to remind the older person to take their medication. The reminder function was also seen as very useful for those conditions where it is important to take medication at a certain time every day (e.g. Parkinson's disease, diabetes, Alzheimer's disease).

Health status monitoring: Health status monitoring such as blood pressure, pulse, temperature monitoring was seen as an important function of the device with over 50% rating this function as important or very important. It was perceived to serve as a way of keeping someone else (e.g. in response centre) aware of health status and deterioration, however it could also be used to facilitate diagnosis of chronic health problems.

Health status monitoring is of particular interest as a large proportion of older people are living with a chronic health condition (this was reflected in participants, with over 65% indicating they were living with a long term condition). In addition to basic vital signs monitoring (blood pressure, pulse, temperature, ECG) it would be useful to include a way for gathering medical information which would allow care providers to manage these older people better in their own homes. This could be achieved by using standard sets of questions which would be collated and monitored over time in order to detect any abnormalities.

Participants showed very little concern (only 7.5% indicate great concern) about sending medical data to health care professionals or health care assistants (26% indicate great concern) however showed much greater concerns about sharing data with non medical staff (38% indicate great concern). This result may effect the way medical data is handled in the response centre and staff employed.

4.4.4 Text function:

The ability to text messages from the device was less important compared to other functions but was of interest to a sub group of participants (e.g. those with speech impairment). Concerns were raised related to the use of buttons, so the WU needs to include buttons of a reasonable size, spacing and most preferred textured surfaces.

4.4.5 Speech/Automatic Speech Recognition (ASR)

The majority of respondents (over 60%) would like a speech function/ASR included in the device, in particular those end users with vision deficits. However some concerns were raised regarding volume of speech (output) and whether the device will 'understand' speech input for those end users who have speech impairments (e.g. Parkinson's Disease/ Stroke). In addition, survey data showed that a majority of the participants were not willing to wear headphones or earpieces and therefore the volume of speech output needs to be at a level that is loud enough to be understood even by those end users who have hearing difficulties.

4.4.5 Environmental control

The environmental control function seems to be more important to carers than the older person as it appears to provide reassurance to carers when the older person is left alone. Carers indicated that they are often worried whether the older person left appliances on (such as cooker, gas hob, etc.) which would place the older person at risk. An environmental control function would alleviate such concerns, as all appliances could be switched off using the device.

4.4.6. GPS

The GPS function was also particularly important to those carers who looked after older people with dementia as it would offer reassurance of the location of the older person should he or she get disorientated or wanders off and get lost. End users themselves would also like further information included in the GPS function, such as local maps, traffic information and directions (much like a satellite navigation system).

4.5 Concerns to be Addressed

Participants also expressed concerns about using a wrist worn device. These primarily related to complexity of functions, privacy, built quality, safety concerns and ease of use of the device.

4.5.1 Complexity of design

One of the key concerns raised by participants with regard to using a wrist worn device was the potential complexity of functions. Participants preferred simplicity of menus and access to functions and a limited number of functions with the focus on those functions that are most needed. As such, end users appear to prefer a device that is individually tailored to them in terms of functions included as this approach would reduce the risk of complicated menus with numerous functions that may not be needed by an individual.

We would therefore recommend that the wrist unit is developed to be as 'individualised' as possible, which could be achieved by developing more than one prototype/system, e.g. by having one model for older people living with long-term conditions, one model for those needing some support in the home environment (activity monitoring) and one for those at risk of falls and with memory deficits, such as dementia.

4.5.2 Concerns about privacy

Another concern raised by participants related to privacy and confidentiality. Participants also showed much greater concern in sharing medical data with non-medical staff (e.g. administrators) than with medical or health care trained staff. This will therefore affect the staffing in the response centres and may require staff to be trained in some aspects of health care as well as issues relating to confidentiality and data protection.

4.5.3 Build quality and safety concerns

Some concerns were raised about build quality of the device, for example whether the WU will be water proof and shock proof, as end users were concerned about wearing the device in the bath/ shower and knocking the device on furniture or when having a fall. In addition, participants were also worried about getting entangled in clothes/catching the device on furniture such as curtains, in case of large buttons protruding from the device.

4.5.4 Ease of use

The ease of use of the device in terms of hardware features was another key concern of participants. Issues raised by participants related to the size and spacing of buttons as well as the texture of buttons. Buttons need to be spaced adequately (which may explain the preference of space model option A and B over option C as the former two designs have buttons on the side rather than on the face of the unit) as well as large enough in size for those users with dexterity problems to use the device. Participants would also prefer to have textured surfaces on buttons as this would facilitate using the device, particularly for those people with dexterity problems.

4.6 Opportunities for Carers

The use of a wrist worn device such as ENABLE could also have benefits for (informal) carers of older people. The main benefits for carers (as perceived by themselves) include increased independence and reassurance thus potentially increasing carers' quality of life. Carers clearly indicated that the use of a wrist worn device by the older person they cared for, would give them more independence as they would be able to leave the older person on their own for periods of time as well as use the device to help manage tasks such as medication reminders on a daily basis.

Carers often feel overburdened and have little time for themselves. Therefore a device such as ENABLE would increase their independence, and allow carers to have more time for themselves and thus potentially increase their quality of life as well as that of the older person. Another perceived benefit of the wrist worn device to carers was reassurance that the older person was well and safe, or in an emergency would be able to contact the carer or the response centre as appropriate. This would allow carers to respond more quickly to the older person's needs.

5. ENABLE PLATFORM

ENABLE as a delivery solution consists of a number of key components (see Figure 6) as outlined below:

- The Service Centre software including the business layer components, the database schema and the web based user interface layer.
- The ENABLE application software for the Mobile Phone.
- The electronic and mechanical hardware for the Wrist Unit.
- The software for the Wrist Unit, consisting of the specific configuration of the operating system and the application software for the main processor and the firmware for a low-power micro-controller associated with sensors.

Following the user requirements, the ENABLE device was developed to meet the following requirements and service provision:

- Open system design to allow tailoring for an individual's/market needs and which allows integration of new sensors, and data collection and services to be remotely deployed and configured across the web.
- A device that can be used both inside and outside of the home and in which a number of previously separate features (falls detection, environmental control, GPS etc.) have been integrated into one unit.

- Simple, flexible and practical user interface which has a colour user interface, language and user independent voice commands and a simple five button operation (Figures 7 and 8).
- Wrist worn falls detection including differentiation between hard and soft falls, and falls prevention.
- Integrated social and healthcare functionality for monitoring of long term conditions and medication reminders.
- Auto connection to mobile/communications for quick and simple dial from the wrist unit.
- Context control of the user's environment e.g. for switching on/off lights as the user enters/leaves a room and location awareness of the use as they move between rooms.
- Emergency call and prompting and inside and outside location detection.

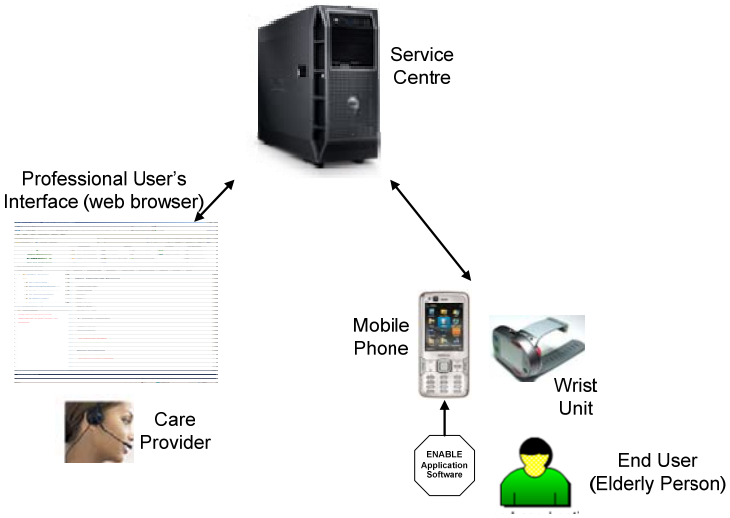


Figure 6: Overview of ENABLE Platform Prototype.

It has also been developed with accessibility in mind:

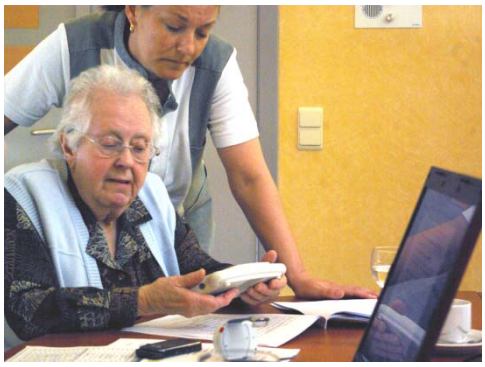
- Navigation of the user interface can be performed using speech commands as an alternative to buttons. These commands are language independent such that any user voice can operate them.
- The buttons and the visual display are large, compared to those on a watch, giving improved access for elderly people for time functions. Such accessibility advances the state of art for accessibility of mobile technology and telehealth and telecare services, especially for elderly people.
- The system is designed to be easily used by somebody with a visual impairment, as they don't have to be able to see the screen. The buttons are in distinctive positions. The automatic speech recognition option gives added accessibility.
- Speech input gives accessibility for people with reduced vision and/or manual dexterity. Combined with single switch input, the system becomes accessible for people with little upper limb movement, tetraplegics, amputees, etc.

Figure 7. *ENABLE Interface/Strap System*

Figure 8. *ENABLE Command Buttons*

6. USER FOCUS, TESTING AND RESULTS

User trials of the ENABLE Wrist Unit device and the services it offers are being conducted in individual's homes and in care homes in the UK, Belgium, Austria, Greece and the Czech Republic between April and September 2010. Fifty wrist units have been manufactured for the trials and a series of short (two weeks) and long term (ten week) trials are taking place across the three month period in order to assess the success of the device, its aesthetics and usability of the interface, and the integrated functionality that it offers (Figures 9-12).

Figures 9 and 10. *ELZA, a resident at WZC Cassiers vzw in Belgium being trained to use the system*


Figure 11 and 12. *Vi, a UK participant using the system outside of and within the home*

7. CONCLUSIONS

ENABLE has sought to address a number of technical, integration and service aligned issues that if solved will provide a capacity for change currently not available through other programmes/devices. Elderly and vulnerable people are faced with a number of issues as they seek to maintain their independence and to maintain their quality of life. ENABLE for example:

- Has created an integrated technology platform capable of serving telecare, telehealth and the combined disciplines. The main innovation of ENABLE is the integration of formerly disparate functionality (ECS, falls detection, telephony, care management, quality of life assessment etc.), into one mobile platform.
- Provides the capacity for different configuration profiles so that functionality is adapted to the special situation of the user. This approach also ensures that the ENABLE solution is open to facilitate changes and extension of performance and adaptation to future needs of an individual.
- Has a falls algorithm built into the ENABLE wrist unit that will differentiate between different motion profiles to allow a greater reliability for the detection of falls whilst removing false positives. The falls application can be integrated with applications so that a single device can be used for a range of services.
- Assesses users on a regular basis through a preventative question set using a standard tool that examines the issues of daily living that increase the risk of falling. This could be linked to a prompting

service that suggest that the user sits down or stops what they are doing for a time thus removing or diminishing the risk of falling.

- Has created a wearable system capable of use at anytime and anywhere with a full range of services and support options including location and alert systems. This means that the device can be used both within and outside of the home.

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