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A Case Study Using a Methodological Approach to Developing User Interfaces for Elderly and Disabled People

Rich Picking*, Alexia Robinet, Vic Grout, John McGinn, Armando Roy, Simon Ellis, and Denise Oram

Centre for Applied Internet Research, Glyndwr University, Wrexham LL11 2AW, UK
**Corresponding author: r.picking@glyndwr.ac.uk*

In this paper, we present a case study on the development of interfaces for elderly and disabled users. The domain of the case study was situated in the home environment, where we focused on producing affordable technologies to enable users to interact with and to control home appliances. We have developed ambient user interfaces that are integrated in familiar home artefacts, such as televisions and digital picture frames. These interfaces are connected remotely to a home network and are adaptive to users' expected increasing physical and cognitive needs. To support the development of the project, we created a novel methodology that is grounded in the ethical issues associated with a project of this nature. Our success with it has led to us presenting it here as a practical approach to developing user interfaces for a range of interactive applications, especially where there may be diverse user populations. This paper describes our journey through this project, how the methodology has been used throughout and the development of our user interfaces and their evaluation.

Keywords: assisted living; vulnerable users; ethical issues

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1. INTRODUCTION

The twenty-first century phenomenon known as the *demographic time bomb* is now well documented, as we experience an increase in the number of elderly people and a reduction of younger people to care for them as they lose their independence in later years. What constitutes 'elderly' is clearly an area of debate, as many people stay healthier in old age than their younger counterparts. However, purely for the sake of clarity in this paper, we use the generally accepted (in western society) age of 65. In Europe, this population represented around 17% in 2007, but is expected to increase rapidly. By 2020, the elderly population will represent an estimated 20%, and by 2050 it will be 30% [1].

This trend has prompted many researchers and developers of information technology to find ways to enable elderly people to live independently for longer. A number of research projects have sought to develop smart home environments to meet the special needs of the ageing population and offer them security, comfort and quality of life [2–5]. Assistive technologies in home environments can help with household tasks, put carers at ease and make sure vulnerable people feel safe in their home. It is well documented that most elderly people would rather stay in their own home rather than in a care home, despite illnesses or impairments that could put their well-being at risk [6]. Although assistive technologies incur financial expense, making them affordable would more than offset the cost of nursing home care. The smart home environment can also offer added value, by monitoring long-term changes that may cause health concerns [7]. Such systems could alert carers and the family of any significant changes in behaviour, diet, daily tasks or health. Systems such as fall detectors, smart pill dispensers, medical equipment to test heart rate and blood pressure, tracking devices and sensors all create a potentially safer environment for people with sensory, cognitive or physical disabilities to live.

Even though computer systems have already shown that they can be powerful aids in home health care, their promise to improve the quality of life and independence of elderly people can only be fulfilled if they are designed to take into consideration the specific needs of their users [8]. In order to solve the problems of accessibility for elderly users who might have cognitive, physical or other limitations, interchangeable or adaptive interfaces are required. Such interfaces integrated with intelligent agents, known as assistive environments, may act as a substitute for care and benefit elderly users by increasing their level of activity and quality of life. Such developments may also serve to provide younger disabled people with similar benefits, as well as for the wider population in general, in the context of the *design for all* concept.

We must be mindful, however, that designing for vulnerable people raises serious ethical concerns [9–12]. The monitoring of users' activity has many advantages, although this is potentially intrusive [13]. In addition, it has been proposed that it is vital to find the right balance of *assistance* versus *nuisance* [14]. Reliance and trust are also central issues [12]. Paradoxically, all the benefits that are offered by assistive technologies may bring negative aspects into the user's life [9]. For example, communication systems that provide alternative ways of communication (video-telephony, email, for example) for people experiencing speech or communication impairment may reduce direct contact with family or friends. A further negative aspect of such technology is that it may actually promote inactivity. The consequences of introducing bad or inappropriate design can make a difficult situation even worse, and hence we need to make sure that our approach to the design and the evaluation of the artefacts we produce are as optimal as possible.

This paper presents a case study using a novel methodological approach to the user interface development process, specifically for vulnerable people where ethical issues have particular importance. The domain of the case study is situated in the home environment, and is focused on producing affordable technologies to enable users to interact with and to control home appliances. Typical home appliances may pose significant usability problems for users with failing physical and cognitive abilities. In the kitchen, for example, washing machines often have complex programmes, food contents in refrigerators and freezers may be difficult to discern (in particular the information on packaging) and ovens can cause serious injury if not used with particular caution. One only has to visit a high street appliance store to become confused by the vast array of varied control panels, displays and features—many of which sacrifice usability for sleek, fashionable design.

To overcome these usability problems, we have developed consistent, ambient user interfaces that are integrated in familiar home artefacts, such as televisions and digital picture frames. These interfaces are connected remotely to a home network via an intelligent set-top box server called the *e-servant*. The interfaces are adaptive to users' expected increasing physical and cognitive needs, as the e-servant monitors their interaction over time, and modifies users' personal profiles according to their changing behaviour patterns. The user interface then automatically adapts, both in terms of its look and feel (for example, in the case of deteriorating eyesight), and the interaction dialogue (for example, in the case of deteriorating cognitive ability).

2. BACKGROUND TO THE CASE STUDY

The case study described here is a component of a wider project called EASYLINE PLUS, and involves academic and industrial consortium partners from Wales, England, Spain and Germany. The aim of the project is to develop a range of advanced white goods, near to market, to support elderly people with or without disabilities in maintaining a longer independent life by compensating for their loss of physical or cognitive abilities.

Sensors using radiofrequency identification (RFID), ZigBee, powerline communication and infra-red technologies enable the system to interact with the home environment. Human activity is monitored by an intelligent server, which we have called the *e-servant*. The e-servant recognizes and adapts to the changing needs as the user grows less able over time. This is done using a combination of pre-configured user profiles that are subtly modified by a neural network sub-system. The research presented in the subsequent sections of this paper has led us to concentrate on user interfaces situated in modified familiar home devices, specifically television sets and digital photographic frames.

3. METHODOLOGY

During the initial investigation in how to approach the user interface development for this project, we undertook a critical analysis of the most used methodologies for interface and software development. There is clear agreement among experts in the field of human–computer interaction for elderly adults that ethical issues must be considered in the design process [15]. Ethical guidelines may be used to accompany methodologies in development and can provide useful sets of principles and duties; however, practitioners have often had difficulty in applying them [16]. Established methodologies such as Merise [17] and Rapid Application Development (RAD) [18] enable participation of end users and senior management in the decision cycle, but do not directly integrate ethics in the process. Indeed, most methodologies take little account of ethical issues, or they might be addressed at the initial stages or some part of the process as with Multiview2 [19] where ethical issues form part of the *organizational analysis* at the start of the project.

In light of the lack of an existing methodology to support our requirements, we developed a new methodology called EDUCATID, an *e*thically *d*riven, *u*ser-*c*entred *a*pproach *t*o *i*nterface *d*evelopment. As the acronym suggests, it is grounded in being ethically driven, in that ethical issues are carefully scrutinized at the initial analysis phase, as well as in iterations of interface prototyping, development and evaluation. Similarly, it is user centred in that users are involved in participative, narrative workshops in the initial analysis phase and also in the method's iterations, and naturally during the usability evaluation phase.

EDUCATID is a simple, rapid and practical methodology that adheres to the four basic phases for interface design methods: analysis, design, development and evaluation [20]. Each phase is informed by a fifth element, which we call the *user analysis* phase. This forms the central hub of the methodology, and involves the elicitation of user narratives as well as ethical and legal inspection. EDUCATID follows a cyclical prototyping paradigm, where each phase may be iterated any number of times, although we recommend a target of three iterations: the first concentrating on prototyping; the second focusing on detailed development; and the third being a verification exercise. Each phase contains a number of activities that have specific inputs and outputs, are easy to understand, have little or no formality and are represented for end-user participation where appropriate.

The EDUCATID methodology is summarized in Fig. 1a and b. The process begins with *requirements analysis*. Background and market researches are undertaken to establish the feasibility of the development project, and to consider previous work in the application domain. In parallel with the requirements analysis phase, the first instance of the *user analysis* phase is launched, where an ethical and legal inspection of the anticipated project is undertaken. We propose the use of Oram and Headon's *ethical triangle* [21], which provides a framework for exposing potential ethical problems throughout the development process of the systems. The guidelines proposed by Abascal and Nicolle [9] (Table 1) can be used in combination with the ethical triangle to provide a practical and valuable ethical audit tool for developers. This approach is presented in further detail in the context of the case study.

The next step of the process involves the second activity in the user analysis phase, namely the *user narratives workshop*. As in Joint Applications Development [22], this takes place very early in the lifecycle. However, as it is a central activity, it is repeated at set points in the process, typically after an instance of the methodology's evaluation phase. The narratives workshop involves end users, as well as technical and domain experts. During this event, typical usage scenarios are identified and described. The output from this feed into the *task analysis* in the requirements analysis phase, documented in the form of use cases. The outputs from the task analysis and background/market research are used to document the *user* and *functional requirements*.

In addition to providing valuable input into the requirements phase, the workshop outcomes also feed into the *conceptual design* phase. Here, *personas* [23] and narrative scenarios, in the form of storyboards, are generated. Personas are then used to create a more formal set of *user profiles*, which represent the typical range of users of the system. The outputs from the conceptual design phase (user profiles and narrative scenarios) are then combined to form the initial activity of the *interface design and build* phase, which we term *interaction modelling*. This activity produces a semi-formalized representation in the form of a pseudocode, which models the tasks users will undertake. Each task is modelled according to every user type, extracted directly from the user profiles. The two remaining activities in the interface design and build phase

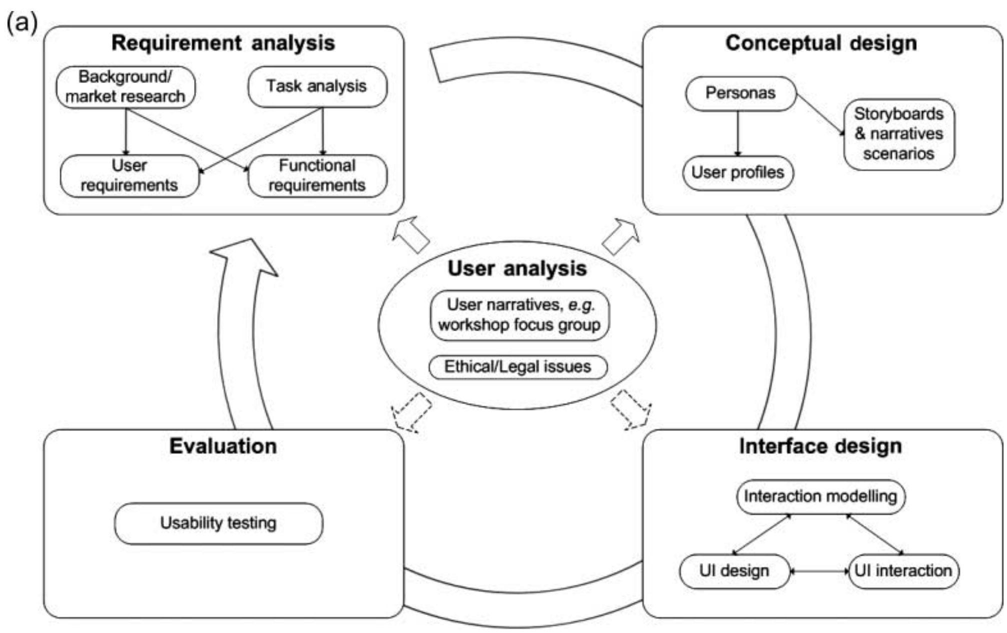

FIGURE 1. Continued.

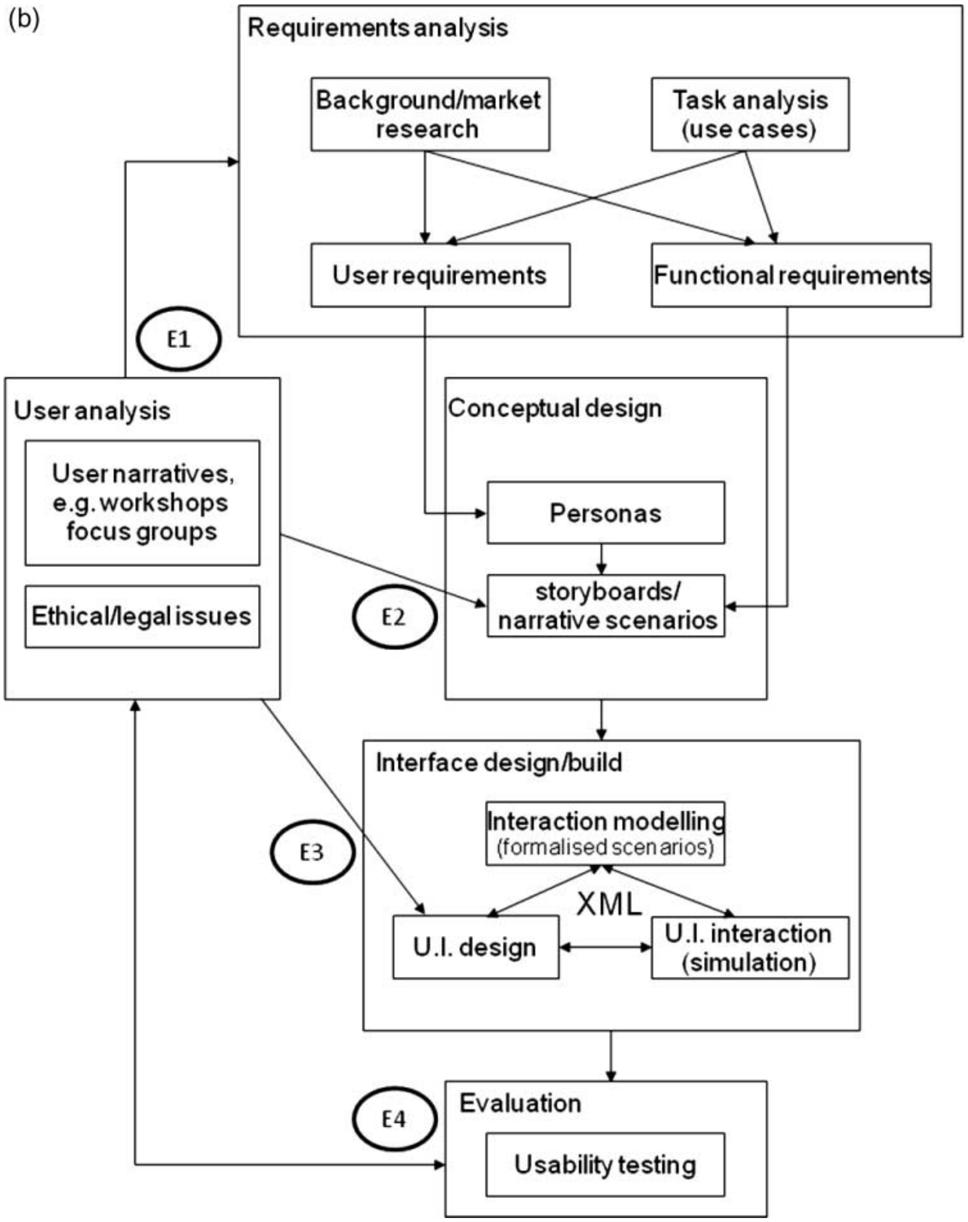

FIGURE 1. (a) Overview diagram of the EDUCATID methodology, showing the *user analysis* phase as the central hub. (b) Flow diagram for the EDUCATID methodology, showing ethical inspection points E1, E2, E3 and E4.

are *user interface design* and *user interface interaction*. User interface design is the physical design of the interface, for example the screens, icons, input and output devices. The user interface interaction is the physical execution of the interaction model, i.e. the running of the prototype or system itself. Once a testable interface prototype is developed, the *evaluation* phase is undertaken. This may be in a laboratory and/or field environment, depending on the nature of the application. The results of the evaluation are used to revisit the original requirements, where the cycle of phases begins again. It is imperative at this stage that ethical and legal issues are re-considered, and that a further narratives workshop is organized. The central theme of this engagement is to present the interface prototype and use it to consult with end users and other stakeholders regarding original scenarios. EDUCATID in practice is now described in the context of the EASYLINE PLUS case study.

4. INITIAL REQUIREMENTS AND USER ANALYSIS

The requirements analysis for EASYLINE PLUS began with a market and literature research exercise, in particular considering results disseminated by other European Projects, such as

TABLE 1. A first approach to socially and ethically aware design guidelines [9].

Risks	Description	Guidelines for HCI designers
Design of inaccessible devices or services	Devices or services that cannot be used by people with special needs, even if they have adequately adapted equipment	Develop a sound study of user needs. Ensure user participation in the design. Use guidelines towards a design for all approach to design.
Loss of privacy	When personal information is stored and/or transmitted without the authorization of the user	Do not store or transmit personal information without user awareness and authorization. Avoid storing or transmitting unnecessary personal information. Use procedures to ensure anonymity (e.g. pseudonyms). Use secure means to transmit and store authorized personal information.
Loss of autonomy	When decisions about the user are taken by other than the user or the person(s) authorized by the user	Avoid unnecessary automatic or external decisions by the system. Inform the user about decisions taken automatically or externally. Allow intervention only by authorized personnel.
Economic factors	Devices and services beyond the financial capability of the users because ‘excessive’ technology is used	Minimize the use of ‘fancy’ or expensive technology. Avoid features not needed by the user that make the product more expensive When possible, select the lower cost choice.
Invasive and/or socially unacceptable location of systems	Systems for personal location that invade personal freedom and/or devices for locations that are socially unacceptable	Use location systems only with stakeholders’ awareness and consent. Delete location information after convenient usage and do not record it unnecessarily. Use discrete location devices; use ‘tagging’ devices only with strict ethical considerations.

AutoHan [24], and products available commercially. Our initial analysis determined that although the technologies are currently available to realize smart kitchen environments, they are often expensive, tend to be aimed at a younger, technologically knowledgeable audience and lack consistent user interfaces.

One of the fundamental objectives at this stage of the EASYLINE PLUS project was to identify the specific needs that elderly and disabled people have in their use of household appliances. To answer this question, open interviews of 80 elderly people were conducted to identify the problems encountered by users with limited abilities while using different household appliances. The records collected were then analysed by accessibility experts within the EASYLINE PLUS team.

The user analysis phase was launched in parallel with requirement analysis with an ethical and legal inspection of the anticipated project. We used the ethical triangle as a framework for this audit (Fig. 2).

At the top of the triangle are *laws* and then *regulations*. These have to be considered first—hence they appear at the top of the diagram. These *constrained ethics* are usually generic, and may be set in law, ethical codes of practice, organizational regulations or professional and statutory requirements.

Further down the triangle, those ethical factors regarded to be of high importance (‘must’) are considered—where those participating in the ethical audit *agree* that a *duty* is imposed, followed by those of middle importance (‘ought’) where an *obligation* is imposed. Finally, the factors deemed to be of some importance (‘should’), where it is *felt* that it is *right* to proceed in a certain way, are considered. Generally, the number of considerations is expected to expand as we move down the list, and hence the triangular shape. Also, although all factors of the triangle can be considered throughout the development process, it is likely that those nearer the bottom will become more prevalent over time. Hence, for this first iteration of user analysis, we concentrated on those factors that reside at the top of the triangle. In our project, this comprised scrutiny and validation by the Glyndwr University ethics committee, which uses its own code of practice for ethical standards in research. Similar codes of practice may be obtained online through the

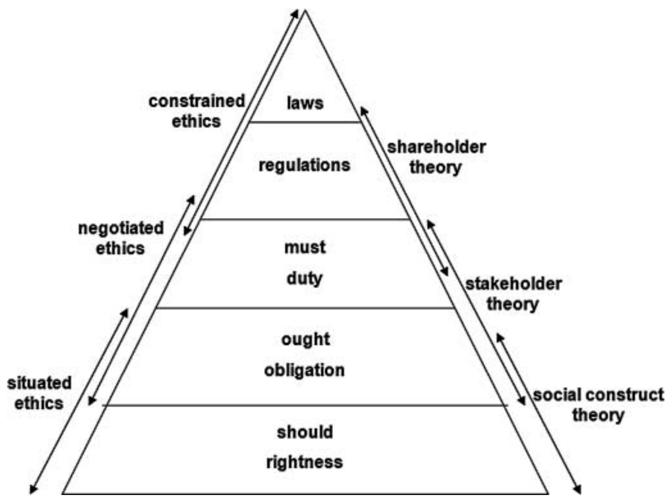

FIGURE 2. The ethical triangle. (The full title for this as proposed by Oram and Headon [21] is 'The culturally negotiated ethical triangle'. We use the short title in this paper for simplicity.) Ethical considerations move from *constrained*, through *negotiated* and into *situated*, as the issues gravitate from the organizational to the individual. This conforms to the three *normative theories of business ethics* [41], which are listed on the right-hand side of the triangle.

British Psychological Society [25] and The British Sociological Association [26].

At this point, we combined Abascal and Nicolle's socially and ethically aware design guidelines with the factors on the ethical triangle. For our project, we considered where each guideline should be placed on the triangle. For example, the guideline *Minimize the use of 'fancy' or expensive technology* was placed in the *must* category, as this is a fundamental requirement of the project; and the guideline *Avoid unnecessary automatic or external decisions by the system* was placed in the *ought* category. Mapping each guideline onto the relevant factors of the ethical triangle provided us with a set of parameters that acted as a tool to verify ethically the ongoing development of the project. We used this approach at each iteration of the EDUCATID method, concentrating more each time on the lower levels of the triangle as the ethical issues became more situated in particular home environments for users with varying profiles.

Next, the first narratives workshop took place. For this, a wide set of participants were selected. Later iterations involved increasingly smaller groups, finally ending with a focus group for the last stage of the system's development. For our first workshop, five members of the EASYLINE PLUS team joined with a group of 10 experts from the fields of telecare, assisted living and smart home technologies, along with 14 service users and carers. Expert participants represented academia, the clinical sector, the social services, charities and assisted living technology developers. During this event, typical usage scenarios were identified and described by both experts and service users (and their carers). The workshop participants separated into smaller breakout groups where they discussed and later presented issues relating to sensory impairment, cognitive needs, physical disabilities, well-being and everyday living. During the workshop, candidate user interface devices were also discussed. Four devices were considered appropriate as candidates to display the user interfaces: a *fixed* device (the digital TV), a *touch screen* device, a *mobile* device (such as a personal digital assistant (PDA) or a mobile phone) and an *ambient* device (e.g. a digital photo frame).

The television was chosen as the central information point since most people own a television, and they are generally familiar with interacting with it on a regular basis. The concept of using a television remote control to interact with other household appliances was also very popular, as long as it could be simple and intuitive to use. The idea of using the four coloured *teletext* buttons was also universally popular. This recommendation from the workshop concurred with the results from the open interviews conducted during the requirements phase. There was unanimous agreement that a single control unit to interact with all appliances would be a real leap forward in terms of usability.

A fixed touch screen monitor was also considered, as it could be situated in the kitchen or embedded in a wall. Generally, touch screens are popular with elderly adults, as long as the interactive buttons are of an appropriately large size [27]. However, such devices are still relatively expensive, and consequently these fell out of the scope of the EASYLINE PLUS project's constraint of affordability, and also broke the *economic factors* aspect of Abascal and Nicolle's socially and ethically aware design guidelines. Mobile devices are convenient and portable. However, the workshop participants rejected these devices as not well accepted by the current generation of elderly people due to the lack of familiarity, small-sized screen and the small keypad. Such failings are corroborated again by Abascal and Nicolle—in this case the first factor of *design of inaccessible devices or services*. Finally, an ambient device, such as an adapted digital photo frame, was a very popular suggestion, as they are inexpensive and unobtrusive, and can be situated anywhere in the home. The workshop participants also discussed accessibility issues, and alternative interaction such as speech input and output were identified as clearly being important options. Task closure was seen to be a real issue for those with visual impairments, for example putting things away after using them, closing doors and switching things off. Locating messaging devices in appropriate places to remind people about such things was discussed, for example in the bed, on the fridge door and so forth.

The workshop event and its outcomes proved to be highly useful, and this facilitated the next EDUCATID activity, where a task analysis using task flow diagrams and use cases helped to verify the shared understanding of how users with differing needs might interact with the appliances and their interfaces (Fig. 3a and b). These graphical approaches

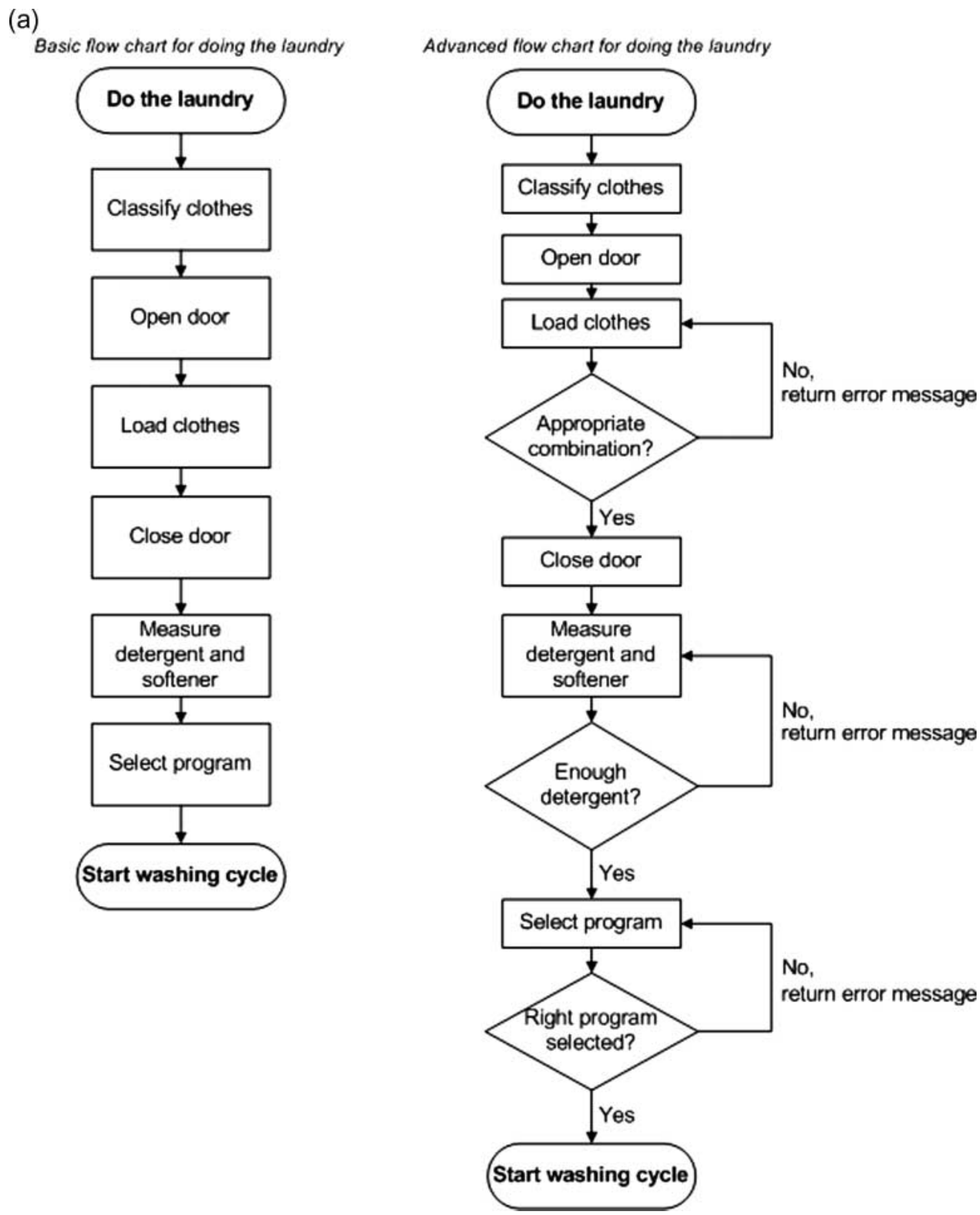

FIGURE 3. Continued.

proved to be simple and intuitive enough for most users and carers to comprehend during later verification with a sub-group of workshop participants. Subsequent to this exercise, the initial functional requirements for the system and the user requirements were drafted.

5. CONCEPTUAL DESIGN

The conceptual design phase began with the generation of personas. We specifically decided to formulate personas for EASYLINE PLUS as our user population is vulnerable, and to involve them in a more intensive participatory design approach may have caused ethical and practical problems. Such issues have been highlighted in the past, particularly by Newell and Gregor [28]. One possible solution to these problems has been successful, where trained performers role-play elderly adults [29]. However, a recognized drawback of this approach is that it can be expensive, hence our adoption of more practical personas and scenarios techniques. We created 10 personas based on our experience with service users in the narratives workshop, and

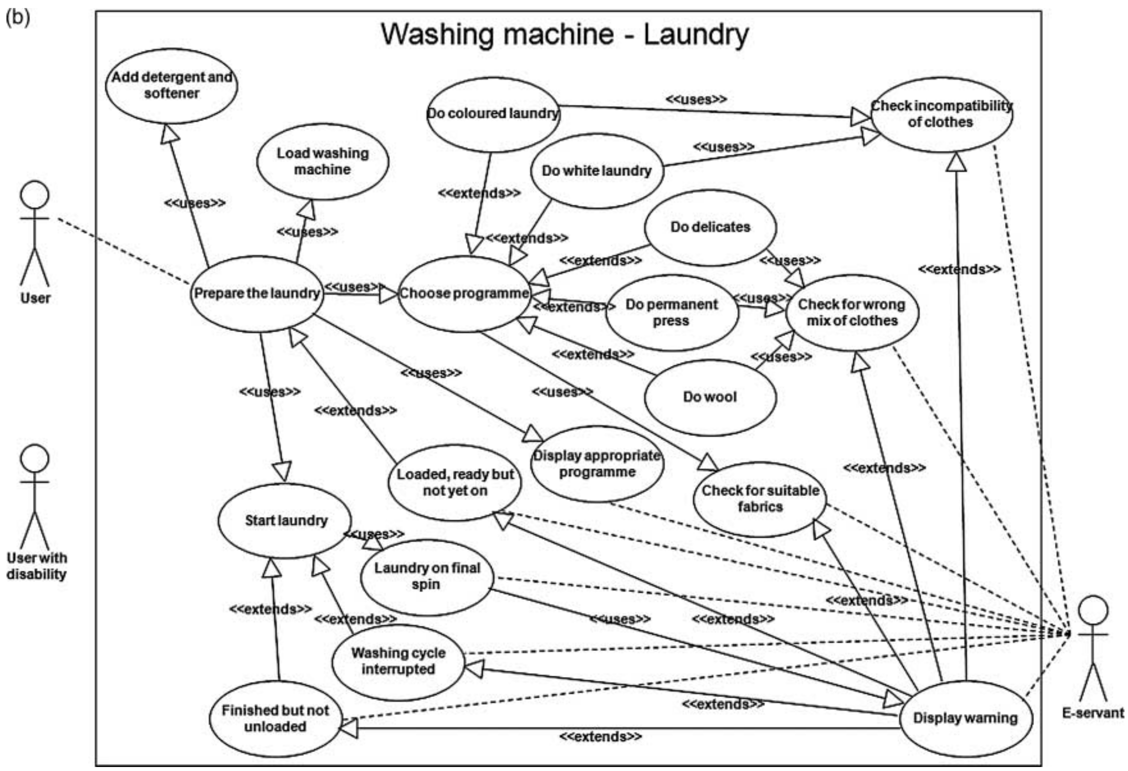

FIGURE 3. (a) Example task flow diagrams for doing laundry, displaying two modes of use for users with differing cognitive abilities. (b) Example use case diagram for advanced use of washing machine.

Hannah, 67 years old, Sweden

"I am looking for technologies that can bring me closer to my children"

Retired, ex-secretary in a bank Has upper secondary education Widowed, 1 daughter, 2 grandchildren	Suffers from mild impairment Suffers from osteoarthritis Owns a computer, no mobile phone

Hannah used to work in a bank as the manager's secretary. She is computer literate. Her arthritis started when she was 55.
Hannah was married for 38 years when her husband died a couple of years ago of lung cancer. She is now living on her own in a quiet residential area in the south of Sweden. She spends most of her time at home doing common household tasks that she hates doing. She enjoys listening to opera music, taking long walks with her dog Bandit, and playing cards with her friends every weekend. She also loves cooking, and talking for hours on the phone to her daughter Michelle who lives two hours away.
Hannah wears glasses, but only for reading or for close work, like card playing. She has a magnifier on her computer, and she can surf the web and check e-mails without difficulty.

FIGURE 4. An example persona.

also from data sources based on European *(Eurostat)* statistics [30]. Characteristics such as age, education, work situation, impairment and technology familiarity were assigned. Figure 4 represents one of the 10 personas created.

Scenarios are short narrative stories describing the user's activities or tasks, often described as *prototypes built of words* [31]. They can illustrate what someone is doing or how to accomplish something. We recorded a number of scenarios as

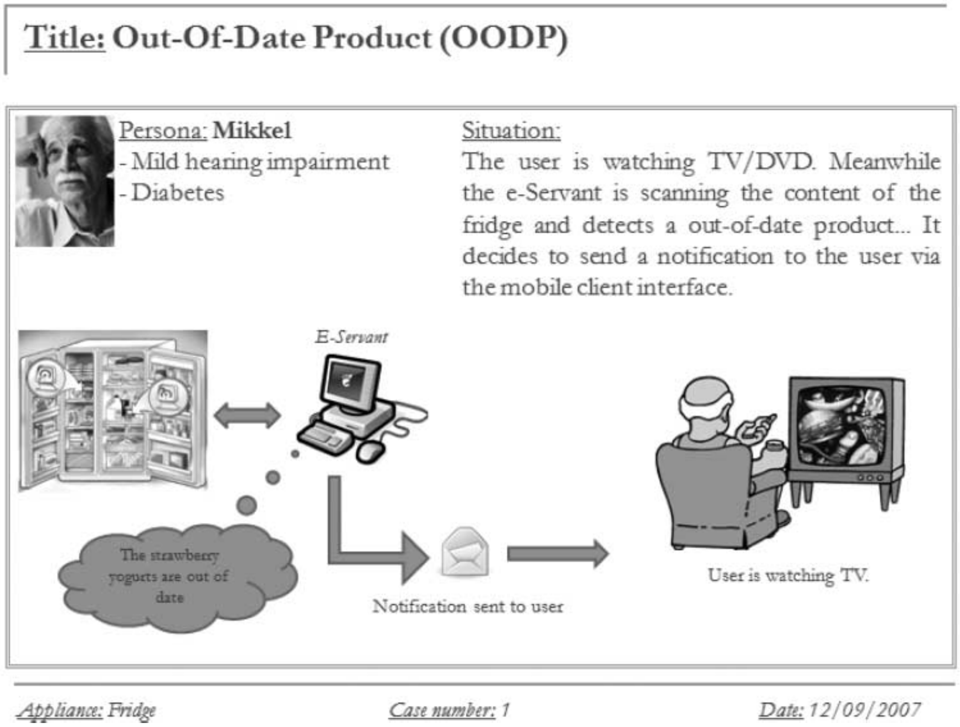

FIGURE 5. An example storyboard, featuring persona Mikkel.

described by participants in the narratives workshop and from functional requirements.

We then converted these into simple to understand storyboards, using the personas as characters in each scenario, an example of which is shown in Fig. 5. This example was actually suggested by an elderly participant of the first narratives workshop.

The final activity of the conceptual design phase involved using the personas to create a more formal set of user profiles, which represented the typical range of users of the system. These profiles were represented in XML format, and incorporated directly into the e-servant's user profile database, to be used in executable form in the actual interface implementation. Our project identified a range of user profiles, including *low-cognitive-ability*, *typical-cognitive-ability* and *high-cognitive-ability*, and for each of the cognitive variations, a *visual-ability* factor was applied. The cognitive ability profiles of *low* and *typical* map onto the two higher scales of the three-tier Mini Mental State Examination [32] (the lowest tier of severe cognitive impairment would render any computer system virtually unusable for such people). It should be emphasized that any professional assessment of individual cognitive state was performed by clinical specialists outside the EASYLINE PLUS project. The initial profiles are adaptively tuned by the e-servant, which can modify certain attributes, such as the profile itself, how often to send reminders of open notifications and the level of help provided by the interface.

6. INTERFACE DESIGN AND BUILD

During the first activity in the interface design and build phase, i.e. interaction modelling, we produced a semi-formalized representation of all scenarios in XML, which modelled the tasks users will undertake. This was carefully scrutinized to accommodate all functional requirements. Each task was modelled according to every user type, extracted directly from the user profiles. The interaction model was then integrated into the user interface design and the executable user interface interaction (at this point, in the form of a simulation). As this was, at this stage of development, a reasonably well-defined process, there was tight coupling between these three activities of the interface design and build phase.

In the EASYLINE PLUS project, a number of alternative prototypes were created. We determined that the usability principle of consistency should be adhered to in that the same interface should be presented on all output devices, and all input should be achieved by using a simple four-icon display, as afforded by the coloured buttons on a TV remote control. On a future touch screen interface, these might be screen buttons. This constrained the interface design options somewhat, but facilitated a simple and intuitive solution. For the first iteration of the design and build phase of development, we decided on the design shown in Fig. 6.

The top part of the screen is used to display the status of each appliance, so that the user can check quickly what is going on in

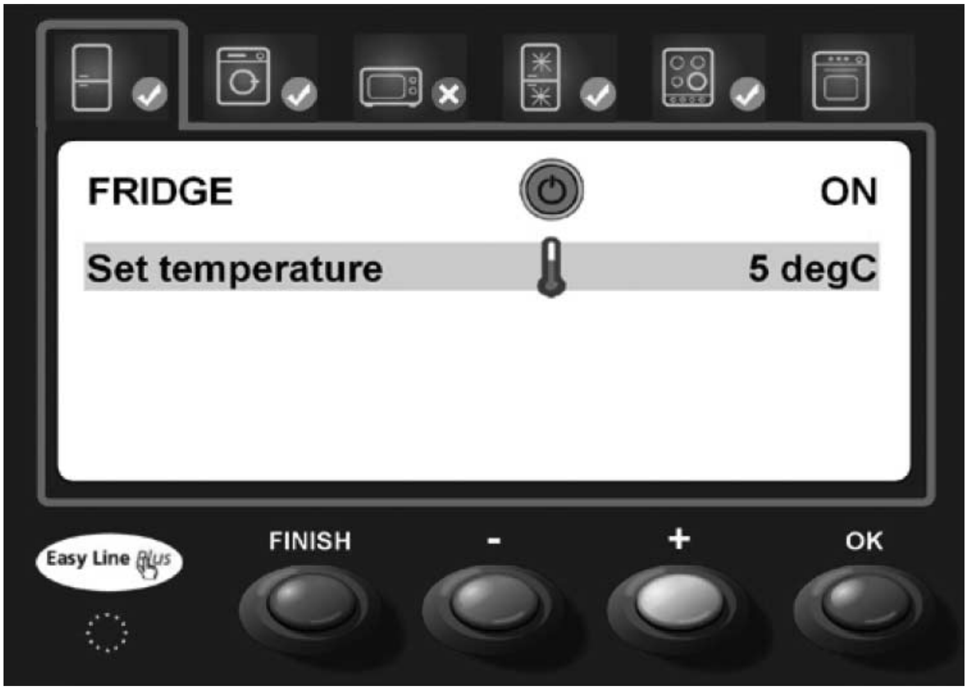

FIGURE 6. Prototype screen showing refrigerator settings control.

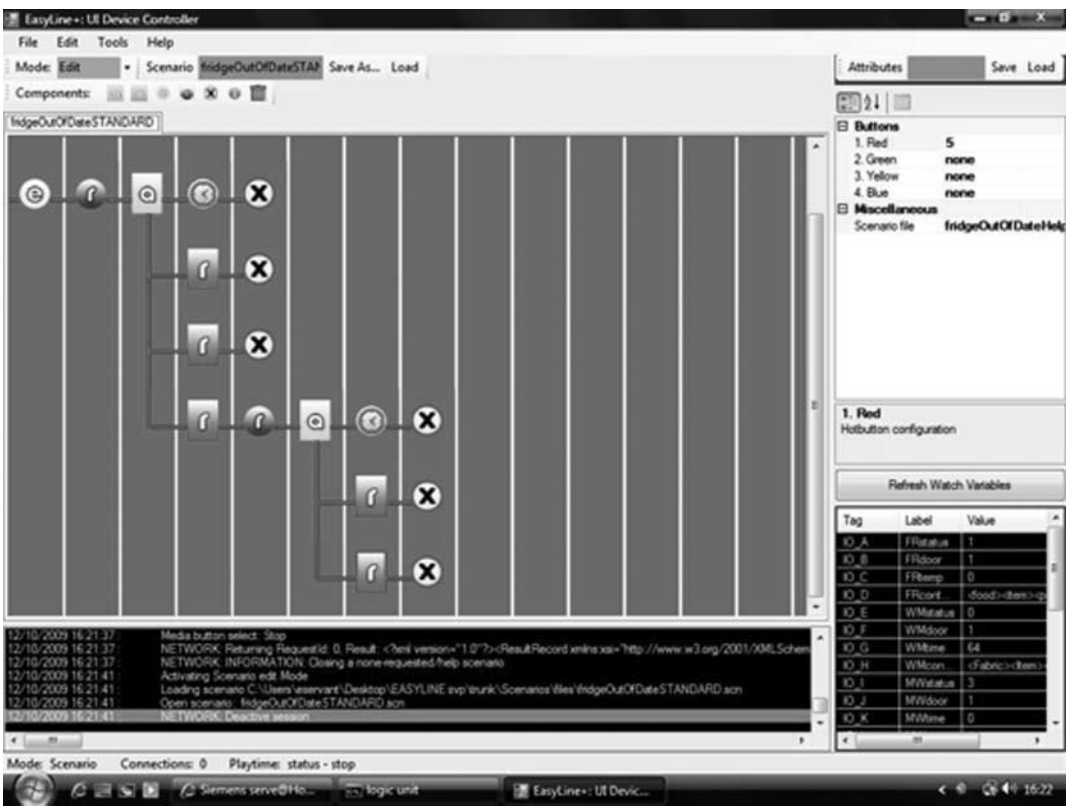

FIGURE 7. User interaction simulator.

the house. This area of the screen also serves as a tab to enable the user to step through the appliances to control them, or to review their status in more detail. The bottom part displays the four coloured buttons, and the middle part is the main frame where the content is updated dynamically to show information or give notifications and warnings to the user when events occur.

At this stage and in accordance with EDUCATID, a further ethical inspection was undertaken, specifically with a view to ensuring accessibility. For the visually impaired user profile, for example, all displayed messages and possible actions were now to be delivered in spoken form in the user's preferred language.

The interaction experience of the various user interface prototypes was tested during the *user interaction* activity. In EASYLINE PLUS, this was controlled through a user interaction simulator, designed and developed by the authors (Fig. 7). The simulator adhered strictly to an event-rule-action protocol, which was read from the XML representation of the interaction model.

In the context of the EASYLINE PLUS project, the simulator acted as a proxy for the e-servant. This facilitated the parallel development of external communication devices, such as user interfaces or appliances. The simulator enabled scenarios to be *played out* in real time, and where the various available communication media between the simulator and the external communication devices could be evaluated. An example scenario might be that the power to the refrigerator has been lost. In such a case, the e-servant sensed the problem, and the appropriate initiating event was triggered. Events were subsequently interpreted by a rule that determined the nature of the action that was to follow. The different types of event maintained a common set of attributes such that rules could be used to determine a following action. In all, there were six constructs that could be combined together in a hierarchy to represent an executable scenario: *start event*, *rule*, *action*, *timer*, *response* and *termination event* (Fig. 8).

The simulator communicated with external devices using an XML message protocol. The first message in a scenario was usually sent by the simulator to an external device. Subsequently, the simulator expected one of several responses back from the external device, such as an acknowledgement from a user interface or a change in status of an appliance. A time-out mechanism was provided to deal with the case where no response was obtained. There were two key message types used: *action messages* and *response messages*. Both these messages inherited the same common attributes.

This testing environment proved to be most useful in improving and refining the interface designs, the task sequences and analyses, and the robustness of the technologies used.

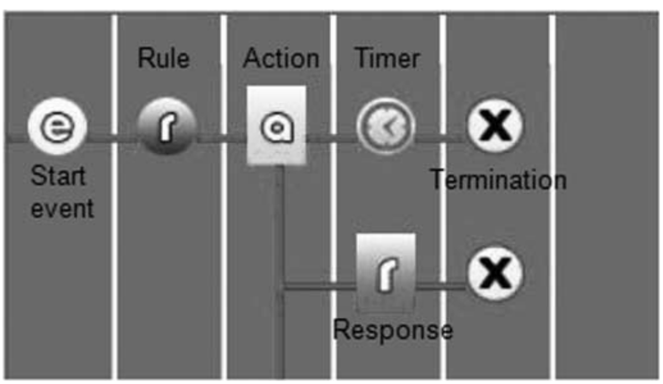

FIGURE 8. Simulator constructs.

7. EVALUATION

For the EASYLINE PLUS project, we conducted laboratory-based studies initially, and during the second iteration of the method, the system was installed in an elderly person's actual home environment. Although the employment of usability laboratories for elderly users has been criticized [29], we found that with sensitive consideration a usability lab does not have to be threatening or intimidating.

For our first instance of the evaluation phase—effectively the pilot testing, we furbished our laboratory in the style of a typical living room, using fixtures and fittings often found in an elderly person's accommodation, including the modified television set and a digital photo frame (Fig. 9).

In our usability testing, we are bound by our own strict codes of ethical conduct, and our use of EDUCATID reminded us to adhere to them (for example, non-maleficence, beneficence, confidentiality, informed consent, trust, honesty and integrity). Our approach at this stage was also mindful of making sure that participants felt supported as well as comfortable in this environment. Consequently, the test facilitator accompanied them wherever necessary during experimentation. We used Dickinson *et al.*'s recommendations of measuring tasks completed with no assistance, with minimal assistance and with significant researcher intervention [33]. We also considered it less intimidating if participants were tested in groups of two or three. Our participants were particularly pleased with this arrangement, especially where physical disabilities seriously restricted user interaction for some individuals.

The outcome of the first evaluation activity identified a number of potential usability issues, such as the loudness of audible warnings where people with varying profiles (for example, levels of deafness) shared the same user experience, the intrusiveness of the system (for example, potentially interrupting a television programme) and the size of the display, especially in the case of a photo frame. Generally, the participants welcomed the EASYLINE PLUS concept, and expressed that they would like to have such features installed in their homes. We have to be very mindful of such positivity however, as it is certainly well documented that elderly users feel valued in participating in usability studies, and are more

FIGURE 9. Usability laboratory showing an elderly and disabled participant interacting with the EASYLINE PLUS user interface (identities of participants have been protected through blurring of faces).

likely than other users to provide positive answers in debriefing sessions.

8. ITERATION OF THE METHOD

The results from the evaluation phase are used to revisit the original requirements, where the cycle of phases begins again. We consider it imperative at this stage that ethical and legal issues are re-considered and that a further workshop or focus group event is organized, and hence the user analysis phase is undertaken again. The central theme of this engagement is to present the interface developments and use them to consult with end users and other stakeholders regarding their original scenarios.

Our second workshop provided the 20 expert and service user participants with a presentation of the progress on the EASYLINE PLUS project, and invited contributions, suggestions and advice on improvements that could be made to the user interfaces. Providing users with more remote control of appliances, rather than of a subset of their features, was a popular suggestion, as it was felt that this would be more empowering for users, as well as ensuring a consistent user interface for all functions. This was an issue that was scrutinized and debated in our second ethical audit, which is described below.

For this exercise, the ethical triangle was again utilized. Unless there have been some relatively major new requirement changes since the first ethical inspection, it is unlikely that the *laws* and *regulations* factor will be important here. Now, the lower levels of *must*, *ought* and *should* take precedence, where the ethics may vary from situation to situation. For example, in the workshop, it was suggested that users *should* be able to control the oven hob remotely, supporting accessibility for physically disabled users. However, this could clearly lead to a potentially dangerous situation, if a hob is activated from another location. Consequently, it was agreed that a hob could be switched off but not on remotely.

While this may be an obvious requirement from a health and safety point of view, a more contentious example follows: the EASYLINE PLUS interface enables a user to control a washing machine remotely (switch on/switch off), but the washing programme is set automatically by RFID transmission via tags sewn into the clothing. Workshop participants expressed a preference to override the automatic setting and set their own programs remotely. This raised an interesting ethical dilemma and caused us to revisit our initial ethical guideline that the system *ought* to *avoid unnecessary automatic or external decisions by the system*. In our initial requirements, it was determined that it would be in fact necessary to automate the washing programmes, as so many users expressed difficulty with this task. It now became apparent that what might be necessary for some users would be unnecessary for others. Consequently, this guideline was moved from the *ought* to the *should* category, and its invocation would depend on the user's situation (for example, cognitive ability). This analysis at the level of *situated ethics* helped us to tune the profiling of users and their individual requirements.

With improved requirements, we then repeated the conceptual design phase, introducing new personas and scenarios where appropriate, and continued through to the interface design and build phase, where improvements to the original prototypes were made and consolidated.

This second iteration of the EDUCATID methodology involved further laboratory studies where necessary, for example where alternative design solutions required scrutiny, or where scenarios had alternative models to be evaluated. Subsequently, we undertook a more summative usability evaluation exercise, both to evaluate the EASYLINE PLUS interface and indirectly to evaluate the effectiveness of using the EDUCATID approach. We conducted between-groups laboratory-based usability studies with heterogeneous groups of users, including elderly and disabled users, people with learning difficulties, as well as 'healthy' adults. We were interested in evaluating the latter group for two reasons. First, it has been documented that elderly and vulnerable participants in usability studies may react differently than they normally would, for example by being over-positive due to their involvement in the study [34, 35]. Comparing their results with what might be termed a control group would potentially identify issues of this nature. Second, our earlier evaluations suggested that the product might be suitable for time-impoverished people (for example, stressed mothers with babies in the home), not just elderly and disabled people.

We selected a total of 27 participants for this evaluation exercise, comprising 9 elderly users, 9 with learning difficulties and 9 from the 'control' group. Fourteen participants were females, the other 13 being males. Of the elderly group, one was aged over 80, four in their 70s, one in her 60s and three in their late 50s. All participants in this group had a range of physical and sensory impairments relating to conditions associated with ageing. The learning group was recruited from an education college that specializes in teaching people with learning disabilities. All these participants were aged <50.

Each group was given a set of scenarios to follow (for example loading the refrigerator, baking food and doing laundry), which involved interaction with the kitchen appliances and the user interface, which for this study was provided on a television screen and a PDA. Participants' activities were recorded in the laboratory, and were subsequently analysed. They were also asked to complete a usability experience questionnaire comprising 20 semantically rated questions (Appendix A), which were categorized according to usability, design and layout, functionality, user satisfaction and expected future use. Each question also invited qualitative comments. A summary of the quantitative results is shown in Table 2.

The aggregated results for every category and for all groups clearly indicate a positive outcome for the usability experience questionnaire. All results were higher than the median value of 2. It can be seen in every category that the control group scored the highest, followed by the elderly group, with the learning difficulties group scoring the lowest in all cases, except in the 'future use' category, where the elderly group gave the most positive response. The higher scores given by the control group could be explained by this group's positive comments on the *potential* of the product, as opposed to its current benefits.

We also carried out an analysis of variance (ANOVA) of every question in the user experience questionnaire. This analysis revealed that there were no significant differences in the responses provided by the three groups ($F = 1.52$, $P < 0.05$), apart from one question that asked whether they felt embarrassment at using the system. The control group and the elderly group expressed no embarrassment at using the interface, whereas some members of the learning difficulties group were uncomfortable with it from this point of view. In particular, two participants were visibly startled when a notification alarm sounded, and this clearly affected their experience. This was evident by their written comments on the questionnaire as well as in the observational analysis. The observational analysis also revealed that all groups reacted quickly and positively to system-generated notifications. The control group performed expectedly better in general, and the only observed usability issues involved elderly users' difficulty with using a standard remote control handset and the small-screened PDA, both of which are easily rectified by selecting alternative input and output devices. The outcome of this study was generally positive, further corroborating the success of the EDUCATID process at this stage.

The aforementioned study took place in parallel with the initiation of an ongoing longitudinal study in the field (situated in an elderly person's apartment), where issues of accessibility,

TABLE 2. Mean results by questionnaire category (range is from low rating of 0 to high rating of 4).

	Overall average	Control average	Elderly average	Learning average
Usability	2.87	3.22	2.79	2.56
Design and layout	2.71	2.90	2.71	2.54
Functionality	2.67	2.89	2.74	2.44
User satisfaction	3.00	3.33	3.08	2.48
Future use	2.55	2.67	2.78	2.01

acceptability and adaptivity of the complete system are measured.

Finally, the third and last iteration of EDUCATID acts as a relatively short closure and review exercise, where the user interfaces can be verified, inspected from an ethical point of view and ultimately accepted by the end users and stakeholder groups.

9. DISCUSSION AND REFLECTION

Our journey through EASYLINE PLUS began with a recognition of the critical impact that ethics would have on a project of this nature. Consequently, we decided to place our ethical decision-making at the centre of our approach. Given the technical nature of the implementation of the system, this project falls into the socio-technical category, leading us to develop an approach starting with the social and ethical issues, and moving from an informal specification of the human–computer interaction through to a semi-formalized and executable interaction model, utilizing tools developed by the authors. We believe and have demonstrated that this approach is practical, understandable and ecologically valid.

Although EDUCATID was developed specifically for the case study presented here, it can be used in the design and development of any consumer-oriented application, such as home entertainment systems, interactive televisions, domestic applications and public domain kiosks. Consumer-oriented applications exhibit certain characteristics that conform to the EDUCATID philosophy. These characteristics are becoming much more prevalent in modern interactive computer systems. Their increasingly ubiquitous nature assures a wide-ranging user population. Consequently, ethical issues arise, as potentially vulnerable people may be exposed to their use, such as the elderly, the young and the disabled. Another characteristic, again associated with a wide-ranging user population, is that the interfaces for such computers need to be easy to use, intuitive, accessible and well structured. Their ubiquity also requires them to be more embedded and ambient, perhaps in familiar appliances in the home, or resident in everyday devices. With adaptation, we believe that the approach could be used in organizational, business and other contexts.

Recognition that ethical issues are critical for interactive systems projects of this nature is one important issue, but providing developers with practical ways of considering these (given that many developers may lack training in ethics) is another. Our demonstration of the ethical triangle and its combination with ethical guidelines offers a practical solution to this problem, and the EDUCATID approach of including ethical analysis at every stage in the development cycle can help reinforce this practice. We do not seek to replace ethical expertise, but we argue that, as most development teams do not possess such a quality, the tools presented here offer a practical alternative. Applying the ethical inspection tool was relatively simple. We developed a table of risk factors in the project and the stakeholders involved rated each one at the EDUCATID-defined ethical inspection points using the ethical triangle's five-point scale. An example of this is shown in Table 3.

In terms of the interfaces we have developed in the EASYLINE PLUS project, our adherence to ethical principles constrained our designs to a certain extent, but we regard this as a positive factor because our simple, intuitive interface designs have been accepted with confidence by our user population.

Our experience of using EDUCATID leads us to compare its effectiveness with other user-centred approaches such as ISO13407 [36], KESSU [37, 38] and LUCID [39]. These approaches have many similarities with EDUCATID in that they follow similar processes. However, they propose flexible

TABLE 3. Results of the ethical inspections at each ethical inspection checkpoint in the EDUCATID lifecycle (two iterations).

ENx = ethical checkpoint in EDUCATID at iteration N and stage x of the method. RFn = risk factors from requirements.	E1a	E1b	E1c	E1d	E2a	E2b	E2c	E2d
RF2 configure appliance								
Usability/accessibility	M	M	**O**	O	O	O	O	O
Freedom of control	O	O	O	O	O	O	O	O
Dangerous settings	L	L	L	L	L	L	L	L
RF3 give advice								
Causing alarm	~O	~O	~O	~**S**	~S	~S	~S	~**M**
Causing interruption	~S	**O**	O	O	O	O	O	**X**
Trust	M	M	M	M	M	M	M	M
RF5 affordability	M	M	S	**M**	M	M	**X**	X

Entries in the table conform to the ethical triangle attributes of laws (L), regulations (R), must (M), ought (O) and should (S). An X indicates conflict between stakeholders and a squiggle negates the attribute. Bold typeface indicates *ethical drift*, suggesting that an ethical issue requires further scrutiny.

frameworks or models upon which to build methodological processes and method selections, whereas EDUCATID provides specific analysis, design and development techniques that are distinctly integrated into the process (workshops, focus groups, use cases, task flow diagrams, personas, storyboards, scenarios, user models and the ethical triangle). While there is undoubtedly a need for flexible frameworks and models to enable individual projects to be tailored according to their differences, we argue that there is also a place for more rigid approaches like EDUCATID, which can be managed and applied practically, especially in situations where there may be a lack of usability expertise available.

The usability evaluation study reported in this paper, which indirectly evaluated the effectiveness of using the EDUCATID approach, suggests that this is a feasible methodology to use for user-centred projects, particularly where ethical issues are critical.

Grounded in prioritizing ethical issues, EDUCATID is the only method with specific and multiple ethical checkpoints in the project development cycle. The application of ethical principles is recognized to be fundamental to professionalism in the discipline of computing, as emphasized in the British Computer Society's Royal Charter, which is empowered to:

> [E]stablish and maintain a sound ethical foundation for the use of computers, data handling and information technology systems; and to adopt any lawful means conducive to the maintenance of a high standard of professional skill and conduct amongst members of the Society (British Computer Society Royal Charter 1984, amended 2003, para. 3(b)

Although the adherence to this *sound ethical foundation* does not specifically mention the development of computer systems here, we should infer that high standards and expectations should apply to any practice within the field of computing. EDUCATID provides such a framework.

Like other user-centred design approaches, utilizing EDUCATID requires effort to engage with the user population throughout. This involves forming relationships with user groups and associations, who need to commit to be involved on a number of occasions in the development process. Such an activity might be regarded by some as difficult, time-consuming and costly. We recognized this as an issue for the EASYLINE PLUS project, and incorporated the use of personas to help alleviate over-reliance on the engagement with user groups. For other projects, personas may be used to varying degrees without prejudice to the EDUCATID philosophy.

Finally, recognizing and applying ethical principles to the degree advocated by EDUCATID might be criticized for adding time, effort and even bureaucracy to a project's development. We argue that although some extra effort is required, as the tools and processes presented in this paper are practical, simple to follow and clearly defined, the EDUCATID methodology provides a powerful approach to developing user interfaces.

10. CONCLUSION

In this paper, we have presented a case study of how an ethically aware methodological approach can be used to develop user interfaces. We have found that although the application of ethical guidelines can constrain the designers' options, it can also lead to simpler and more intuitive solutions. The user interfaces we have designed are grounded in being familiar to the user population, a factor considered fundamental for universal usability [40].

Acceptance of technological innovations for elderly and vulnerable people is not only dependent on good design, but also need to be affordable too. It seems certain that the cost of technology will reduce in the forthcoming years, as computer literacy and novel device familiarity improves. Such trends will provide us with new opportunities, as well as new challenges. There will be further practical and ethical problems to overcome.

Predicting how elderly people's independence will be supported by technology is still not clear, although the level of investment into research in this area provides some indication of how important this issue has become. What is certain, however, is that the changing population distributions we are experiencing indicate that we have no choice but to find technological solutions to the problems of an ageing society.

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APPENDIX A: USABILITY EXPERIENCE QUESTIONNAIRE

Usability

1. Do you think the product was easy to use?

Very difficult	**Difficult**	**Normal**	**Easy**	**Very easy**

2. Do you think it was easy to learn how to use the product?

Very difficult	**Difficult**	**Normal**	**Easy**	**Very easy**

3. Do you think the product adapted to your particular needs and abilities?

Totally does not adapt	**Does not adapt**	**Adapts**	**Adapts well**	**Totally adapts**

4. How do you think the product reacts to the different input devices?

    a. Touch screen

Very bad	**Bad**	**Normal**	**Good**	**Very good**

    b. TV remote control

Very bad	**Bad**	**Normal**	**Good**	**Very good**

Design and Layout

5. Do you consider the product attractive?

Totally unattractive	**Very unattractive**	**Attractive**	**Very attractive**	**Totally attractive**

6. Was the screen easy to understand?

Very difficult	**Difficult**	**Normal**	**Easy**	**Very easy**

7. What do you think about the sounds of the product?

Very bad	**Bad**	**Normal**	**Good**	**Very good**

8. Do you think that the spoken notifications were comprehensible?

Totally incomprehensible	**Very incomprehensible**	**Comprehensible**	**Very comprehensible**	**Totally comprehensible**

9. Did you find the sound level adequate?

Totally inadequate	**Very inadequate**	**Adequate**	**Very adequate**	**Totally adequate**

10. In general, how does it look to you?

Very bad	**Bad**	**Normal**	**Good**	**Very good**

Functionality

11. In general, do you think the product is suitable to accomplish the purposes explained at the beginning of the test?

Totally unsuitable	**Very unsuitable**	**Suitable**	**Very suitable**	**Totally suitable**

12. Do you think the product could help you to carry out daily activities?

Totally unhelpful	**Very unhelpful**	**Helpful**	**Very helpful**	**Totally helpful**

13. Do you think the product could increase your quality of life?

Not at all	**Not much**	**Some**	**Very much**	**Totally**

14. Do you think you will could live more independently using this product?

Not at all	**Not much**	**Some**	**Very much**	**Totally**

Satisfaction

15. Were you comfortable using the product?

Totally uncomfortable	**Very uncomfortable**	**Comfortable**	**Very comfortable**	**Totally comfortable**

16. Did you feel embarrassed using the product?

Totally embarrassed	**Very embarrassed**	**Embarrassed**	**A bit embarrassed**	**Not embarrassed**

17. Overall, are you satisfied with the product?

Totally unsatisfied	**Very unsatisfied**	**Satisfied**	**Very satisfied**	**Totally satisfied**

Future use/outcome

18. Do you think you might become dependent on the product if you use it in the future?

Great dependence	**Much dependence**	**Some dependence**	**Little dependence**	**No dependence**

19. Do you consider that this product may isolate you from your actual social relationships?

Total isolation	**Much isolation**	**Some isolation**	**Little isolation**	**No isolation**

Finally, how would you improve the product?
