Journal of Ambient Intelligence and Smart Environments 7 (2015) 849–860
DOI 10.3233/AIS-150351
IOS Press

The design methodology for studying smart but complex do-it-yourself experiences

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Abstract. This article illustrates design-oriented human–computer interaction (HCI) research for creating do-it-yourself (DIY) experiences for emerging technologies. It contemplates the design objectives for the DIY construction processes through the lens of Ecological Approach to Smart Environments (EASE) and by exemplifying three case studies. The first case study introduces the design of the Home Control System of a nursing ecology for the aged. The second case study presents the Music Creation Tool research in music therapy ecology for those with disabilities, and the third study, Life Story Creation, presents a memory-sharing application for elderly amateur writers. The article carefully considers the role of users in HCI research, who in the DIY context are expected to be active and motivated crafters and builders of their personal environments. The focus of research, the user experience studies, aims at supporting creating, configuring and sharing experiences within the constructed prototypes, and at determining the new experiences that emerge from the research. The concluding objective for the article is presenting of a design framework for involving the initiative domain owners to the DIY research.

Keywords: Human–computer interaction (HCI), do-it-yourself (DIY), ecological approach to smart environments (EASE), user experience design (UX), intelligent environments (IE)

1. Introduction

This article presents the do-it-yourself (DIY) research of smart experiences through three case studies: Home Control System [23], Music Creation Tool [26] and Life Story Creation [22]. The empirical research for constructing the proof of concept prototypes has been explained in previous papers, and the themes for the DIY-construction in terms of the user expectations are briefly reflected in the article [19]. This article, however, considers in depth the design methodology for DIY IE: how to choose the participants; what methods to use and how to study experiences in the context of use.

Kuznetsov and Paulos define *do-it-yourself* as a culture that aspires to explore, experiment and understand by doing things by oneself [21]. The technology-mediated DIY culture, which this article contemplates, is part of wider phenomena that involve e.g. the maker movement, hacker communities, prosumerism and digital fabrication. All of them involve communities that are mainly ad-hoc groupings drawn together by shared interests. The common determinator is that, within the ecologies, people create and share their work without gatekeepers or geographic restrictions [14]. The research presented in this article highlights the role of amateurs – even people with no computational skills – who eventually deploy and benefit from the DIY technologies: the elderly and those with disabilities.

The roots for the technology-driven and networked DIY culture can be associated with the DIY movement starting from the late 1980s. The earliest experiments were related to music creation activities, when easy availability of computers and MIDI made the production and recording of music accessible, both in terms of the tools and of not needing to learn the specialized skills of playing an instrument [27]. More recently, the integration of social computing, online sharing tools, and other HCI collaboration technologies

has made it possible to adopt DIY cultures and practices more widely [9]. Thousands of DIY communities share or create their projects with technical and networked means; communities that focus on handicraft, everyday home improvement, guerrilla gardening, experimental music, citizen journalism, solving of social problems and amateur astronomy [14,21,24,31]. Such sites as YouTube, eBay, Facebook, Flickr, and Wikipedia have taught ordinary people how to contribute and collaborate online. Online DIY communities, such as Instructables, Dorkbot, Craftster, Ravelry, Etsy, Spoonflower, Crafster and Adafruit have encouraged single-subject enthusiasts to use computing in order to find the means for collaborating and sharing their work. Within these communities, users create and import their own content for others to share in the public virtual spaces of Web 2.0 and add value by commenting, recommending or tagging each other's content [29].

When it comes to the sharing mechanisms of the Web, it has been stated that we have now advanced from merely creating static web pages (www) and sharing them by social networking (Web 2.0) towards the ubiquitous computing Web 3.0 [15]. Depending on the context, the concept of Web 3.0 varies between understanding it as the semantic web, the web of things or the web of services. In this article, the emphasis is on the latter connotation.

Consequently, the research presented in this article focuses on the supporting of specific services targeted for nominated ecologies; the aim has been to develop customizable technologies for the aged and people with severe paralysis. The foremost objective has been the building of platforms for constructing incremental, intelligent user-driven experiences that may be shared in the envisioned Web 3.0.

2. Background to the DIY in IE research context

Callaghan et al. have presented some broad alternatives for defining the set up for research and development of IE systems [5]. At one end are the autonomous learning and self-adaptable services of the environment, and at the other, the self-configuring services with which people may intimately and explicitly be involved in the programming of collectives of devices that they may also have defined themselves. This latter approach has been nominated as the context for the research presented in this article, although, as Callaghan et al. have remarked, it is a more laborious alternative for the people using the systems. It has, however, one important advantage: people will have more control over their technology-mediated environments.

At present, there are many commercial single-board computers and microcontrollers that provide the means for the physical combining and configuration of sensors and devices; platforms such as Arduino, Raspberry Pi and mbed. On these platforms, it is possible even for layman DIY enthusiasts, with some computational knowledge, to aggregate sensors and smart devices; to design combined mash-up systems and make self-created smart experiences. The connection of multiple applications to create a larger application is achieved by (open-source) middleware, which is considered to be a fundamental tool for the design and implementation of smart environment applications shared over a network [13].

As regarding the technical design philosophy for the construction process of DIY IE, Newman et al. [28] have earlier proposed an approach called recombinant computing. This dictates that computing environments may be created from the bottom up – by creating individual entities to be part of an elastic, ever-changing whole. This philosophy also determines that these entities can be designed and introduced with a thought that they might be used in many different ways and under different circumstances. The pervasive interactive programming (PiP) technique proposed by Chin et al. [6] also puts the user at the centre of the system's programming experience by exchanging autonomous learning for explicit user-driven supervision. It offers non-technical users the possibility to configure and customize sets of coordinating pervasive devices without the need to employ conventional programming methods. Later, Chin et al. have also proposed a soft-appliance vision, which they have introduced for the purpose of an expedient DIY device ecosystem, but anticipated that there is a yet greater need to find a way of categorizing the social and technological relationships [7].

Bonino and Corno see the next step in IE research being achieved by driving the research with user needs [4]. Beckman et al. have anticipated that the end-user sensor installation mainly enhances users' sense of control, but the concept also offers several other advantages: it reduces costs, accommodates diverse deployment environments, and increases users' acceptance of the technology [3]. Cook et al. expect the approach to advocate a new focus for HCI: including the investigation of the mechanisms for sup-

porting and enriching human socialization and interaction, and orienting the research toward community and cultural enhancement [8]. Understanding people, their personal backgrounds, their different levels of computational thinking and their felt experiences is an important qualification for accepted and acknowledged DIY IE [30]. This article advocates research in which people are allowed to take control of their personal, smart surroundings, and at the same time to lower their barrier to technology-mediated DIY creation activities.

3. Objectives

The principal motivator for the presented research in the three exemplifying case studies was the idea that our environments will gradually turn intelligent. The contextual methodology for the design and research was chosen to be the Ecological Approach to Smart Environments (EASE) [18], in which the theoretical foundation can be found from the ecological psychology. The methodology introduces modes for product, remote and immediate design with an objective to design complex systems through divergent perspectives. Two modes of the EASE approach were identified as feasible for the construction of the specific intelligent DIY experiences: 1) remote design mode, for creating an ontology-based creation and configuration system, and 2) immediate design mode, for creating smart experiences and applications mediated by the Internet. According to Keinonen [20], remote design creates conceptual, infrastructure, methodological, regulatory, competence or resource-related foundations upon which others may develop products or local practices. Immediate design refers to a mode of design characterized by its responsiveness to users' immediate needs, intensive user participation, continuous incremental improvements, and the utilization of open do-it-yourself platforms (ibid.).

The remote design objective of the case studies was to build an underlying architecture that would be stable and compatible, yet flexible and anticipating. The immediate design objective was aimed at providing supporting DIY technologies that would be easily available, controllable and configurable. Another immediate design objective was to study the sharing mechanisms within the designated ecologies. The construction objectives of the EASE approach set the foundation also for the HCI studies. The first objective was to determine the specific ecologies, including the relevant social groups and the technological frame. Furthermore, it was not at all obvious how the communities should be approached: what were the suitable conventions and methods for engaging participants in research? The conventions employed were expected to deliver the design implications for technical prototypes, but an equally important objective was to study what meaningful experiences the technologies provoked. The eventual HCI objective was to define a methodological framework for designing DIY IE service concepts.

3.1. Doing design research together with users

When constructing the proof-of-concept prototypes, the appropriate concern for HCI research was to consider the human ecologies that formed around the technologies. Users of the technologies were expected to show initiative, be active, and share the responsibility for developing their own, personal intelligent environments. The literature review provided evidence of "Pro-Am users" who seemed to be the most interesting group of practitioners suitable for closer investigation. Leadbeater and Miller have described Pro-Am users to be disruptive innovators in the DIY context that introduce marginal and experimental projects to markets [24].

The expertise, however, did not seem to be enough to embrace the complete role of users in the DIY ecology context. Another criterion was the users' level of involvement. For the case studies, the most interesting characteristics related to the involvement properties that were found in 'local' and 'warm' experts. Stewart has coined the term 'local experts' to be used for people "who sustain informal networks and help other individuals and groups adapt and cope with new ICTs" [35]. According to Stewart, local experts act as bridges or channels, transferring knowledge and examples of use and equipment between particular social settings. He uses the term 'local' meaning not only geographically local, but also local in terms of communication and interaction in physical space and via communications technologies. Bakardjieva has introduced 'warm experts' to refer to people who are technical experts sympathetic to those who need help and support with ICTs, and who possess understanding both of the people they are helping and of the technologies [2]. Consequently, the first objective for the case studies was to study these user characteristics in the communities, and then define the supportive technical ecologies.

3.2. Defining the relevant DIY IE experiences

Over the years, there has been broad discussion concerning user experience (UX) as a key focus to be addressed in the design and development of emerging technologies [16]. Also, the EASE approach suggests that the focus of ecological research should be on experience design. The experience design investigations of the case studies leaned on the experience-centred design approach, which have been proposed by Wright, Wallace and McCarthy to emphasize the power of dialogue and co-production in the UX design context [36].

The relevant DIY-related experiences were studied by first taking a brief overlook of the broader literature, and then pursuing the experience design approach by defining some broad categories of description for the experiences that emerged within the design-oriented research setup. Consequently, the case studies focused on the particular experiences of creating, configuring and sharing. The experience design studies concluded in defining the emerging, new user experiences generated by the introduced technologies.

4. Overview of the case studies

4.1. Home Control System for an intelligent nursing ecology

The remote design research of the Home Control System was aimed at supporting elderly people in living more independently at home and in an intelligent nursing home [23]. The technical system was a proof-of-concept prototype that included a tool enabling the combination of networked objects of the environment (see Fig. 1). The focus was on controlling the illumination of the environment, the front door lock control, long-term follow-up of the activities (with possible notifications and alarms to an external system), and the use of spoken dialogue interaction to control parts of the system. The project was built on earlier research that acknowledged how the devices were placed within an environment, how the combinations of these devices were managed practically, and how these devices worked together [6,17,28,34].

The first focus group co-design session with Pro-Am users – a group of nurses – was arranged in December 2010, and the second session in May 2011. The nurses were selected as co-design partners based on the early evaluations, according to which the elderly occupants, the end-users, would have had anxieties regarding the technologies introduced. The nurses provided care at the Villa Jussoila nursing home (in Rauma, Finland), as well as care for outpatients. The participants were aged 28–42, one (1) male and three (3) females in both evaluation sessions; two (2) of the participants attended both sessions. The participants were considered to be ideal co-design partners because of their domain knowledge and computational expertise: all the nurses were accustomed to the Wiktio W10 home care system, which was the existing IE technology platform at the Villa Jussoila nursing home at that time. The co-design sessions were arranged in the nursing home facilities. The final usability evaluation was carried out in early 2012; these consisted of nine (9) persons, four (4) males and five (5) females, aged 22–56. Three (3) of them were caretakers of the elderly or people with disabilities, and the rest were considered more as the relatives of end-users. The prototype tool was validated by usability studies in a demo room at VTT Technical Research Centre, Tampere, Finland.

Fig. 1. Home Control System concept.

4.2. Music Creation Tool for those with disabilities

The first research set up for the immediate design was identified from the music therapy environment for people with mild or moderate (Diagnosis ICD-10) intellectual learning disabilities [26]. The aim of the prototype was to allow these people to play music in a therapy context, with the long-term objective of creating an environment for sharing their creative work. The Music Creation Tool consisted of software and smart adjustable instruments, for which the inspiration came from the early digital DIY movement (from the late 1980s). The co-design sessions were carried out by the music therapist who fine-tuned the instruments and selected the musical templates for end-users with disabilities.

Fig. 2. Video observations of the Music Creation Tool.

The Music Creation Tool was evaluated in three phases. The first contextual studies provided material for defining a suitable research framework. When the initial version of the prototype was ready, it was evaluated in a care home for the disabled at the Rinnekoti Foundation, Espoo, Finland. The evaluations were carried out in August 2010. The participants were the music therapist and his customers, aged 26–58, one (1) female and five (5) males. All of the interviewees knew each other beforehand and were accustomed to participating in music therapy sessions. The last evaluation phase was held between October and November 2010, at the same location; this time there were four (4) participants attending the sessions, aged 21–58; all males. The video observation period lasted for 1.5 weeks, in which time the music therapist was responsible for the music therapy context and recording of the sessions (see Fig. 2).

4.3. Life Story Creation service for seniors

The second research set up for the immediate design was the Life Story Creation case study that developed an easy DIY system for elderly people to create their personal retrospections [22]. The aim was to support meaningful activities that the elderly said they preferred in the early user studies, and to study technical means to support the tasks. The final prototype was a Web 2.0 service application that focused on content creation, and especially, the sharing of work (see Fig. 3). The HCI studies focused on the experience factors, and aimed at discovering design implications for constructing the sharing mechanism.

The initial user studies were carried out in September 2010 at an institution for senior citizens in Kuopio, Finland. The focus groups consisted of fifteen (15) persons; six (6) males and nine (9) females, with an average age of 70. The participants were seniors living independently, most of whom had rich leisure activities.

Fig. 3. Life Story Creation application.

One group was composed of casual writers, and three of expert writers. All the interviewees were familiar with information technology, using mobile phones and computers on a daily or weekly basis. Many of them were also acquainted with social media. The second user study for the Life Story Creation was carried out in November 2010 in Tampere, Finland, at a time when an raw version of the prototype was available. The participants were aged 55–69; four (4) females and one (1) male. All were senior citizens – four (4) retired and one (1) self-employed – and all were writers in the same activity group. Each of them was familiar with information technology; they used mobile phones and computers on a daily basis. Most were acquainted in some way with Web 2.0, by using e.g. Facebook, genealogy- and chat applications.

5. Methods and practices

Abowd and Mynatt were among the first to notice the task-centric evaluation techniques inadequate for studying ubiquitous computing [1]. Leonard-Barton (1995) has specified that, in technology research, the traditional elicitation methods are more adequate when both the technological possibilities and users are well known, but their adequacy decreases when less is known about either the technology to be used or who is to use it [25]. Apparently, this is the case when constructing DIY technologies that should be flexible and configurable by a divergent set of users. In such cases, Leonard suggests employing more “emphatic” qualitative and design-oriented methods, as these construct more appropriate information. Forlizzi and Battarbee have advocated design-oriented methods for designing interactive systems, especially when it is critical to understand the social and collaborative aspects of interaction and the user experience [11].

Consequently, the methods for studying the DIY ecologies were chosen to favour design-oriented and co-design approaches (see Table 1). The methods

Table 1
Methods used in chronological order

Method	Case study
Early elicitation methods	
Shadowing	1, 3
Contextual inquiry	2, 3
Design probes	2
Semi-structured acceptance interviews	3
Complementary design-oriented methods	
Scenario evaluation	1
Visualizations	3
Benchmarked applications	1
Interviews	1, 2, 3
Video observations	2
Co-design methods	
Focus groups	1, 3
Sketching	1
Paper prototypes	1
Explorations in sonic interaction	2
Walking interviews	1
Methods for analysing the results	
Usability studies	1
Interaction analysis lab	2
Subjective assessment	3

Note: In the case study column, each project is described by numbers: Home Control System = 1, Music Creation Tool = 2 and Life Story Creation = 3

were supplemented with ethnography and user-centred methods. The co-design processes for facilitating the user research of DIY ecologies fell under the methodological frame of participatory design, which generally aims at democratizing design so that the people to be affected by the systems should also be able to participate and influence the design process [32].

The objective for defining the practices and methods was to come up with appropriate method sets that would be suitable for studying technology-mediated DIY concepts at large, by assessing their value for the specific ecology studies. In Table 1, the methods used are arranged in four categories: early elicitation methods, complementary design-oriented methods, co-design methods and methods for analysing the results.

6. Main findings

The main contribution of the HCI research was to provide design implications for the constructing of the proof-of-concept prototypes developed by a multidisciplinary research team. Those prototypes are explained in detail in articles [22,23,26]. This article, however, limits itself to three key HCI objectives. The first contribution is the definition of specific social ecologies and the characteristics of participants in the design-oriented research setup. The second contribution is the study of DIY experiences in the emerging technology context that focused particularly on the creating, configuring and sharing experiences, and the definition of new experiences that arose when DIY technologies were introduced to the social ecologies. The third contribution is the design framework that may be employed for constructing DIY IE, particularly when the focus of HCI research is on experience design.

6.1. *Ecologies and characteristics of the participants in co-design phases*

The EASE approach has highlighted the importance of describing human ecologies with the development setup. The descriptions of human ecologies in the case studies are presented in Figs 4–6; they illustrate the relationship between participants and designer/facilitator.

The Home Control System research engaged nurses in the co-design process and end-users in the final evaluation of the system. All the nurses were considered to be Pro-Am users according to their level of computational thinking, but only one of them was considered to be a local, warm expert mediating the computational expertise within the ecology. All the participants in this ecology worked closely with the designer in the co-design phases (see Fig. 4).

The music therapist was the nominated co-design partner in the Music Creation Tool ecology: a domain professional, a Pro-Am in computational thinking, and a local, warm expert. The therapist worked closely

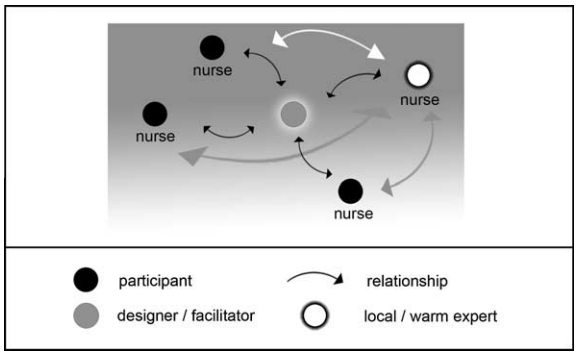

Fig. 4. Home Control System co-design ecology.

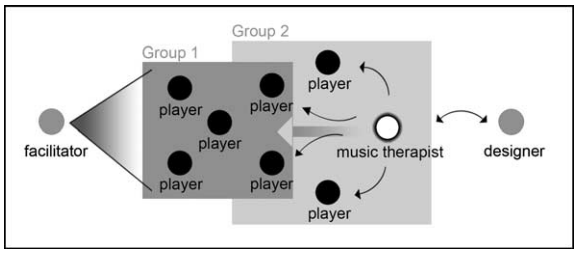

Fig. 5. Music Creation Tool co-design ecology.

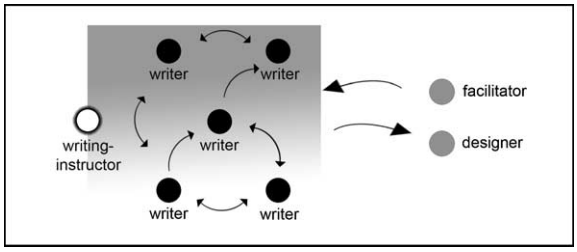

Fig. 6. Life Story Creation co-design ecology.

with the designer on constructing the tool; otherwise, the novice end-users were studied through observations (see Fig. 5).

In the Life Story Creation ecology, the teacher of the writing group was considered to be the local, warm Pro-Am expert of the group; however, it turned out that the design of the system benefited more from the involvement properties relating to the willingness to create and community orientation, which the amateur writers possessed. The amateur writers were in this way selected as the most suitable co-design partners instead of the Pro-Am expert (see Fig. 6). It should be noted that, in this case, the immediate design requirements also necessitated the designer to work in close cooperation with the ecology participants.

6.2. The DIY IE experiences

At the core of the do-it-yourself culture is the creativity, craftsmanship and the community orientation. From this perspective, the most important experiences for the experience design studies were nominated to be the creating, configuring and sharing experiences, in addition to the emerging new user experiences. As the experience studies also contributed to the design of the prototypes, it was important to associate the experiences with the context of use. In practice, the experience studies were carried out by evaluating the configurations and technologies in the context of use, and eliciting findings that related to the defined experiences.

Table 2
Categorization of the experiences

DIY-related experience	Create & configure	Share
Delight in making things by oneself	2	
Pleasure of everyday creativity	2,3	
Reward of the process	3	3
Sense of togetherness	2,3	3
Enjoyment at being noticed and recognised	2	2,3
Pleasure in feedback and support	2,3	2
Sense of inspiration	3	
Self-esteem	2	2,3
Arousing emotional experiences in others	1,2	
Experience relating to the feeling of control:		
Flexibility of the system	1,2	1
Customization possibilities	1,3	
Personification possibilities	1,2,3	1
Local control	1,3	1,3
Being able to complete a job more effectively	1,3	2,3

Note: In the right-hand column, each project is described by numbers: Home Control System = 1, Music Creation Tool = 2 and Life Story Creation = 3

Table 2 contains broad categories of description for the initiative experiences that were confirmed in research (in the left). The experiences were established upon the broad DIY-related background literature [14,21,24,31]. The feeling of control was considered to be the critical IE-related experience that should be supported by the technologies (the experiences relating to feel of control appear as the last six experiences in the table), introduced e.g. in [3,5,10]. The right of the table contains an assessment of whether the experience was associated with the creating and configuring experience or with the sharing experience.

Shedroff has proposed that, after gaining an understanding of the well-intentioned experiences, the next task is to describe the work on translating these into the desired media [33]. The following is a description of the efforts in designing for the nominated experiences; the desired media in the research setup is roughly interpreted as DIY IE technologies.

6.2.1. The creating and configuring experiences

The principal creating and configuring experiences of the Home Control System related to the device and component connectivity – what kind of setups the users wanted to create and combine from the components provided in the nursing ecology, and what they expected to be ready-made. These experiences were studied according to the type of connections the par-

ticipants made in the paper prototyping sessions; more specifically, what setups they made for the inhabitants. For example, the nurses created setups that could be associated with the feeling of control – simple configurations to support the inhabitants who could not move from their beds. One of the most influential results of the studies was the utmost limit of the DIY system to which nurses determined that they, or their patients, would create and configure the components. It was clearly stated that the more challenging configurations were expected to be made by someone – the local, warm expert was mentioned explicitly – for the benefit of the community. This finding highlighted the role of experts in the ecology, and also the gradual DIY flexibility that was expected from the technical system. From the prototype, the participants required specific, ready-made templates for the constructing activities – often described as an activity: first duplicating and then modifying – in order to create setups within the system's tool. These requirements defined the limitations of flexibility of the proof-of-concept prototype.

The Music Creation Tool needed to be flexible and provide options according to the various skill levels of the players with disabilities. The nominated experiences were pursued by observing the players, and by interviewing the music therapist who carried out all the creating and configuring activities of the tool on behalf of the end-users. The built-in software components helped the music therapist to create the "premade music experiences" that in turn gave pleasure to the players. Encouraged by the observations, the development team continued supporting this experience. Because the Music Creation Tool also included tangible instruments, one of the key objectives was to observe how the end-users interacted with the modifiable instruments in the therapy situation. When observing the experiences relating to the creation and configuring activities, the concentration was on their motoric skills. The observations revealed that the group would have required even more adaptable instruments: more flexibility and alternatives for the physical components that would have provided enhanced affordances and supported the different skill levels of the players.

The Life Story Creation application was founded upon templates that the expert amateurs assisted in creating and defining. The templates contained stages that guided the creation process. Within the community, the creation and configuring activities seemed to be an important clue in connecting the community together and assisting in making the service valued. The experience design investigations were pursued by providing different modes for the creation tasks within the service that would support the differences in purpose. Transfer of these experiences to the application requirements revealed that there should have been even more alternatives for the configuring tasks within the templates.

6.2.2. The sharing experience

Although the architecture in the Home Control system was created to support the sharing of the configured scenes, in the prototyping reality they could not be shared with another entity. The sharing experiences were thus limited to supporting the setups users created by themselves. During the evaluation sessions, the nurses speculated that they would have required different sharing mechanisms for nurses, patients and relatives. When it came to translating these finding into the proof-of-concept prototype, the development team faced difficulties. As it was too laborious to implement the requirements into the prototype, in the end the prototype consisted of one UI that tried to satisfy various experience-related needs.

In the Music Creation Tool, the sharing experience was closely merged with the music therapist's task as a mediator in the music therapy context. The music therapist was the only one doing any type of sharing; the observations confirmed that the players did not even share the experience of playing together. However, the observed players seemed to have a subjective enjoyment of the new experiences that were aroused by the tool. When translating these experiences into the technical system, the iteratively constructed prototype appeared to provide sufficient means. The final aim, however, had been to share the musical experiences through social media. The observed music therapy sessions demonstrated that the participants were highly dependent on the well-timed instructions of the therapist, but the sharing of music would have necessitated even more efforts from the warm expert.

Of the three case studies, Life Story Creation was the one in which users shared most of their work during the evaluations. The life-story writers provided instructions and comments for each other, or read the life stories of the other writers. They stated that at the core of the sharing experience was the fact that people wanted to help each other and to construct the ecology around their mutual interest. Concerning the translation of the experiences into the desired technical system, the case study demonstrated how the supportive ecology should be built into the application from the very beginning by providing opportunities for sharing. The participants were critical of the mode provided for

sharing within the application; there should have been alternatives for sharing the content more intimately, and at the other end, for offering the full publication process so that the work could be shared with a wider audience. Furthermore, the participants wanted to extend the sharing network to other domains. They provided a considerable amount of substance for what the other domains should be, for instance a genealogy service, a recipe store, a former classmates archive, various traceable events of relatives and friends, organisational activities, other peer groups, and information about specific places.

6.2.3. New emerging experiences

In addition to the elicited and confirmed DIY-related experiences, the design-oriented research brought about two sets of new experiences. These findings are not necessarily unique, in the sense that the phenomena around most of them have been issued within the intelligent environment research before. The relevance of the formulated new experiences is, however, that they are based on the evidence of the user studies.

The first set of new experiences related to the physical and digital realms of the ecologies and the piecemeal construction of DIY IE. The second set of experiences recognised the need for defining a conclusive experience when considering the technological ecology layer. It is acknowledged that the two sets of experiences are in some sense contradictory. The first set of new experiences related to:

- The physical and digital co-existence of the "things" in the environment
- The flexibility in the component modularisation
- The need in experiencing digital "things" with analogue disguise

The second set of experiences related to:

- Understanding the digital ecology as a conclusive experience
- Experiencing the ecology through the affordances or the "smart thing" functionalities
- Contentment of the substituting interaction options

The experience of the physical and digital co-existence of the "things" in the environment was met during the early prototyping in the Home Control System evaluations. In this case, the nurses expressed a particular concern about how the existing analogue devices and new smart devices cooperated in the environment. There was consideration, for example, of how the configurable switches could be differentiated from the "normal" light switches. Considerations of the co-existence of physical and digital things in the environment have been found to be a crucial problem when designing for evolutional construction environments. For the design, the experience of the physical and digital co-existence of "things" thus suggests that attention in the short term should be paid to the interconnecting point of the digital and physical realms. The experiences relating to the dual existence of functioning and non-functioning smart objects will need to be attended to for quite some time ahead.

The experience of the flexibility of the component modularisation in the DIY context may be associated with the modularised embedded computer devices that require only fine-tuning, versus the recombining of individual smaller-scale components that require much more effort in the connection phase. However, the latter may provide more possibilities for personification. During the early research for the Music Creation Tool, there were several attempts to provide users with the possibility of combining and integrating singular sensors attached to the musical devices. At the other end, there were the ready-made smart devices – game controllers, gamepads, joysticks and motion-controlled consoles such as Wii, Guitar Hero and Blobo – that were configured and fine-tuned. The ready-made smart devices were confirmed as being more suitable for the particular research setup, although, in general, the integration of singular sensors and modularised components are expected to be at the core of DIY systems. Also emerging from the Music Creation Tool evaluations was the need for experiencing digital "things" with analogue disguise. In the case study, the physical combining and configuration of sensors and devices allowed the shape of an instrument to have many different forms; yet surprisingly, in such cases it seemed to matter even more that the artefact appeared familiar and the affordances were recognisable and intuitive. This experience was observed to be extremely important for the particular user group; their preference for the guitar-like appearances of the instruments was in fact confirmed in all evaluation phases.

The conclusive experience of the digital ecology has been one of the long-term research paradigms in intelligent environment research. The experience counters with the aim of reducing the cognitive burden of learning by shrinking the conceptual distance between the actions in the real world and what is programmed in the virtual world [10]. The issues related to the question of how to make visible, tangible and

perceivable the affordances that the physical environment provides, and preferably turn them into a map of affordances. The crossing point of the physical and digital realms has usually been concretized by the user interface (UI), which offers the interaction possibilities between human, computer and the environment. The interface provides the representation for the user to understand the available components and configurations i.e. experiencing the ecology through the affordances or the "smart thing" functionalities. In the Home Control System, the device-centric solution was accomplished through taking a snapshot of the environment by physically selecting all the environment's active devices. Each snapshot could then be activated and deactivated from the UI. In the Home Control System evaluations, the participants speculated on how the inhabitant could remember the particular triggers of the environment; which controller performed a preconfigured task, and what tasks were related to specific things in the environment. It seemed extremely difficult, however, to address the reduction in the cognitive burden completely by using one, all-inclusive UI. The research led to the belief that the conclusive experience should somehow be affordable in the physical environment.

In the Life Story Creation case, the multimodality of interactions was considered through the possibility of using spoken language dialogue as an alternative interaction method for typewriting. In the Home Control System, the participants were also provided with an alternative of bypassing the UI by using spoken language dialogue if the required setups were very simple. Overall, the experience has been labelled here as the contentment of substituting interaction options. It should be expected that the new interaction techniques, relating to the multimodal systems and haptic interfaces, apparently also cultivate new forms of experiences. These techniques have been studied widely within the HCI field, and the studies have demonstrated that, when introduced to physical environments, they may provide an unlimited source of inspection material for the experience design studies.

6.3. Framework for co-creating DIY service concepts

The method set selected for the case studies aimed at answering the question: what is the design strategy for the construction of DIY IE? What follows is the concluding framework that is the final HCI outcome of the user studies. The framework consists of a pre-co-design phase, a co-design phase (preferably involving the Pro-Am users) and a post-co-design phase. These were confirmed to be necessary in the ecological design of DIY IE by the case studies presented.

Pre-co-design phase

- Ethnographic research or contextual inquiry; preliminary ecology studies for determining the context of use
- Determination of the community members and different levels of users; their identity, characteristics and position in the ecologies
- Collation of information on the specific context e.g. by means of benchmarking applications or semi-structured acceptance interviews
- Meaningful specification of the information, including the construction of stories and scenarios
- Definition of the DIY IE concept
- Definition of the relevant experiences for the context, e.g. by means of a literary review
- Definition of the key stakeholders to work with in the co-design phase

Co-design phase involving Pro-Am users

- Presentation of the information:
  - The DIY IE concept definition
  - Predefined scenarios and visualizations
  - Benchmarked applications
  - Co-evaluation of their relevance for the participants
- Co-designing the conceptual models of the service, e.g. by sketching conceptual descriptions, or by using paper prototypes
- Compilation and sharing of new information and interpretation of the results (iterative process)
- Redefinition of the DIY concept
- Co-design of a specific system/service with a more specific objective

Post-co-design phase

- Definition of the criteria for analysing the findings and providing of interpretation
- Analyse the process: redefine what makes a good experience

In the case studies presented in this article, the early phase ecology studies, and the co-creation of concept, with the contribution of all the participants, assisted in defining the technological ecosystems and important criteria for the services. The sets of tasks in the framework determine the tasks for the HCI facilitators, but also, at a more general level, define the new role of co-design partners in design-oriented IE.

7. Conclusions

Leadbeater and Miller have listed a set of global reasons why research should focus on active DIY communities: the longer life span of the population, growing levels of education, the spread of social mobility as people develop distinctive lifestyles, changes in occupational patterns (the need to develop a second career) and consumers spending on leisure and services [24]. They go as far as to predict that Pro-Am communities will be the new R&D labs of the digital economy, but argue that it is the task of the public service institutions to equip users with tools and education for doing-things-by-themselves as well as providing safe spaces and environments in which they can network and learn. The research presented in this article contributed to this call by supporting the participation of those unlikely to be the first in joining DIY construction processes: elderly and those with disabilities.

The contribution of this article was to determine the ecology construction for the do-it-yourself intelligent environments by presenting three exemplifying case studies employing remote and immediate design strategies of the EASE approach. In this article, the design-oriented research has been described as the core methodology for engaging users in the construction process. The studies carefully defined the characteristics of users and illustrated Pro-Am experts, with local and warm orientation, as important co-design partners in research – but equally important inside the communities sharing their expertise and advice.

In an experience design research setup, the defining of human ecologies was of critical importance, because the collaboration with (and between) users exposed the experiences relating to creating, configuring and sharing. Based on a literary review, these experiences were defined as critical aspects during the DIY development processes, and they were confirmed as predominant, with varying importance depending on the case. Another important result of the study was the six new discovered DIY experiences. They were related to the physical and digital realms of the ecologies, the piecemeal construction of DIY and the need to define a conclusive experience when considering the technological ecology layer. The most intriguing aspect of these was the way each of them implied of new design challenges.

The limitations of the case studies are acknowledged as follows. The new knowledge of the article is based on the local understanding of certain studies that describe particular ecologies, and thus cannot be applied uncritically to other cases. The studies focused on particular community samples and concentrated on the nominated design-oriented approach. Also, the users in all the case studies were expected to invest considerable effort in understanding, co-designing and using the technologies within a limited time. A longitudinal study might have better verified how the DIY technologies would have been adapted, used and, particularly, how they would have evolved within the ecologies.

The greatest value of the remote and immediate design studies was the way they helped to build the proof-of-concept prototypes and identify future design opportunities. In future work, the information gained from the case studies will be implemented in the research of smart objects and products. Fortino et al. [12], for example, have proposed a promising approach for the development of smart objects and smart objects applications based on agents. This, however, necessitates that the set up for research moves towards the other alternative for the development of IE systems presented by Callaghan et al. [5]: the autonomous learning and self-adaptable services.

Acknowledgements

The case studies were carried out as part of the Eureka/ITEA2 DiYSE project in cooperation between Technological Research Centre of Finland (VTT), There Corporation, Wiktio Oy, Finwe Ltd., Geniem Oy, Rinnekoti Foundation, Tampere University and Laurea University of Applied Sciences. Special acknowledgments to Johan Plomp, Hanna Lammi, Matti Luhtala, and Janne Laitinen for their contribution to the empirical HCI work.

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