Designing for older adults: adaptable interface as an approach to address diversity in older users' capabilities

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Abstract: This study started with the aim to develop an approach that will help designers create interfaces that are more intuitive for older adults to use. Two objectives were set for this study: 1) to identify and investigate one of the possible strategies for developing intuitive interfaces for older people; and 2) to identify and investigate factors that could interfere with intuitive use. This paper briefly presents the outcome of the two experiments and how it has lead to the development of an adaptable interface design model that will help designers develop interfaces that are intuitive to learn and, over time, intuitive to use for users with diverse technology prior experience and cognitive abilities.

Key words: Interaction design, intuitive use, inclusive design method, stress, older adults, cognitive abilities, and prior experience

1. Introduction

A significant section of the older population (65+ years) has difficulties in using modern consumer products that have complex interfaces and extensive functionalities. Inability to use modern technologies such as computers, mobile devices, the Internet, and ever increasing self-care medical devices puts the older population at a disadvantage in terms of their ability to live and function independently [15].

In addition, increasing life expectancy and a decline in fertility rate have resulted in changes in world demographics over the past two decades. It is estimated that by the year 2050, over 22% of World's population will be aged 60 and above [16]. This trend will also see a proportionate increase in the number of older people in the workforce [33]. Shrinking care resources will likely see older adults working beyond their normal retirement age in most of the developed world [22].

Coupled with this change in demographics, past decades have seen a substantial increase in the use of technology in all aspects of daily living. The gradual shift from hardware-based to microprocessor controlled software-based products has brought a higher level of abstraction into interaction with products [17, 25]. Older generations, who grew up with relatively older technological paradigms, have been left behind. This has resulted in a digital divide between young and old [39, 60]. Although the use of technologies such as computers and the Internet is increasing among older people, an age-based digital divide still exists [15]. Primary aim of this research was to bridge this divide by helping designers develop products that are more accessible for older population. This research hypothesised that designing technological products that are more intuitive for older people to use can solve this problem. An intuitive interface requires minimal learning as it mostly relies on prior experience of the users for effective interaction [6, 25].

2. Background

2.1 Intuitive use

In the context of interaction design, Blackler [7] and Hurtienne [27], based on their extensive literature review of the nature of intuition, suggest that - Intuitive use of product interfaces involves unconscious use of user's prior-knowledge related to the product in use. In other words, the user is familiar (based on their earlier encounter with similar products) with different features and functions of the product [10, 27]. Intuitive use of an interface can be recognised by the following characteristics [7]: It is fast and effortless, it is generally non-conscious and does not involve conscious reasoning or analysis and it is based on relevant past experiences

2.2 Prior experience and ageing

Prior exposure and competence with related technologies are essential for intuitive use of interfaces [7, 10, 27, 38, 43]. One of the important reasons for older people finding contemporary interfaces difficult to use is their low domain-specific prior knowledge [26, 46]. Moreover, prior knowledge of technology is a lot more variable in older people when compared with younger people. There are many reasons behind older people being deficient in prior knowledge and more varied in their capabilities. For example, age-related cognitive degradation [34, 39], low perceived self-efficacy [4, 15] and cohort effects [17, 39].

As people age, they tend to specialise in an area of their choice. Their other interests also tend to become more focused. Each individual has different needs, professions and interests, and this brings about the variability in older people [52] . Older people are also slow in adopting new technologies, as they do not see a need to keep up with technology for the sake of doing so. However, where they see a need, they do embrace the technology without reservations [15]. Finally, age-related cognitive decline slows down acquisition of new knowledge [3]. The awareness of this limitation probably also compels older people to be more selective in determining what they should learn.

These and other related factors results in two issues regarding domain-specific prior knowledge in older people: 1) the variability in their knowledge and 2) not in pace with contemporary technology. The other side of the story is that lack of prior knowledge could lead to low perceived technology self-efficacy, which in turn has the potential for causing technology anxiety. Both low domain-specific prior knowledge and technology anxiety can impede intuitive and successful use of complex contemporary technological products. Difficulties in using technological products in turn feed and amplify their already low perceived technology self-efficacy. Low technology self-efficacy discourages adoption or use of new technological products, resulting in low domain-specific prior knowledge. Thus, this is a vicious, self-perpetuating loop. However, on a positive note, older people are aware of these limitations and are not averse to embracing new technology when they see a need for it [15].

This study has addressed these issues by conducting two experiments, Experiment 1, systematically investigated redundancy (the use of both text and icons) in interface design as one of the strategies that could bridge the variability in older people's capabilities, and help them use complex technological devices intuitively and, Experiment 2, investigated the relationships between technology prior experience, self-efficacy, technology anxiety, complexity of interface (nested versus flat) and intuitive use in older people. Overall 137 participants between ages 18 to 83 years had participated in this study.

2.3 Research approach

There is a steady increase in research that is also focused on understanding how to design for older people. However, most of the research available focuses on ageing as a variable in understanding patterns of technology usage, preferences and difficulties [51]. What is more necessary is research that explains why the age differences occur. For this reason, it is essential to investigate mediating factors such as cognitive abilities and experience [51]. Addressing this need, this study was specifically designed to investigate age differences from the perspectives of both chronological age and cognitive abilities. The outcomes of this study are summarised in Sections 3.

3. Summary of findings

The outcomes of two experiments conducted for this study have highlighted that older age groups, when compared with younger age groups, are very diverse in their capabilities in terms of technology prior experience and cognitive functioning.

In brief, Experiment 1 investigated redundancy (use of both descriptive text and icons) in interface design as a strategy for intuitive use by older people [48, 49]. The outcome was surprisingly different from what was initially hypothesised. Findings suggested that a simple text-based interface was much more helpful for older people than a redundant interface. One of the reasons emerged was that this could be due to age related degradation in visual information processing, as both symbols-based and redundant interfaces are visually more complex to process compared to text-based interface. Not only did older people use the text-based interface more intuitively they also made fewer errors compared with their use of the redundant interface. This implies that they are able to learn the functions of the text-based interface on the task. This was a highly significant finding as it challenges most of the reviewed literature which suggested that redundancy in interface would be beneficial for older people and people with low domain-specific prior knowledge. Results and in-depth discussion of Experiment 1 are published as two papers [48, 49].

Experiment 2 primarily investigated the relationship between age, technology prior experience, complexity in interface structure (nested versus flat) and the impact of this relationship on intuitive use of contemporary technological products [50]. As expected, older people took less time to complete the task on the interface that used a flat structure when compared to the interface that used a complex nested structure. All age groups also used the flat interface more intuitively compared with the nested interface. Interestingly, older participants did not make significantly more errors compared with younger age groups on either interface structures. Overall, the findings suggest that when the tasks are designed with consideration of the cognitive limitations of older people, the age differences are minimal for most age groups, except for the oldest age group (73+), who were significantly slower and used the interfaces less intuitively; however, they did not make more errors. Results and in-depth discussion of Experiment 2 is published as a book chapter [50].

From a cognitive processing perspective, both experiments revealed that central executive function had the most impact on time to complete the task, intuitive uses and errors. Central executive function is one of the memory systems that are affected by the process of ageing. Central executive is also involved in learning and the retrieving of knowledge from long-term memory. Both the experiments showed that some older people, although reported high domain-specific prior knowledge, did not do well on the task because they scored low on

cognitive measures. In summary, both these experiments have shown that the use of contemporary technological products is mediated by both domain-specific prior knowledge and cognitive abilities.

4. Facilitating intuitive use for older users

When it comes to implementing approaches suggested by Blackler [7] and Hurtienne [27] to designing intuitive interfaces for older people, designers face two major problems. First, because of the complexity of their functions, designing of contemporary technological products require use of prior knowledge from higher sources on continuum of knowledge sources [8, 24]. Knowledge from higher sources on the continuum is not commonly shared in the population [24]. In addition, older people are a very heterogeneous group in terms of both prior knowledge and cognitive capabilities. Therefore, for designers to find common knowledge of this target group before developing intuitive product interfaces could be a very complex and extremely resource-intensive exercise in terms of both time and money.

Second, there are some models that postulated a structure of prior knowledge and a process of decision making that suggest how prior knowledge could be applied in reaching a goal [7, 26, 31, 47]. However, little has been determined about how to elicit prior knowledge from the target users. Although there are some suggested tools to investigate users' exposure and competence with technology, they only inform us of what and how much users know. As this study and other related studies [35, 46] have shown, these measures may not be enough. There were occasions where older participants reported high prior knowledge but scored low on cognitive tasks, and did not do well on the task times. On the other hand, there were occasions when participants scored low on technology prior experience and high on cognitive tasks, and did well on task times.

This finding suggests that it is also important to know, apart from their technology exposure and competence, how the target users make use of prior knowledge under different circumstances and situations. A person might have the required knowledge about a device but, for various reasons, may not be able to retrieve it when required. In summary, the data from this study and relevant literature suggests that, in practice, it might be difficult to develop product interfaces that are entirely intuitive to use for a group of people with diverse capabilities.

On the other hand, it was also observed in this study that many older participants used controls on the interface non-intuitively/correctly on the first encounter but started using the same controls intuitively during subsequent encounters. Some of these correct uses were based on the trial and error process and others were through logical reasoning. In general, younger participants who scored high on technology prior experience tend to learn the controls faster or learn intuitively based on the related experiences or reasoning.

Moreover, as Experiment 2 has shown, when the interface was designed to accommodate limitations of the older users there were very few age differences observed in the number of errors made. Similarly, in Experiment 1 there were no significant differences between age groups, in terms of errors, on the text-based interface. In other words, older people could learn the interface on task when it was designed according to their limitations. This finding is also supported by other related research that shows that a text-based interface aids learning of an interface without external help [11, 63]. Keeping these findings in perspective, it might be prudent to aim for developing interfaces that are intuitive to learn rather than intuitive to use. An intuitive-to-learn interface has potential to counter the variability in prior knowledge and cognitive abilities over time and, eventually, to make the interface intuitive to use. An intuitively learnable interface in this context can be defined as 'an interface that

allows a person to intuitively apply various strategies to learn and to successfully use a unique interface during first and early encounter'.

In summary, existing methods for developing intuitive interfaces are not effective when target users have varied cognitive and technological abilities. The data from this study and related literature suggests that effective use of a product is based on prior knowledge and learning on the task, mediated by cognitive abilities. These findings suggest, therefore, that it would be more practical if product interfaces were built for intuitive learning rather than intuitive use.

5. Designing and design methods

Blackler, Popovic [9] reported that designers found their proposed conceptual tool for designing for intuitive use difficult to use and overly prescriptive. As this current study also involves developing an approach for designing interfaces that are intuitive to learn and use, this section briefly reviews the relevant literature that looks at the reasons why existing tools/methods are not adequate in meeting current requirements. Moreover, it is important to note that a basic understanding of design activity and how designers work contributes to making useful suggestions for the strategies or tools that can help designers to develop intuitive interfaces for older adults.

6. Design methods

Over time, a large number of design methods or models have been published and are usually grouped under the term 'design methods' [14]. It seems that there are as many design methods as there have been authors and no two authors have agreed on a method [20]. Some models are descriptive, simply describing the sequence of steps in designing, and some are prescriptive, suggesting systematic processes to follow.

The intention of design methods is to bring an amount of control in to the increasingly complex design and manufacturing process of products, to help in making sure that there are no costly mistakes due to oversight or omissions [14, 29]. However, many designers do not apply design methods because at times they are too formal, rigid and systematic [14]. There is a good reason behind this mistrust: design methods do not work [20]. A comment made by Alexander [1], in an interview on design methods, succinctly captures this point of view: '…my feeling about methodology is that there are certain mundane problems which it has solved – and I mean really incredibly mundane' [1]. Furthermore, Alexander [1] comments on future directions in design methodology, stating that: 'Until those people who talk about design methods are actually engaged in the problem of creating buildings and actually trying to create buildings, I wouldn't give a penny for their efforts' [1]. These and similar observations made on design methods have shifted the focus from prescriptive models of design to a greater consideration of design as a cognitive activity [59].

6.1 Cognitive process of designers

Designerly ways of 'knowing' and communicating differ from scientific approaches [2]. In an interesting study, Lawson [36] compared the way scientists and designers find solutions to a problem. He found that scientists use a strategy where they systematically analyse a problem to find an optimal solution. In contrast, designers tend to explore the problem cursorily, and proceed to suggest a variety of solutions, and settle for one that is most

satisfactory. In other words, scientists use problem-focused strategies and designers use solution-focused strategies [14].

Many cognitive studies on design observe that reuse of knowledge (from earlier relevant design experiences) through analogical reasoning is a central approach in design [5, 12, 58, 59]. Klein & Brezovic [32], in their research on the design process, found that designers seldom use systematic decision making strategies during practice. Visser [59] extends this notion by stating that design activity is mostly opportunistically organised. In other words, designers approach a design problem in a non-systematic and multi-directional way (could be top-down, bottom-up, in breadth or in depth). The direction they take is based on their subject knowledge, information at hand, their representation of design problems and the state of their design in progress.

Experienced designers solve design problems primarily based on their past experiences (i.e. intuitively). During the initial stage of a design process, they try to find earlier solutions that are similar to the present problem, proceed to fine-tune them and see if they could help them in their present situation. A study by Kim & Yoon [30] on the cognitive process of interface designers found that designers base initial design concepts on their prior experience, reusing elements from earlier designs that are relevant to the current task. They adopt opportunistic or bi-directional design processes when addressing issues in design problems that closely match their prior knowledge. Visser [57, 58] suggests that this opportunistic design process is a result of designers cognitively selecting the most economical actions in solving design problems. She also suggests that when an activity is opportunistically organised, any system/method that imposes a hierarchical or structured design process will severely constrain the designer [57].

7. Strategies for design for older people

Most of the prescriptive design methods are not able to meet their intended objectives because designers seldom use systematic decision-making strategies during practice [32, 59]. In other words, suggesting any rigid external structure or rules may not produce the desired design outcome. In view of this observation it was decided to present a possible approach that would allow interested designers to contextualise the findings of this study with their own requirements, methods and cognitive process.

7.1 Intuitively learnable interfaces as an approach to designing for older people

The findings from this research suggest that, for a first time encounter with a product interface cognitive ability and domain-specific prior knowledge are important factors that will decide the effectiveness of its intuitive use. This research and related literature also show that, for novice users and users with low prior experience and age-related cognitive decline, use of a simple text-based interface with flat interface structures would be beneficial. Text-based interfaces are easier to learn without external help for older people, and for people with low prior knowledge and cognitive abilities.

However, text-based interfaces offer minimal spatial cues for visual search [13]. This could be a problem for older people, as age-related decline in visual information processing reduces their ability to search in a cluttered visual environment [19, 22, 23]. In contrast, symbols offer strong visual and spatial cues and it is much easier to learn them and to remember their location in the interface structure. Most of the research supports the view that a symbols-only interface is more efficient once users have learnt the system [11, 13, 41, 53, 54, 64]. On the other

hand, Experiment 1 showed that older people found the symbols-based interface most difficult to use. Camacho et al. [11] attribute this to inherent ambiguity in the interpretations of symbols.

Widenbeck [63] noticed that, on a redundant interface, people learnt the meaning of symbols through their textual labels. Redundancy in the context of information communications is also often suggested for minimising the ambiguity of symbols and for aiding their comprehension and learning [61, 62]. Keeping this in mind, it might be better that once the functions of the interface are learnt on the text-based interface, it could progressively be switched to redundant interface to help with learning the meaning of the associated symbols; finally, the interface could move to a symbols-only based interface for the most effective use of the interface.

Similarly, although a flat interface structure is good for making information more accessible, too many options tend to clutter the screen, resulting in more strain on the limited spatial ability of older people. Here again, it might be better to structure the options into a simple nested interface once the user learns all the functions of the system thereby reducing the visual clutter [42].

In practice, these findings strongly support universal/inclusive design paradigms, such as the multi-layered interface design proposed by Shneiderman [55], and ordinary and extra-ordinary interaction developed by Newell [44]. The multi-layered interface paradigm proposes that interfaces should have different layers of complexity based on the capabilities of target users. The basic idea behind a multi-layered interface is that a person can select the interface level based on their current ability and move up the levels as they acquire more experience with the system. One of the advantages of a multi-layered interface is its flexibility to adapt to multiple user categories with varied prior knowledge and cognitive abilities. Most importantly, it allows users to develop their own learning curve based on their current abilities [40].

This process also supports Newell's design paradigm, which suggests that products be designed for older people first and then extended to use for other age groups. The basic idea is that, if a product is designed to accommodate (for example) people with low vision, it not only helps people with low vision but also people with normal vision in a low visibility condition. A very good example is given in Newell's [45] publication: an automobile that was designed specifically for older people with low mobility later went on to become best selling car in the United Kingdom.

Until recently, implementation of the multi-layered design paradigm was difficult as most consumer products had physical controls, and these are very difficult to customise to the abilities of the user. However, recent trends show that more and more products are using touch-screen interfaces with minimal or no physical controls. Therefore, it would now be an appropriate time to embrace a multi-layered interface design paradigm. Moreover, Experiment 2 also showed that older people are comfortable with touch-based devices and a simple multi-layered interface structure. Recent research also suggests that, regardless of their cognitive or physical deficiencies, older people find touch-based products easier to learn and use [21, 28, 56].

7.2 Adaptable interface model for intuitively learnable interfaces

There is some research that compares different implementations of multi-layered interfaces: static, adaptive, adaptable and mixed-initiative. A static interface is one that does not change; adaptive interface change is controlled by the system; adaptable interface change is controlled by the user; and a mixed-initiative interface is a mix of adaptive and adaptable [18].

Findlater and McGrenere [18] found significant support for adaptable interfaces from a general population sample. They also reported that, although static interface was most effective, when participants were guided by example, there was no significant difference between static and adaptable interfaces. In a related and much more recent study, a multi-layered interface paradigm was tested on small screen device with older participants [37]. The outcome of this study [37] suggests that older people benefited most from an adaptable interface. On the negative side, it was also observed that their performance was affected when the interface was changed from reduced-functionality to full-functionality. However, this change did not affect the learning of the full-functionality interface. Overall, Leung, Findlater [37] report that a multi-layered interface had benefitted older participants more than the younger participants in terms of learning and time to complete the task.

Based on the literature and the outcome of this research, a multi-layered interface model is proposed for designing and developing intuitively learnable interfaces (Figure 1). Although the proposed model illustrated in Figure 1 shows only three layers, in practice, the number of layers can be varied depending on the complexity of the interface being designed.

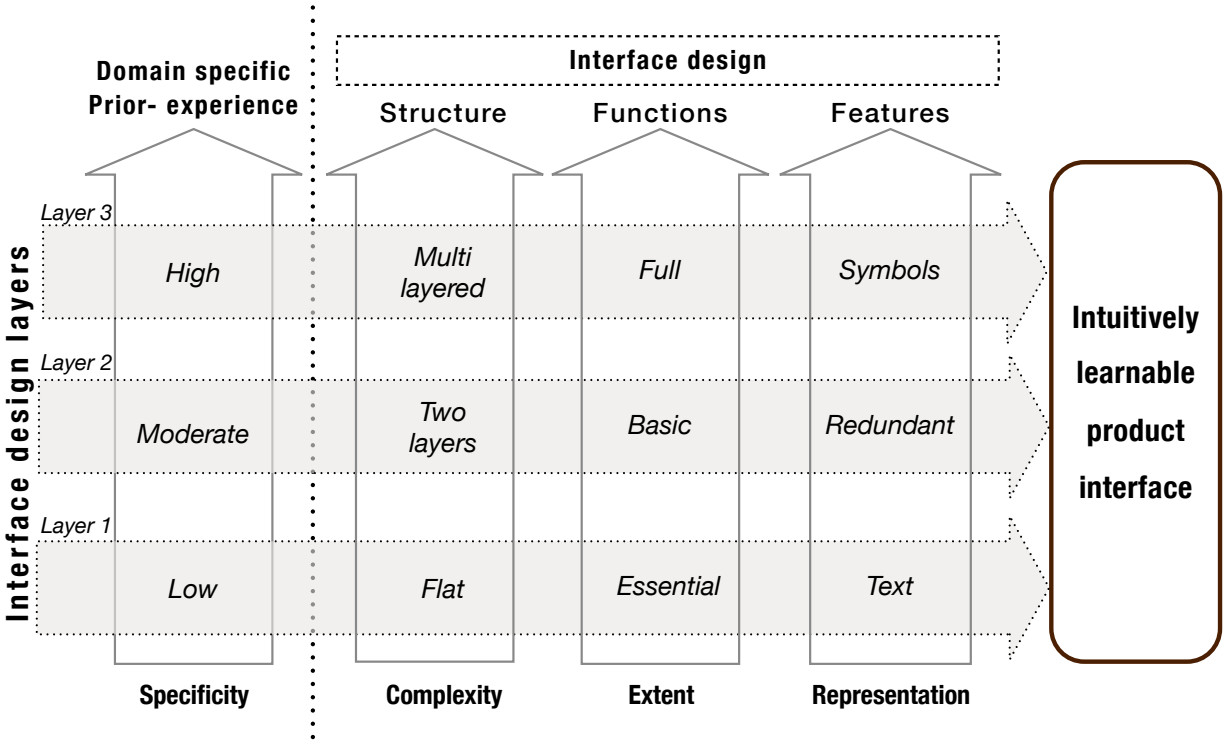


Figure 1: Adaptable interface model for intuitively learnable interface

The core idea of the model is to illustrate how levels of domain-specific prior experience are related to the levels of complexity of the interface structure, functions and features. A person with low specific technology exposure and competence will find a flat interface structure with essential functionality and text-based representation most beneficial for intuitive learning. On the other hand, a person with high specific technology exposure and competence may find a multi-layered structure with full functionality and symbols-only representation more efficient to intuitively learn and use.

In terms of implementation, a platform that allows direct manipulation or touch-based interaction is essential for allowing smooth transitions between the interface levels. The interface should be designed with flexibility to

vary the complexity of structure from flat to nested, of functions from essential to full access, and of features from textual representation to symbols-based representation.

Designers could face some limitations when implementing this model. As Leung et al. [37] note, a sudden change from partial to fully functional systems might require substantial learning. To avoid such problems, transition between the interface levels should be planned so that it requires minimal learning. However, this issue needs further research to investigate different methods for changing interface levels in small increments. Whether the actual multi-layered interface implementation is adaptive, adaptable or mixed-initiative also needs further investigation to see how older people will cope with each.

8. Conclusion

This study was started with an aim to propose strategies to develop interfaces that appear more intuitive for older people to use. In general, the findings of this study show that older age groups are more heterogeneous in their capabilities than younger people and that their intuitive use of contemporary technological devices is mediated more by domain-specific technology prior knowledge and cognitive abilities than chronological age. This highlights the fact that the development of entirely intuitive-to-use product interfaces is extremely difficult mostly due to diversity of older people's prior knowledge and cognitive abilities. Indeed, this finding is of enormous importance to the interface design field as it implies that most of the existing design methods for developing intuitive interfaces may be ineffective for older users.

The findings of the study do show, however, that when interfaces are developed with consideration for the cognitive limitations and prior experience of older people, using simple text-based interface helps older people to learn and, over time, to use complex technological products more intuitively. This finding, combined with other related research, leads to the proposal of an adaptable interface design model for intuitive learning as the most optimal strategy for developing complex technological product interfaces for older people.

An adaptable interface allows older users and users with low domain-specific prior knowledge to use a simple text-based, flat-structured interface to help them learn and successfully use the new product interface during early encounter, and over time, the interface can progressively be changed to a symbols-based, nested interface for more efficient use. In other words, this model will help in designing products that are intuitive to learn and which, over time, are intuitive to use for older people with varied abilities.

An enormous advantage of an adaptable interface model is that it removes the necessity for developing products specifically for older people. In effect, this provides an economy of scale to the development of new products. Indeed, most of the current generation touch-based products can be reprogrammed to suit the needs of a wide range of ages and user capabilities. Above all, what is most significant and encouraging for the field, and people in general, is that this model has the tremendous potential to finally bridge the digital divide between older and younger generations.

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