Redundancy in interface design and its impact on intuitive use of a product in older users

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Abstract: Many older adults have difficulty using modern consumer products due to their complexity both in terms of functionality and interface design. It has been observed that older people also have more problems learning new systems. It was hypothesised that designing technological products that are more intuitive for older people to use can solve this problem. An intuitive interface allows a user’s to employ prior knowledge, thus minimizing the learning needed for effective interaction. This paper discusses an experiment investigating the effectiveness of redundancy in interface design. The primary objective of this experiment was to find out if using more than one modality for a product’s interface improves the speed and intuitiveness of interactions for older adults. Preliminary analysis showed strong correlation between technology familiarity and time on tasks, but redundancy in interface design improved speed and accuracy of use only for participants with moderate to high technology familiarity.

Key words: Intuitive use, ageing, usability, cognition, interface design, design

1. Introduction
Recent decades have seen a substantial increase in the use of technology in all aspects of our lives. The gradual shift from hardware-based to microprocessor controlled software-based products has brought a higher level of abstraction into interaction with products [1,2]. Members of older generations who grew up with older technological paradigms have been left behind [3]. Furthermore, age-related decline in both cognitive skills and sensory and physical abilities is also one of the contributing factors. Older adults are also less likely to use complex devices intuitively and are slower when compared to younger people [4,5]. Although this realisation has led to research on understanding the use of technology in the aged population, not much attention has been paid to interaction design that would help older users in exploiting these new technologies [6].

This research proposes 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 [1,7]. This paper discusses the results of an experiment investigating the effectiveness of redundancy in designing interfaces that are intuitive to use for both older people and people with low prior experience with related technology.
2. Intuitive interaction
At the time of this writing there are two groups of researchers, Blackler [7,8] and Hurtienne [1], working on intuitive interaction and both have defined the basic nature of intuitive interaction. In terms of definition, both the research teams agree that intuitive interaction is based on the past experiences of users and they use this experiential knowledge unconsciously [9]. Intuitive use of an interface can be recognised by the following characteristics:
(1) It is fast and effortless
(2) It is generally non-conscious and does not involve conscious reasoning or analysis and
(3) It is based on relevant past experiences.

2.1 Designing for older adults
Many older adults have difficulties in using modern consumer products due to their complexity both in terms of functionality and interface design. According to Docampo Rama [10] at least three factors contribute to this difficulty:
(1) complexity of user interface,
(2) age-related changes in cognitive abilities, and
(3) generation-related differences in experience with technology.

However, a more recent study, on using technological products effectively, did not find any significant generation-related differences in older people [11]. On the other hand, studies confirm that decline in cognitive functioning affects the speed and accuracy of using complex technological products [5].

It is generally agreed that old age causes a decline in cognitive skills, which in turn affects learning of new information. Not all skills are affected with aging, for example crystallised intelligence (like vocabulary) remains constant or improves over age. Fluid intelligence (such as problem-solving, learning, and pattern recognition abilities), on the other hand, declines markedly [12]. Moreover, research points out that this decline is not global and varies from individual to individual. Recent studies on ageing and intuitive use of technological products concluded that older people are an extremely diverse group and that familiarity and specific cognitive abilities (central executive function) are more relevant to fast and effective use of products than chronological age [5,13]. The Central executive is an active component of the Working Memory system. It is a limited capacity system used for tasks that involve decision making, directing attention to relevant information, suppressing irrelevant information and allocating cognitive resources when performing more than one task simultaneously [14]. Central executive function deteriorates with age and the effect of this decline becomes more pronounced as the complexity of the cognitive tasks increases, such as when a task requires simultaneous storage and processing of information [12].

2.2 Older adults and prior experience
The way people handle current technology could be based on the kind of technology they were exposed to during their formative years (10-25 years) [15]. People can be identified as belonging to certain “technological generation” based on kind of consumer products technology they were exposed to in their formative years [2].
Czaja [16] suggest that a group of people belonging to a certain technological generation will find it hard to use devices from newer generations mostly because they lack prior experience with related technology.

Prior experience with technology is a strong predictor of performance on a variety of computer-based tasks [17], such that the more experience a user has with related technology the faster they will learn to use newer ones [5]. Recent empirical research on prior experience and usability of products found that interactions that exploit user’s prior-knowledge are significantly faster and are less prone to errors [5,13,18]. Furthermore, technology familiarity (prior-knowledge) is also an important factor in intuitive use of an interface for older people [13]. On the other hand, ageing causes, albeit at varying levels, decline in fluid intelligence, which in turn slows down the acquisition of new knowledge. This could be one of the reasons why older adults find it difficult to use new technological products intuitively [8].

3. Redundancy and intuitive use

Some studies discovered that older users have difficulty assessing the functionality of interfaces that use graphics extensively [19]. It is also observed that graphics based interfaces can increase extraneous cognitive load and can have adverse impacts on learning their functionality [20,21]. It is suggested that using descriptive language to define functionality of a button could help in using an interface intuitively [19]. Recent research also shows that older people tend to perform better with words than symbols [8]. This research also suggests that redundancy in interfaces might help older and users with low prior experience. Redundancy refers to repetition of content in different format. The repetition has to be in alternative physical form, for example, voice and text or picture and text [22]. Further more, redundancy of graphics and words is most beneficial to accommodate individual differences in cognitive abilities [23].

There is a considerable amount of research in the field of educational technology that suggests the use of multimodal representation to reduce the cognitive load for the learner. Cognitive Load Theory [24] is one such outcome that is used extensively to inform the design of product’s user interfaces. This theory focuses on efficient use of available cognitive processing ability for learning. Cognitive load can be described as the amount of working memory resources used at any point during the learning process. Sweller [25] suggests that if information is presented in two modalities, for example audio and visual, demand on working memory is reduced. Research also indicated that more working memory is available when dual modalities are used [26]. Some interaction design research also suggests that redundant textual description that restates what is shown in a diagram is very beneficial for novices or learners with no prior knowledge. However, redundancy is detrimental to users with high prior knowledge [27]. Sweller [25] terms this as the redundancy effect, which states that if one form of information representation is intelligible by itself, repeating it in another form will increase cognitive processing load. For example, graphical interface with redundant textual (Figure 1) is helpful for novice users to learn the function of this function, however, for expert users both forms of representation are intelligible, hence redundancy effect.

![Figure 1: Graphical representation of start function](image)

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Gould and Schaefer [19] suggest that exploiting redundancy in interface design could help in making products more intuitive for people with degraded cognitive ability and people with low prior experience. However, there is no data available that supports their suggestion. On the other hand, some studies suggest that redundancy in interfaces can have negative consequences for advanced or expert users [27]. In summary, although some research indicates importance of redundancy in interface design there is no data available that informs us on the impact of redundancy on intuitive use of a product. This experiment was designed to investigate if redundancy in an interface has any impact on intuitive use, especially in older people.

4. Experiment design

This experiment was designed to investigate whether the lack of necessary knowledge in older adults to interact with the current generation technological devices [2] can be mitigated by employing redundancy in interface. The research questions for this experiment were:

1. Does redundancy help in using a product intuitively by novice (low/no prior experience) or users with age-related cognitive degradation?
2. Is redundancy in interface design detrimental for expert users?
3. What are the differences, in terms of time on task, between age groups?

The design of the experiment was based on studies investigating intuitive use conducted previously [8]. This experiment is a cross-sectional, between-groups matched-subject design. Participants for this experiment were recruited from different sources to maintain a good sample of the general population. Individuals from various organisations (like, sports clubs, educational institutes, recreational facilities and retirement resorts) were approached to ask if they could volunteer to take part in this study. Overall 60 participants, 15 per age group, participated in this study (Table 1).

4.2 Variables, methods and measurement tools

The Dependent variables for this experiment were time to complete tasks and the number of intuitive correct uses. This paper discusses the variable, time to complete task, only. The Independent variables and their levels are listed in Table 1. Selection bias was controlled by matching participants in each level of both independent variables. Furthermore, to minimise effects of extraneous variables participants were carefully matched for gender, level of education, Technology Familiarity.

Table 1: Independent variables and their levels

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Levels of Independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interface design</td>
<td>Words only interface (uni mode)</td>
</tr>
<tr>
<td></td>
<td>Symbols only interface (uni mode)</td>
</tr>
<tr>
<td></td>
<td>Words plus symbols interface (redundant)</td>
</tr>
<tr>
<td>Age</td>
<td>Young (17 to 39 years)</td>
</tr>
<tr>
<td></td>
<td>Older young (40 to 59 years)</td>
</tr>
<tr>
<td></td>
<td>Younger old (60 to 74 years)</td>
</tr>
<tr>
<td></td>
<td>Older old (75+ years)</td>
</tr>
</tbody>
</table>
In addition, following variable were measured to provide potentially useful ancillary data (Table 2).

Table 2: Ancillary measures

<table>
<thead>
<tr>
<th>Issues controlled</th>
<th>Instrument used</th>
<th>Impact on independent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Technology predisposition</td>
<td>Questionnaire</td>
<td>People with high technology self-efficacy are less anxious when interacting with complex technological devices.</td>
</tr>
<tr>
<td>Lifestyle</td>
<td>Questionnaire</td>
<td>Pursuing challenging activities, learning new things. Research shows that a person who is mentally active by maintaining a challenging life style shows less age-related cognitive decline.</td>
</tr>
<tr>
<td>Vision</td>
<td>Snellen reading chart</td>
<td>Visual acuity</td>
</tr>
</tbody>
</table>

4.1 Apparatus and measures
This experiment uses a commercially available body fat analyser as a test product. This device was selected after carefully reviewing other over-the-counter health monitoring devices, including blood pressure, glucose and cholesterol monitors. The decision to use the body fat analyser was primarily based on the assumption that this product provides enough interest for both younger and older participants. Hawthorn [29] suggests that a test product should be perceived as useful to sufficiently motivate the participants to engage them in the experiment. For the actual experiment a virtual version of the product was used as it was not possible to modify the physical device to test the “Interface” independent variable. The virtual product was used on a touch sensitive LCD monitor. Two cameras were used to record the experiment (Figure 2a) for later analysis using Noldus Observer software. One camera was positioned to record participant’s facial expressions and body language (Figure 2b); and the second camera was positioned to record the tasks performed by the participant on the screen (Figure 2c).
This research used triangulation of data collection methods. These were concurrent verbal protocol, observation of interaction tasks, interviews and questionnaire rating scales. Observations were video and audio recorded which are subsequently coded and analysed using the Noldus Observer, observational software. The Noldus Observer assists in quantifying data based on combinations of independent variables, behaviors, and time criteria. The data generated was exported into SPSS for statistical analysis.

4.3 Procedure

This experiment was conducted in the QUT People and Systems Laboratory. The whole experiment was scripted to ensure consistency between participants. Participants were first welcomed to the laboratory and were given an information package that explained what the experiment was about, and what it meant to participate in it. Once they understood all that was stated in the package and if they did not have any doubts about their participation in the experiment, they were asked to sign the consent form. Then they were shown around the laboratory and the experiment setup was explained. Once the participants were well settled and comfortable with the environment, the experiment began. Participants were also informed that they could stop the experiment at any time and request to delete all the records of their participation. The protocol of Experiment is listed with explanation in Table 3.
Table 3: Experiment protocol

<table>
<thead>
<tr>
<th>No.</th>
<th>Activity</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technology familiarity</td>
<td>questionaire to gather information on: Age, gender, education, life style and</td>
</tr>
<tr>
<td></td>
<td></td>
<td>technology familiarity</td>
</tr>
<tr>
<td>2</td>
<td>Vision test</td>
<td>A Snellen chart is used to measure visual acuity with, if any, prescription</td>
</tr>
<tr>
<td></td>
<td></td>
<td>glasses or contact lenses.</td>
</tr>
<tr>
<td>3</td>
<td>Familiarisation session</td>
<td>Virtual calculator is used to familiarise participants in using touch screen</td>
</tr>
<tr>
<td></td>
<td></td>
<td>and concurrent verbal protocol</td>
</tr>
<tr>
<td>4</td>
<td>Anxiety test</td>
<td>State anxiety test to measure the current level of anxiety of the participant</td>
</tr>
<tr>
<td>5</td>
<td>Task 1</td>
<td>Participants are asked to do Task 1 of the experiment</td>
</tr>
<tr>
<td>6</td>
<td>Task 2</td>
<td>Participants are asked to do Task 2 of the experiment.</td>
</tr>
<tr>
<td>7</td>
<td>Anxiety test</td>
<td>Post experiment State anxiety test to measure the current level of anxiety of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>the participant</td>
</tr>
<tr>
<td>8</td>
<td>Cognitive measures</td>
<td>Interactive questionnaire to measure cognitive processing level of the</td>
</tr>
<tr>
<td></td>
<td></td>
<td>participant</td>
</tr>
<tr>
<td>9</td>
<td>Retrospective interview and</td>
<td>Semi-structured interview to gain an insight into reasons behind participants’</td>
</tr>
<tr>
<td></td>
<td>rating scales questionnaire.</td>
<td>actions while performing tasks.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rating scales questionnaire to gather information on prior-experience of</td>
</tr>
<tr>
<td></td>
<td></td>
<td>participants with interaction elements that are similar to the virtual test</td>
</tr>
<tr>
<td></td>
<td></td>
<td>device</td>
</tr>
</tbody>
</table>

Task 1 involved switching on the device, inputting necessary details (age, gender, weight and height) and saving the data followed by instructing the device to measure and display body fat mass and volume. Task 2 involved switching the device on, recalling saved data, updating the data and instructing the device to measure and display body fat mass and volume. Participants were informed that, if they were not comfortable to divulge their personal information, they could provide false, but realistic, data. They were also informed that help would be provided on request if they were unable to complete a task after repeated attempts.

5. Results and Discussion

Preliminary results suggest that a negative relationship may exist between technology familiarity and time to complete the task (Figure 3). Younger people (22 to 41 years) also tended to score higher on the technology familiarity and were more likely to use interfaces faster than older people (59 and above years). Significant time difference was observed between young and old in completing the task on redundant interface (Young $\bar{x} = 4.33$ minutes, Old $\bar{x} = 7.33$ minutes). Both these findings support results from earlier studies [5,8,13,30].
However, contrary to the prediction, participants with low to moderate technology familiarity took more time ($\bar{x} = 6.67$ minutes) to complete tasks on the redundant interface (text and symbol) than did those on text only interface ($\bar{x} = 4$ minutes). Moreover, younger participants with high technology familiarity were much faster than their older counterparts on redundant (text and symbol) interface (young $\bar{x} = 4.5$ minutes, old $\bar{x} = 8$ minutes).

Processing-speed Theory, proposed by Salthouse [31], suggests that ageing causes slowing down of processing speed. However, if older people were allowed more time on task, the performance differences between young and old would be minimal. On the other hand, recent studies by Blacker et al. [13] and Lewis et al. [5] show that older people also tend to make more errors. However, on text only interface of this study, in terms of time on task and errors, there was very little difference between older and younger participants.

Moreover, it was observed that older people, when compared with younger participants, tended to take more time to recover from mistakes and also appeared more anxious on difficult task, especially when they make mistakes. This could be due to age related decline in central executive function which impacts ability to deal with complex cognitive tasks [12]. Blacker et al. [13] have also reported relationship between central executive function and rate of errors and time on task in older people.

6. Conclusion
This study was designed to investigate if redundancy in product interface design facilitates intuitive use in older people. The study involved participation of people of ages between 20 to 66 representing four age groups. Preliminary results suggest a strong correlation between technology familiarity and time on task. Redundancy in the interface did not improve speed or accuracy in participants with low technology familiarity. However, it had a positive impact on people with moderate to high technology familiarity in using product interface much faster and more accurately. The reason could be that all participants, as they were using this device for the first time, are novice users. From this perspective, redundancy in interface did improve speed and accuracy in novice users.
with moderate to high technology familiarity when compared to interfaces that used only one mode of representation (text only or symbol only). Further analysis of the data, taking into consideration age, education, technology predisposition and lifestyle, is expected to give much more clarity in interpreting the data.

It was also observed that, when compared with younger people, the older people took more time to recover from mistakes and also tended to get more anxious when task got difficult. Both of these issues will be further investigated in next set of experiments.

7. Acknowledgements
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References


