EVALUATING THE ROLE OF PRIOR EXPERIENCE IN INCLUSIVE DESIGN

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Declaration

With the exception of where stated, this thesis is the result of my own research, conducted within the Engineering Department's Engineering Design Centre (EDC), University of Cambridge. This research was conducted between June 2008 and June 2011 and the thesis itself has not been submitted in part or whole as consideration for any other degree or qualification at this or any other institute of learning. This thesis does not exceed the limit of 65,000 words and 150 figures and tables.

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Abstract

This thesis investigates the role of prior experience of products and its affect upon interaction. It has been shown within this work that technological experience of products is related to age, and that this has implications for the success of subsequent interaction. This research adds weight to a growing body of literature that has identified age related and generational differences toward product interaction. Implications for intuitive design such as the use of familiar features and icon design are also identified. The adoption of a novel inclusive design approach, framing interaction using an interactional, behavioural model, is proposed as a potential method to identify issues that cause unnecessary interactional complexity.

The effect of prior experience and design upon interaction was investigated by performing three main experimental studies that assessed individuals' performance with products and identified the problems real users' experience through inadequate product design. The findings reveal that older participants' ability to learn and transfer knowledge for successful product interaction may be adversely affected by design. Older users recognised fewer features and iconic warning symbols than younger users, and this appears to place them at a disadvantage in terms of learning and intuitive interaction. Technological experience was found to decrease with age, further compromising older users' ability to draw accurate inference from products.

The contribution of this work is to provide the design community with new knowledge and a greater awareness of the diversity of user needs, and particularly the needs and skills of older people. The hope is that the awareness of this knowledge can, in turn, assist toward the community's development of better design methods. The approach introduced can be applied to new and existing products alike and can aid the development of products that are more accessible and easier to use for a wider proportion of the population.

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Wilkinson, C. and Dix A. (2010). 'Considering prior experience and expectation in automotive safety system development' in proceedings of the 4th Irish Human Computer Interaction Conference, iHCI 2010, Dublin, Ireland, pp. 51-58.

Wilkinson, C., Langdon, P.M. & Clarkson, P.J. (2010). 'Prior experience and learning: Generational effects upon interaction'. Designing Inclusive Interactions. Springer-Verlag: United Kingdom, pp.145-154.

Wilkinson, C., Langdon, P.M. & Clarkson, P.J. (2009). 'Investigating prior experience and product learning through novel interface interaction' in 5th International Conference on Universal Access in Human-Computer Interaction (Part I), San Diego, California, USA, pp. 654-664.

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APPENDICES

1: Introduction

The intention of this thesis is to detail the study of the effects of prior experience and memory on interaction with a view to understanding how the use of technology can be facilitated for an increasingly ageing population. This includes how products and devices can be designed to enhance their ease of learning and usability. This research contributes to an increasing body of literature that has identified age related and generational differences toward product interaction, and identifies implications for intuitive design. This work shows how prior product experience, and particularly age, influences the ease with which users are able to interact with products. Age and experience are shown to affect users' knowledge of interface icons and features, and this has a significant impact upon successful interaction. A unique feature of this work is the way in which it has determined interactional complexity during this process. Instances of complexity were highlighted by classifying human behaviour in terms of skill, rule and knowledge-based activity, and observing where interaction was reduced to a knowledge-based level. Under such circumstances, it was evident that users were attempting to acquire or affirm knowledge and that they were being prevented from performing at a more desirable, skill-based level. Identifying the design features causing this interference allows them to be addressed as part of an overall inclusive design approach that will improve product interaction for all users, irrespective of age or experience.

The remainder of this chapter introduces the immediate research area, describing the need for further investigation, based upon the issues raised. The overarching research question that the work examines is stated and the research approach and overall structure are defined.

1.1 Motivation for Research

Inclusive Design is an approach that aims to create interfaces, artefacts and products that are applicable, appropriate and accessible to as many users as possible within the constraints of the design specification (Keates & Clarkson, 2003). Thus, it is not considered as design specifically catering for those with reduced capability, physical or cognitive impairment, but attempts to optimise design for maximum accessibility in conjunction with minimizing the user effort required for interface or artefact interaction for all users (Deisinger et al., 2000). The intention is that this approach will provide salient solutions; solutions that work as effectively for the impaired as they do for the unimpaired. In order to maximise accessibility and minimise user effort for efficient and effective interaction, inclusive designers have to better understand both what the design brings to the user and what the user brings to the design.

1.2 Why Investigate Knowledge and Prior Experience?

Consideration of prior experience and other factors such as the context of use and environment of interaction are required to create truly usable and inclusive products, and are key considerations in the performance of usability evaluations (Nielsen, 1993). Mayhew (1999) also advocated consideration of users' psychological characteristics, knowledge and experience, and users' physical characteristics. By increasing understanding of these factors and applying them within inclusive design, the potential exists to increase the long-term profitability of product manufacturers and enhance the competitive edge of such companies whilst concurrently assisting in the production of better products for all end users (Dong, et al., 2006).

One approach to achieve this is to examine how humans learn and interact with interfaces and designs, and by understanding more about how learning occurs, use this knowledge to influence future design in terms of ease of learning, use, and access to all (Inclusive Design Group, 2008).

1.3 Why Investigate Age and Generational Effects?

This research aims to investigate learning and the effect of prior experience, capturing further information regarding what occurs during interaction with products. This includes products of a novel nature, about which, users may possess limited, or non-existent internal concepts. In order to ensure this work is inclusive in nature, other significant areas of interest are generational effects and the effects of ageing upon interaction. As humans age, cognitive and physical capabilities decrease as a factor of natural human atrophy (Rabbit, 1993, Tarakanov-Plaz, 2005). Cognitive processing speed, the ability to switch attention, engage selective attention and working memory, textual comprehension and response time to complex motor tasks all affect behaviour and task performance (Chan et al., 2009, Nichols et al., 2006). Although older individuals may have larger memory banks of interface and interaction knowledge upon which to rely, they may experience difficulty retrieving useful chunks of memory that help them interact with familiar or non-familiar interfaces, and this may be linked to the knowledge that older individuals are required to exert greater effort in learning new tasks (Howard & Howard, 1997). Docampo-Rama (2001) and Freudenthal (2001) refer to such differences in age and experience as the Generational Effect, identifying particular stages in life during which individuals are optimally receptive to adopting and interacting effectively with new technology. This is typically seen to be manifest in those under 25 years of age.

Inclusive design attempts to address these issues in its quest to assist designers design products, artefacts, and systems, for maximum accessibility regardless of age and impairment. Literature indicates prior experience of products is important to their usability, and that the transfer of previous experience depends upon the nature of prior and subsequent experience of similar tasks (Thomas & van-Leeuwen, 1999). Familiarity of the interface design, it's interactional style, or the metaphor it conforms to (if it possesses one), appear to be key features for successful and intuitive interaction (Okeye, 1998).

There are also other important design implications under investigation. Initial findings of this research provided evidence of the extent to which users avoided reading instruction manuals. This prompted further investigation and consolidated the need for designers to effectively convey product and interaction information through the product design itself. The extent to which this has been successful has also been scrutinised.

1.4 Design and Design Practice

Throughout the thesis there are numerous discussions of design and the design process. In order to convey how this work relates to these processes and how the knowledge gained may transform the understanding of the design community, an overview of traditional design practice and more contemporary design approaches will hereby be afforded.

1.4.1 A Traditional Design Framework: The Waterfall Model of Design

The waterfall model of design (largely attributed to Royce, 1970) is a stepped process consisting of requirements specification, system design, implementation, testing and maintenance (Figure 1).

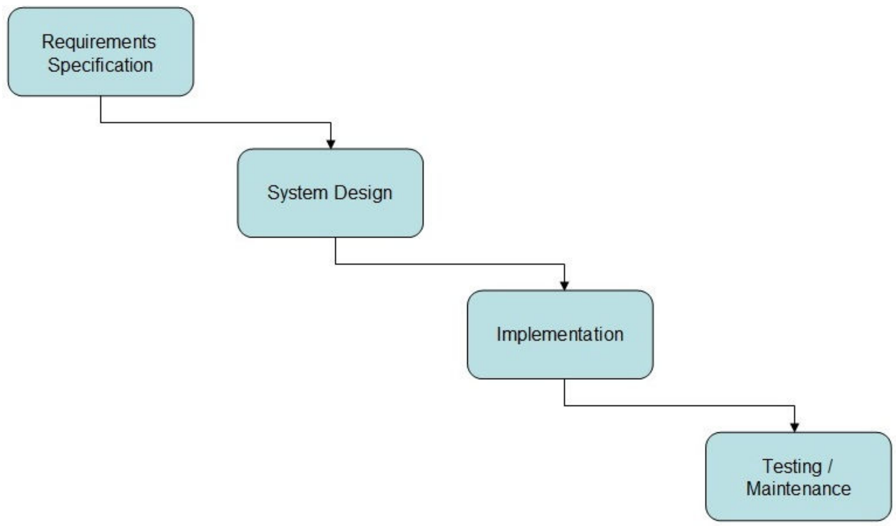

Figure 1: The Waterfall Model of Design
(Royce, 1970)

Usually applied to software design, users are involved within the initial requirements or system specification stage, but subsequent user involvement is often argued as being insufficient with different parties often being responsible for the initial requirements elicitation and the later testing and evaluation stages, and poorly developed or maintained feedback loops (Grudin, 1991). This approach is indicative of non-user-centred design approaches that may lose valuable insights about user perceptions of developing designs, and may also facilitate the implementation of systems or designs that are far from ideal from a user perspective, as in reality development projects are rarely entirely sequential and users are not always able to accurately state all their requirements explicitly (Dhall, 2009). In such a scenario, there is an increased likelihood of designers using their personal skill sets as natural points of reference and not engaging with the full and diverse spectrum of potential users (Nickerson, 1999, Lewis et al., 2006). Design practice is often time and financially constrained causing user involvement in the design process to be seen as an expensive luxury; the benefits of user involvement are not always fully understood and organisational structures do not always facilitate such interaction (Grudin, 1991).

1.4.2 The Inclusive Design Approach: Participatory Design Thinking

Participatory design aims to develop new technologies with the close involvement of stakeholders and end-users through cycles of requirements gathering, prototype development, implementation and evaluation (Sharma et al., 2008). In this way, participatory design can be seen as an attempt to understand and involve people throughout the design process with the intention of creating more appropriate, applicable, and user friendly products. This research, too, can be seen as an attempt to better understand the diverse needs and requirements of an older demographic by involving them inclusively within a process that will foster and develop knowledge acquisition for the design community. The intention is that this knowledge might assist toward the subsequent design, development, and manufacture of products or tools that are more immediately accessible and usable to a wider proportion of the population, including the older generation. User involvement within the design process is seen as the key solution to overcoming this imbalance and, in this way, all participants within this research can be considered as members of a participatory design group, capable of influencing all aspects of design (Figure 2).

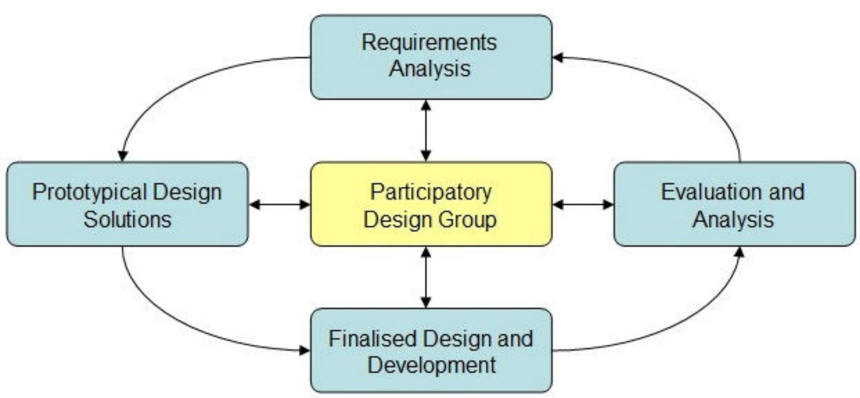

Figure 2: Participatory Design Process

1.4.3 Contributions to Design and Design Practice

The overall intention of the thesis is to generate knowledge to inform designers and thereby the design process; similar to the Total Quality Management ethos (Schonberger, 1986, Powell, 1995) of doing things right first time largely removing subsequent retooling requirements. The presupposition presented is that design can, and has, traditionally failed in this respect. The aim of the research is to highlight where insufficient designer consideration has negatively affected usability and product interaction for all users – young and old alike. This also has a cost implication on product and brand loyalty. Adopting the inclusive design approach forming the basis of this thesis has the potential to increase usability regardless of age, reduce subsequent manufacturing retooling and operational costs, and widen the market for existing or potential products, designs, and artefacts. As a whole, the thesis contains knowledge that will help designers formulate better design methods. It aids and increases design knowledge and understanding, can help designers to produce informed designs that will be applicable to a wider proportion of the population and designs that work more effectively and optimally first time and 'out-of-the-box', and can thereby increase product adoption and product or brand loyalty.

1.5 Older People as Product Users

There is much debate in literature as to what constitutes the age-related definition of older adults and older people (Tanner & Harris, 2007, Morris et al., 2007). For the purposes of this research, older people and the older generation are defined as those belonging to the age-range of 60-80 years of age to allow examination of age-related differences in terms of prior experience and interaction in comparison with younger groups of users. This approach also conforms to Tanner & Harris's (2007) observation that:

> "…research studies involving older people usually adopt a chronological definition of old age (for example, selecting samples of people who are over the age of 60 or 65)."
>
> (Tanner & Harris, 2007, p.9)

Although declines in health, and mental and physical function, are more likely in old age, these are by no means inevitable (Rabbit et al., 1993, 2004, 2006). This means that older adults are a most diverse demographic group encompassing a wide range of health and ability states. Goodman-Deane et al. (2009) suggest that designers must fully comprehend the diversity of this group, and that in order to do so the inclusion of older users in the design process is paramount. Many of the older participants involved in this research are actively engaged in their community with busy social lives. Many of them are members of committees, volunteer with charities, or are heavily involved in care duties with grandchildren or spouses. This clearly demonstrates the fact that older adults do not necessarily conform to the traditional stereotype of dependent, lonely, isolated and incapable. On the contrary, discussions with older participants demonstrates that many older adults wish to maintain very independent, community based, active lifestyles, but that technology is not always designed to facilitate or enhance such activity. The goals of inclusive designers are to create interactive technologies that are enjoyable, pleasurable, motivating, and satisfying, and these aims are largely dependent upon users' acceptance of technology, their perceptions of the technology and their level of engagement with it (Preece, 2002). To do this, however, greater understanding of this demographic and the diversity they represent is imperative.

1.6 Product Area: Novel and New to Market Home Technology

The focus of this research particularly targets household products that users of all ages might be able to purchase from high street stores in the United Kingdom. The two products involved, an electronic electricity meter and a multifunctional laser-level, are computer-embedded products with varying degrees of Graphical User Interface (GUI), and the use of Liquid Crystal Display (LCD) and additional external design features, were common to both instruments. As such, they may be considered more toward the do-it-yourself spectrum of home products. These products were chosen as vehicles to examine the effects of prior experience upon individuals' performance with products and identify problems real users may experience during interaction with technology. Both products when used were new-to-market and, as such, novel. This was an intentional aspect in their use, as the research aimed to investigate how product design may communicate aspects of use and knowledge to users with little previous experience of the product in its current embodiment and if, purely due to the product's design, users were hampered in their ability to understand or interact. Conceptually, these products are not necessarily new but their embodiment was, and this also allowed investigation into how effectively knowledge of other interfaces and designs (prior experience) may be transferred during interaction. The administration of a questionnaire developed from the work of Blackler (2006) was used throughout the research to investigate the extent of familiarity and frequency of interaction with more generic home and personal products, including satellite televisions, mobile telephones, laptops, and satellite navigation systems. The two new-to-market and novel products were also included in the questionnaire to identify any instances of previous use that may have contributed to or biased performance, and are afforded further description within the work.

1.7 Research Aim

The overarching research question has been born out of the need identified through a comprehensive study of the literature to address a number of factors within the design arena that may overlook or insufficiently acknowledge age-related user requirements in the initial and subsequent phases of design. In summary, the research question is:

Is there further knowledge to be gained for the design community from the study of generational differences in terms of prior experience and contemporary product interaction?

The overall research question is addressed methodically on a chapter-by-chapter basis. The following chapter introduces the literary contributions to the area and provides context as to where this research is positioned. The third chapter presents an experimental methodology and research plan that breaks down the overall question into sub-component aims. Chapters 4, 5 and 6 then address these sub-component issues, looking specifically at prior experience, mental model development and the acquisition of knowledge through interaction. Chapter 7 examines the effect of age on product experience and how individuals' approaches to instruction manual use may affect usability and intuitive design. Chapter 8 is largely seen as the culmination of this approach, as it not only classifies interaction at a granular level to determine where and when knowledge is acquired and developed during interaction, but goes further to identify where instances of interactional complexity are caused by design. Chapter 9 then discusses the implications of the individual results in terms of how they relate to the area of research and the overall research question. A critique of works follows and suggestions for future research are then proposed.

1.8 Overall Contribution

By understanding in greater detail both the information that individuals bring to product interaction (their prior experience) and the information interaction necessitates they acquire, designers can utilise this knowledge in the creation of designs that fit more effectively and more immediately into the users existing knowledge base. Success at this stage is often recognised in reports by users of products or designs that are considered particularly user-friendly and intuitive. This, in turn, can result in increased product and brand loyalty, although it is clearly not only the designers and manufacturers that benefit from these advances; individuals as product-users themselves can literally ‘feel-the-difference’ and the opportunity is thus provided to accommodate those who were previously excluded from the design process, by designing for the wider population.

This research contributes to literature by identifying further age related and generational effects toward product interaction. It also exposes implications in contemporary design that impede intuitive product use. A method is detailed that shows how framing interaction in terms of skill, rule and knowledge-based activity allows the design aspects causing greatest cognitive or interactional difficulty to be identified. Establishing where design directly compromises interaction facilitates the redesign of features that can reduce complexity and make products more accessible, easier to use and adopt. Overall, the contribution of this work is to provide the design community with new knowledge and a greater awareness of the diversity of user needs, and particularly the needs and skills of older people. The hope is that the awareness of this knowledge can, in turn, assist toward the community's development of better design methods. Ensuring products can be used more intuitively by a larger demographic will also enhance the target market, increase commercial potential, and enhance the usability of products for all users.

1.9 Summary

Chapter 1 has provided an introduction to the thesis stating the overall research question and structure of the research. The following chapter will introduce the literary landscape of the area to provide context as to where this research is positioned. The chapter will conclude by developing the specific research questions and objectives this work sets out to investigate.

2: Literary Observations and Contributions to the Area

The intention of the initial chapter was to introduce the effects of prior experience and memory on interaction with a view to understanding how the use and design of technology can be facilitated for an increasingly ageing population. This chapter expands upon this concept by explaining the difficulties older users face when interacting with modern products and designs, and how consideration of their specific needs may have been overlooked within the design process. It also introduces the notion of product interaction being designed and viewed as a process of communication between designer and user. Furthermore, it highlights how design can affect and facilitate learning, knowledge acquisition, and mental model development, and the importance of designing for individuals' needs, expectations and experience.

2.1 Background to an Ageing Population

According to the Office for National Statistics (2008) the number of people in the United Kingdom aged over 60 has recently overtaken the number of those under 18 years of age, and this trend is set to continue. By 2035 it is predicted 23% of the UK population will be aged over 65 and although this will be one of the lowest proportions in the European Union, Japan will see one-in-three aged over 65 (Population Trends, 2010). The Department for Work and Pensions (2011) has indicated that increases in life expectancy are likely to account for half a million people in the United Kingdom being over the age of 100 by 2066 and so a product design that caters for both older people and younger users, with or without impairment will appeal to an ever-increasing commercial market. Distinct interactional differences can be made between user groups, purely on the basis of age. A study by Langdon et al. (2010) reported how symbols identifying features of an interface across product families were recognised by different generations. Older generations of participants failed to recognise some of the modern symbols used. According to Docampo-Rama (2001) this is a factor of exposure to technology at a particular stage in life – modern symbols and layered computer interfaces being more familiar and most suited to the interactional processes of those 25 years and younger. Freudenthal (2001) also found elderly users performed slower in information retrieval tasks which required searching in a hierarchical structure in comparison to younger adults. Such findings may explain the difficulties experienced by older generations interacting with a variety of current products and designs that employ menu-driven interactional styles whilst they also experience a general decline in their cognitive and physical abilities (Tarakanov-Plaz, 2005). With increased age comes reduced contact with other people and reduced access to information that is readily accessible to the younger generation (Renaud & van Bijon, 2008). Therefore, older users increasingly desire and expect technology to add value to their lives by providing access to a more social, active, meaningful and independent life (Mallenius et al., 2007).

Kwon & Chidambaram (2000) found that perceived ease of product use significantly affected users' extrinsic and intrinsic motivation to interact with and adopt new technology. Similarly, Phang et al. (2006) concurred that perceived ease of use and perceived usefulness were significant factors in product adoption and interaction. They suggest considering both the physical limitations of the device as well as the limitations of the surrounding physical context (screen size, memory, storage space, input and output facilities), and acknowledge that the physical and cognitive limitations of ageing have very real affects upon technology uptake. Osman et al. (2003) revealed that older users expressed a preference for products with easy menus, followed by large screens and buttons as a result of age affecting manual dexterity and the visual system. These factors were all considered to affect product ease of use. Arning & Ziefe (2007) found that whilst older users' *intention to use* may exist, *actual* use was impacted by perceptions of ease of use, learning and understanding development. Burke & Mackay (1997) suggest mental model development can also be compromised with age, as it takes the older generation longer to distinguish between important and irrelevant stimuli in the product and environment. This may also explain why it takes them longer to learn to use modern products and devices.

2.2 The Designer Problem

Literature suggests that the views of older people are not being sought to inform the design process (Hansen et al., 2007). This lack of involvement in the design and evaluation stage may be responsible for causing some of the generational and age-related issues that prohibit and exclude a larger proportion of the populous interacting with products and designs, and may explain older peoples' reluctance to engage with new technology. Individuals' views are not sought and, due to that reason, designers fail to realise and cater effectively for their specific needs. This in turn may manifest itself in reluctance on behalf of this very section of the population to purchase or interact with many forms of modern technology. Nickerson (1999) also argues that designers have failed to engage with the full spectrum of potential users including the older generation, and Lewis et al. (2006) point out that designers are typically male, under 35 and unimpaired, and have been accused of designing for themselves and their personal skill sets as a natural point of reference. The danger being that designers assume that all users possess the same cognitive and physical abilities as themselves. Failing in this way to understand or connect with all potential user groups and their particular requirements, may risk alienating or excluding a significant proportion of the population (Figure 3).

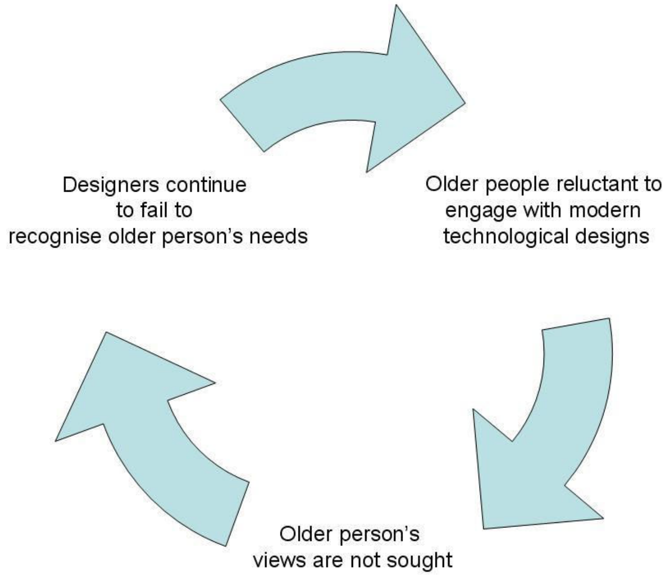

Figure 3: Cycle of design oversight influencing the uptake and engagement of technology

This also makes poor and short-sighted business sense (Hollins, 2008). Failing to engage with older people forming part of an increasingly influential market force is seen as a missed opportunity. Many consider that product designs catering for both older people and younger users, with or without impairment, will appeal to an increasing commercial market and thus make good commercial and ethical sense, benefiting a wider cross-section of society (Middleton et al., 2006, Coleman, 2001). User involvement is seen as the key solution to overcoming this imbalance. Dong et al. (2006) proposed that by including a more representative sample of all end-users – less-able bodied users, children, and the elderly at an early stage within the design process, designers no longer need to use their own knowledge or personal points of reference as the norm by which to design. Catering for diversity within the target market should not be a unique approach. It should be prerequisite for all design and a natural component within requirements specification. Design should consider the user as an individual, possessing individual aptitudes, experiences and other human characteristics, accounting for the abilities and limitations of all potential users (Tainsh, 2006). Products designed in this way will be capable of being used by people with the widest possible range of abilities, within the widest range of situations, reaching most, if not all, potential end users (Buhler, 2001).

2.3 Communication and the User Experience

Interaction can be viewed as a form of communication. Communication is considered a two-way process, and has been defined as the transmission of information in such a way that the recipient comprehends the senders' intention (George, 2006). In the context of design, this two-way process remains, but can be considered in different terms. This idea is captured neatly by Eveland (1986) who, referring to technology, proposed that technology was merely a materialised form of information and that interaction with or through interfaces, products or artefacts could essentially be viewed as the communication or transference of information, and is depicted in Crilly et al.'s (2008) communication-based model of design (Figure 4).

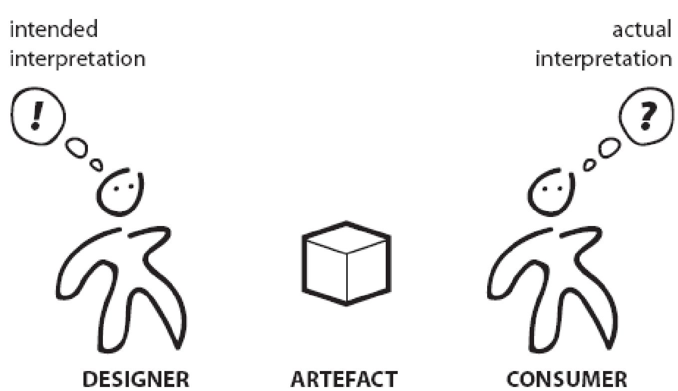

Figure 4: Communication-based model of design (Crilly et al., 2008)

It is the designers' responsibility to consider what the user will bring to the interaction and this notion has been encapsulated below to convey the communication, information and understanding flow within interaction (Figure 5).

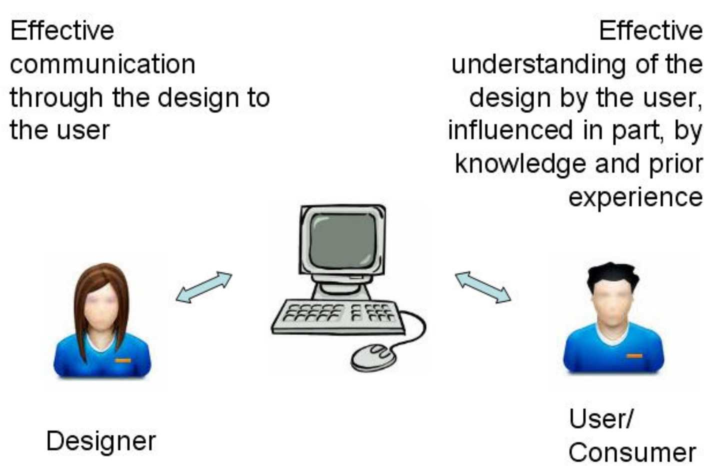

Figure 5: Communication and understanding flow

Inclusive designers attempt to understand both what the design brings to the user and what the user brings to the design. Part of this information exchange is facilitated through the product design itself – it can indicate the product type or area, its purpose or function, and innate properties such as stability or strength. This communication is not restricted to purely the verbal or auditory mediums, but may include visual design and iconic messaging or other non-verbal communication (Persad et al. 2007). Karlsson & Wikstrom (2006) also identified that the use of semantics could be an effective tool for enhancing product design and use, particularly to a novel user. Users too will have expectations as to how the product or interface will behave and how interaction is likely to occur. To succeed, Jordan (2006) posits that designers must comprehend their target market on a cognitive, physical *and* emotional level. This includes understanding users' attitudes, values and expectations in an attempt to understand how these factors may influence what they desire and expect from a product. An individual's perception of a device can be influenced by the messages they receive from different product features, visual cues regarding branding and colour, and tactile cues such as surface texture (Henson et al., 2006).

2.4 The Effect of Age on Interaction

Langdon et al. (2010) reported that the technology generation and age of a product user will affect their expectations of interfaces, the range of features those interfaces will possess, and the skills as individuals they have at their disposal to interact effectively. Skill sets, it would appear, are continuously increasing. Dewsbury et al. (2007) report that as the number of skills required to participate in modern life increase, so does the level of technological understanding required. One suggested solution to this increasing problem lies in liaising with user groups directly: observing different user groups' use of technology and discussing the role it plays within their lives, would help establish what users find difficult. It is also suggested older, disabled and impaired users are currently set aside in the design process from the mainstream user, and it is recognised that these very groups often consider themselves to be techno-phobic, unfamiliar, and averse to learning how to interact with new systems. It is important therefore, to recognise that individuals' ability to interact with everyday products tends to decrease with age, in conjunction with both natural atrophy of physical and cognitive ability (Persad et al., 2006). Some of the issues that should be considered include: fitness, dexterity, joint range of motion, muscle strength and cognitive ability. The effects of ageing can reduce an individual's ability to reach, hold and manipulate objects and therefore design should allow for this (McDonald et al., 2007). The initiation of responses and their execution also become slower especially in novel situations (Olson and Sivak, 1986).

Norman (2002) believes the young appear more open–minded to alternative problem solving strategies, proposing that they are also keener to experiment and less afraid of making errors. Motivation may also be a factor with young people being more motivated to utilise modern technology to communicate and for social interaction (Mescellany, 2002). Older individuals appear to employ slower, error-reducing approaches to interaction, where younger generations adopt greater speed and tolerance of error as an element of a speed-accuracy trade-off strategy (Langdon et al., 2010). As individuals move on from the formative under 25-year-old period documented by Docampo-Rama (2001), it appears they become less flexible to adopting new interaction strategies and mechanisms (Weiss, 2002).

2.5 Human Error within Interaction

To bridge the gulf between designers' knowledge and their awareness of the needs of currently excluded users, greater understanding of how a larger cross-section of individuals behave, according to the stimuli they are presented with and the context of that interaction, is paramount. All users make mistakes, and Kletz (2001) classified human error accordingly:

- Those occurring because the intention is wrong (mistakes)
- Those occurring because someone knows what to do but decides not to do it (violations)
- Those occurring because the task is beyond the mental or physical capability of the individual (mismatches)
- Errors due to slips or lapses of attention (correct intention, incorrectly executed)

In a summation that is in accord with Inclusive Design, Kletz proposes that the human tendencies of people should be accepted and designs created to accommodate them, using the understanding of how individuals behave to create more effective design solutions. Lardner & Reeves (2006) concur, positing that unsafe or erroneous behaviours are rarely intentional: the behaviour normally making sense to the person performing it. They suggest interactions follow a stepped process:

- Antecedents: occurrences prior to a resulting behaviour, that prompt or trigger that behaviour
- Behaviour: the resulting behaviour that occurs
- Consequences: the subsequent consequences of the occurring behaviour

This provides some insight into the basic processes of interaction and learning: behaviour is largely a function of its consequences, people do what they do because of what happens to them when they do it and as a result, what people do (or do not do) is reinforced. Systems or products can be assessed to determine the potential or actual mistakes which may occur. Smith et al. (2006) confirm Kletz's premise that individuals are naturally error-prone stating:

"…no matter how good the product is, it is impossible to make the product error proof: humans are inevitably fallible."

(Smith et al., p. 58)

Rasmussen (1982) considered error in terms of cognitive function, and classified error in the following forms:

- Skill based errors – variability of force, space or time
- Rule based errors – related to cognitive mechanisms; classification, recognition or recall
- Knowledge based errors – errors in planning, prediction and evaluation

Human performance is heavily influence by the environment and the conditions under which the individual performs the action. Factors that can adversely affect performance include high cognitive workload, poor ergonomic design, inadequate training or situational complexity (O'Hara et al., 2000). Wickens (1992) proposed a four-stage model of Human-Information Processing accommodating human-error, to convey what occurs during interaction, and as a function of natural cognition influencing behaviour (Figure 6).

Stage	Occurrence	Potential failure
Perception	Information perceived from the environment by the senses…	Misperception of information
Memory	Is combined with information stored in memory…	Failure to implement a step in procedure due to memory lapse
Decision making	To arrive at a decision and used to initiate…	Failure to integrate data and information causing misdiagnosis of situation and inaccurate decision
Action	An action	Accidental performance of inappropriate action

Figure 6: Four stage model of human-information processing (Wickens, 1992)

2.6 Perceptual Processing and Environmental Interaction

There are numerous theories proposed to explain the form and way in which information is perceived and encoded, and the extent to which such processing is a conscious activity.

2.6.1 Connectionism

The connectionist approach, based on Hebb's (1949) cell assembly of cognition theory, considers that knowledge gained through experience is encoded and stored in memory in elements or nodes that form neural networks. When information in the environment is perceived (unconsciously or otherwise) nodes of the network associated with previous experience of this perception, or potentially similar perceptions, are activated and this activation spreads to other nodes. These clusters of associated nodes are referred to as models that provide the individual with an immediate bank of information. If the activation of clustered nodes proves successful to understanding of the environment or completion of a task at hand, the model for that task or environmental element is reinforced. Activation of extra associated nodes that were deemed relevant to task completion may become more permanently associated with the clustered network or mental model involved. Repeated activation may therefore modify and strengthen the associated neural network or mental model.

2.6.2 Experientialism

Johnson (1987) proposed that an individuals' experience of the world consisted of a combination of sensory-motor, emotional and social elements that were refined into Image Schemata: internalised structures of human experience that guide and facilitate subsequent understanding. These schemata are considered, not to be fixed, but flexible abstract patterns that are modified through further interaction with the world. This is largely in accordance with Gregory's (1972) views on environmental and informational perception and actors in a scene subconsciously, or otherwise, formulating hypothesis upon the stimuli presented, and the hypothesis being constantly compared to memory traces (prior knowledge and experience) to assess if the current hypothesis should be supported, modified, accepted or rejected. In this way, the physical environment can influence the behaviour of the actor, operator or product user (David, 2008). Norman (1988) describes mental models as being the constructs or models individuals have of themselves, other individuals, their environment and the objects with which they interact. Norman proposes that individuals develop models through experience, training and instruction (learning) of devices, and that the model is created on the basis of two phenomena: the perception of the device's function and likely behaviour through its design. Thus, design may have a significant effect upon individuals' ability to perceive likely action or function, and thereby inhibit effective interaction. The knowledge contained within these internal, cognitive models can be transferred between interfaces if the designs are consistent and are based upon interactions with which users are familiar (Ravden & Johnson, 1989). According to Kellog (1989) consistency appears to be a key feature in facilitating transference: consistency of interface design, interface element or feature, or environmental element.

2.7 Interaction and Learning

Interaction and task completion can be considered as activities utilising the resources available through the mind, body and world (Clark 1997). In order to ease the process of learning and interaction, Norman (1988) advocated the benefit of providing all necessary information for successful interaction within the interface itself, with the intention of facilitating the correct perception of the systems function and behaviour by users, whilst reducing the level of cognitive loading and perceptual processing required. This notion is often associated with Norman's work and can be seen as a design characteristic of *Affordance*: a phrase used to describe characteristics of a device, product or artefact that indicate or suggest how it should be operated (David, 2008). Interaction is thus viewed as a constant learning process. This is compatible with the flexible mental model approach. With a familiar interface, information processing and subsequent human responses may be automatic and un- or sub- conscious. Rasmussen (1993) proposed a model that accounted for fluctuations in the level of consciousness required during interaction based on his assumption that individuals operated at a level that was appropriate to the familiarity of the situation, and an individuals' previous experience of it, or something similar, and also accounts for learning as a process. This model was expanded upon by Wickens et al. (1998) to account for the type of processing that occurred. Wickens et al. proposed that at the Skill-based level, automatic processing occurred and that at the Knowledge-based level, conscious, analytical processing occurred (Figure 7).

Skill	**Rule**	**Knowledge**
High familiarity/experience Non-conscious Automatic process	Familiar with tasks but lacking experience Rule-based processing: Rules: If-Then associations between environmental cues and actions that are stored in memory	Novel situations – no stored rules or associated cues/actions, therefore a slow, analytical conscious level of processing adopted
Expert	**Intermediate**	**Novice**
Large knowledge and rule base	Some knowledge based rules	No knowledge base or rules

Figure 7: Wickens et al. (1998) definitions of skill, rule, and knowledge-based processing

Blackler (2006) proffered that between the two, Intuitive Processing occurs. However, Bowers (1984) considered intuition merely an unconscious mode of processing that accessed stored information to facilitate decision making. Richman et al. (1996) described intuition as being tantamount to recognition: something having been seen or recognised before, or possessing similarity to something seen or recognised before, and that this recognition generally occurred unconsciously. Similarly, Cole (1996) likened it to a more simplistic occurrence of often unconscious pattern recognition. Rouse (1986) considered humans to possess “exquisite pattern recognition abilities” (p.355) and this in accord with the notion that humans are “furious pattern matchers” proposed by Reason (1990, p.66). Reason suggested that if a solution can be achieved by pattern matching without the need to apply rules or use all but minimal conscious thought, the individual could be considered to be operating automatically, at the Skill-based level. Accordingly, increases in conscious activity and the application of Rules were indicative of operation at the Rule or Knowledge-based level; knowledge itself being gained through experience (learning) in context. Edge et al. (2006) posit that whenever individuals arrange or interact with objects in the physical (or virtual) world, they rely on feedback in order to modify or adjust behaviour and confirm the effects of behaviour through *direct manipulation*. This also confirms expectation within the realms of technology development. This development impacts on user lifestyles, and can lead to new ways of interacting with products in numerous environments: at home, in the car, and at work. These effects are not limited to how users interact with products, but can also affect their expectation of them, thus it is important to appreciate the relationship between user, product and environment (Figure 8).

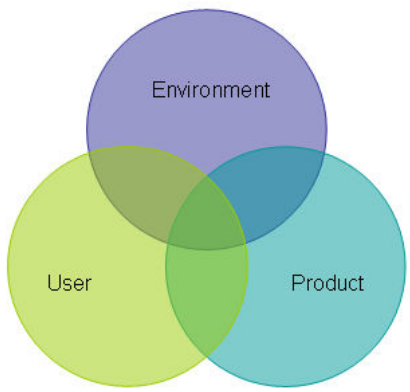

Figure 8: Triangular relationship between user, product and environment

Monk (1998) stressed that to be usable and accessible, interfaces need to be easily understood and learnt, and in the process, must cause minimal cognitive load. Effective interaction consists of users understanding of potential actions, the execution of specific action, and the perception of the effects of that action, and ultimately a user evaluation of the effect of that action in terms of their overall goals. Users' mental models of products are also significant in this process: the internal or mental representations reflecting their understanding of product behaviour and interactional requirements.

2.8 Perceptual Processing during Product Interaction

Persad et al. (2007) proposed a model of perceptual processing and cognition during product interaction based upon the work of Wickens & Hollands (2000) but incorporated the product within the interactional process (Figure 9).

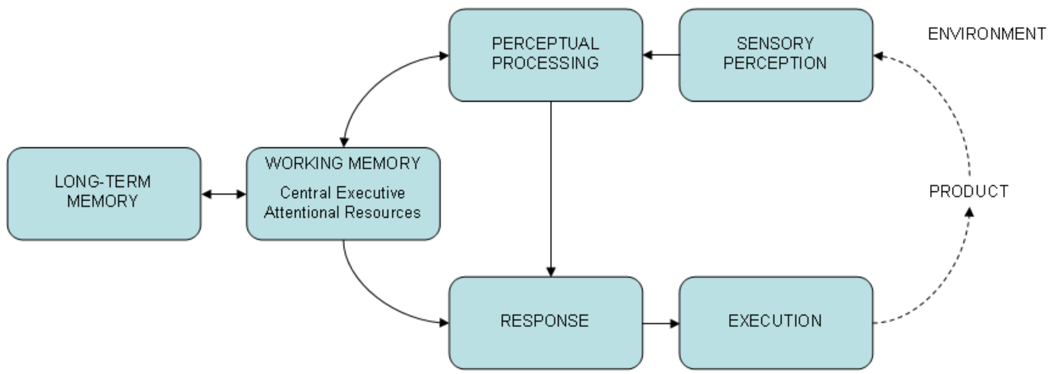

Figure 9: Model of perceptual processing and cognition during interaction (Persad et al., 2007)

Sensory organs perceive stimuli regarding the product and the environment within which the product and user is situated. Through the act of perceptual processing, automatic responses will be triggered leading directly to the execution of action, or information will be fed to the Central Executive. The Central Executive function searches Long-Term Memory to determine if a similar stimulus has been previously experienced. If so, it will attempt to ascertain what the resulting actions were. This previously acquired information will be fed through Working Memory leading to execution of a response decision. The speed of response-retrieval will be dependent upon the similarity of the current situation to that which has been previously experienced. Individuals create mental models in working memory based on environmental cues and prior experience stored in long-term memory. Perceptual processing also extends to language comprehension and may include visual or iconic messaging, iconic design and other non-verbal communication. System feedback provides users with the opportunity to assess their current situation with their desired goal situation, assists users in understanding how the product works and assists in learning.

As its indirect descendent, this model helps to explain how Rasmussen's (1993) Skill, Rule and Knowledge-based (SRK) approach accounts for fluctuations in the level of consciousness required during interaction. The SRK approach is based on the assumption that individuals operate at a level appropriate to the familiarity of the situation, and an individual's previous experience of it or something similar (Thomas & van-Leeuwen, 1999). Wickens et al. (1998) expanded the Rasmussen model to account for the type of cognitive processing that occurs (Figure 10).

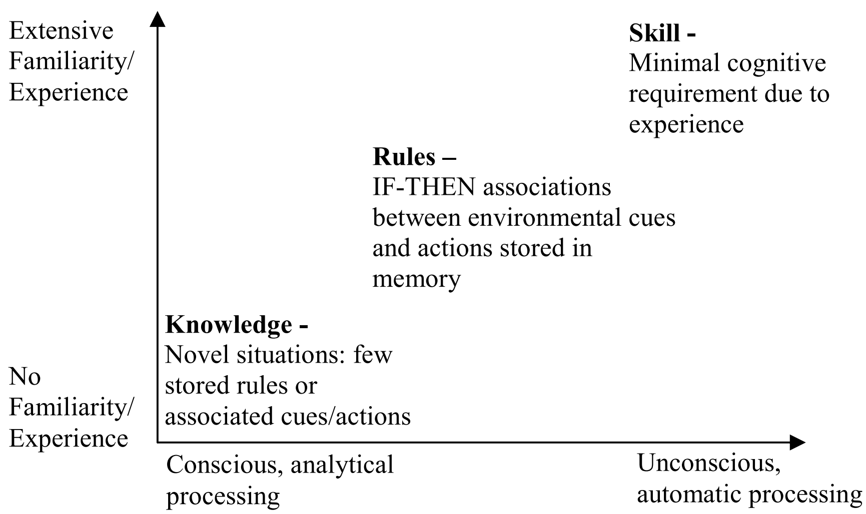

Figure 10: Wickens' (1998) expanded version of Rasmussen's skill, rule and knowledge-based processing model

Skill-based activities are often highly rehearsed procedures of behaviour. Increasing the automaticity of behaviour through repetition (making a cup of tea for example) reduces cognitive loading and allows attentional and cognitive resources to be directed toward other aspects of interaction (Wickens & Hollands, 2000). Such actions can be identified as being highly practiced and fluently executed, requiring a minimal amount of conscious effort in their implementation. Considered almost automatic, these actions are often swiftly repeated or repeatable (Embrey, 2003, Sicart, 2008). The application of rules to achieve the desired outcome is indicative of Rule-based behaviour – the scenario may be familiar but to achieve task completion may require the application of conscious attention to execute the associated rule-based response (Rasmussen, 1993). Knowledge-based behaviour is characterised by the exhibition of advanced reasoning (Wirstad, 1988, Reason, 1990). This approach often occurs in novel scenarios, where the situation is unfamiliar: cognitive effort and resources are deployed in understanding the current situation and developing pathways to the desired end-goal scenario which must also be conceptualised. A consequence of exhausting all the options or behaviours at the skill or rule-based level is increased cognitive element and situational demand. Resultant interactional response times are usually greater than either skill or rule based interaction activity (Reason, 1990). Thus, interaction typically requires greater attention and situational awareness, and is often prone to error (Alario & Ferrand, 1999).

This framework has been used to better understand, detail and design interaction in terms of information processing and can be used to classify human behaviour (Vicente, 1999). It therefore lends itself to this research, as an approach that might contribute to determining how interaction can be classified at a granular level to indicate what, when, and where, knowledge is sought and learned within interaction.

2.9 Overall Research Aims and Objectives

The intention of this research is to contribute toward mounting literature that has identified age and generationally related differences in product interaction and identify implications for intuitive design, knowledge acquisition, and learning, that may be overcome with the adoption of a novel inclusive design approach. Chronologically, this research is a continuation of the work by Langdon et al. (2010) and thus a brief synopsis of this specific work is well placed.

Langdon et al. investigated the effect of prior experience on consumer products, finding that the age and technological generation of the user would affect both their expectations of the product or its required method of interaction, and that the generational effect would influence the skills or responses users had at their disposal.

Four crucial notions were outlined:

- Similarity of prior experience to the test-scenario was a main determinant of performance
- Some evidence for gradual age-related decline in individual capability
- Trial and error approach often adopted in novel situations –
  - this may not be age, sex, or experience specific
- Strong technology generation effect –
  - older users reluctant/unable to complete a task with a digital camera

It was considered that prior experience of products was critically important to subsequent product usability. Also, that the effects of prior experience were strongly dependent upon the similarities of key functional features and perceptual appearance of the task and product. The methodology adopted included the administration of a prior experience questionnaire to elicit information regarding participants experience with products, the frequency with which they were used, and the brands with which they were familiar. Other forms of data capture involved retrospective protocols whereupon participants viewed a video record of their action and stated what they were doing and thinking at the time. Conclusions focused upon the evidence presented that product interaction-learning may be facilitated by:

- Use of generic/previously well-learnt and transferable functional features
- Clearly identifying key visual features associated with function
- Avoidance of product states or error states that are not accompanied by clear, visible feedback or the results of actions

This research, then, set out in some way to replicate the findings of Langdon (2010) that the age and technological generation of the user affects expectations of the product or its required method of interaction. This work goes further by not only examining age and generationally related differences in product interaction, but also investigates ease of learning and knowledge acquisition and the effects of interactional complexity upon these processes.

This led directly to the development of three main subcomponent research aims, designed to address the overarching research question. The overarching research question will be reiterated and the subcomponent research aims presented below:

Is there further knowledge to be gained for the design community from the study of generational differences in terms of prior experience and contemporary product interaction?

Subcomponent research aims:

1. *To investigate the existence of age-effects regarding prior experience and any associated effects upon interaction with a number of household products*
2. *To verify if a correlation between product experience and age exists on a larger scale, outside of an experimental setting, and to investigate the extent to which individuals self-report using or avoiding instruction manuals when interacting with products and the associated implications for design and designers*

3. *To investigate the efficacy of framing interaction in terms of Rasmussen's (1993) Skill, Rule and Knowledge-based Model of behaviour and thereby determine how knowledge acquisition is facilitated and identify instances of interactional complexity.*

The following chapter will expand upon these aims and outline a methodology for identifying how and when learning occurs during interaction, to reveal what information is learned in that process, as well as indicating the product elements that cause interactional complexity for users. This section will also define the empirical evaluation methods used to measure the effectiveness of interaction design and exactly how each of the above aims will be investigated.

3: Methodology

This chapter sets out the justification for the experimental approaches used. Initially, the techniques used will be introduced and the justification for their inclusion in the body of work presented. The latter part of this chapter will detail a number of factors that are consistent in each of the experimental investigations and these are explained to minimise unnecessary repetition in the subsequent stages of the work. The rationale for selecting the products used in the studies is presented, and the research plan is documented to show how each of the research objectives will be investigated.

3.1 Methodological Grounding

There is a reciprocal relationship between the research questions to which researchers' attempt to find answers, and the methodological decisions made toward that aim. The method may influence the questions posed, and the questions posed may influence the methodology employed (Sackett & Larson, 1990). During a departmental methodology seminar on the 16th February 2009 A. Maier explained that there are, in broad terms, two distinct camps of methodology a researcher can adopt; the case-oriented, inductive approach and the scientific, hypothesis-driven, deductive approach. The case-oriented approach is typically grounded in theory and by focussing upon an area, it attempts to observe trends, or similarities and allows a hypothesis/theory to evolve from the knowledge acquired, moving toward an overall prediction, and using tools such as archiving, interviewing, ethnographic observation and questionnaire administration, which are generally considered qualitative in nature (Eisenhardt, 1989). Conversely, the scientific, hypothesis-driven, deductive approach adopts an empirical, repeatable, data-driven stance, which attempts to study phenomenon in isolation, and utilises the result of study to generate new theories or influence understanding of current theory through experimentation and scientific method (Wolff & Krebs, 2008). A dualistic, mixed-method approach is considered one that affords the most useful understanding and output from applied study, and is in accord with Eckert et al.'s (2003) views upon design theory, which suggested that developing design knowledge requires a multi-disciplinary approach, involving fields including psychology, sociology and computer science. The primary goal being to gain insight into human behaviour, attitudes, experience and knowledge applied during interaction, it is felt a combination of both a quantitative, scientific approach and a more qualitative ethnographic approach will have the potential to yield the most valuable data.

Studying Plowman's (2003) overarching representation of the numerous tools available for study in this area, it is possible to pinpoint the various tools that this research intends to utilise, covering the spectrum as a whole (Figure 11).

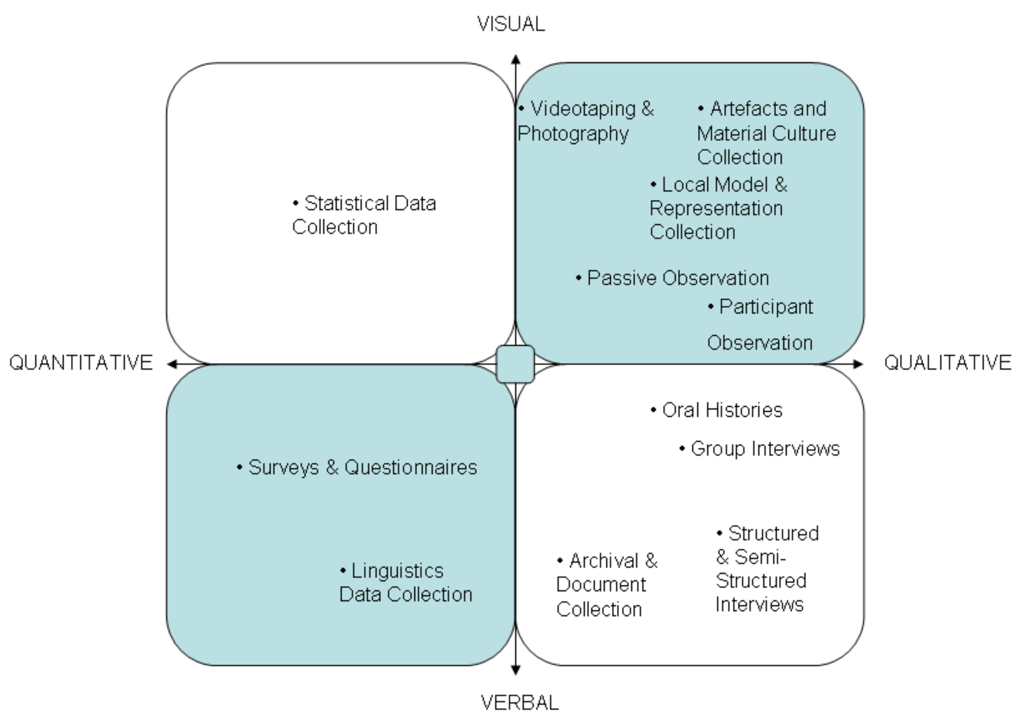

Figure 11: Cross-section of research tools available (Plowman, 2003)

The approach, as detailed above, is used to maximise both qualitative and quantitative data acquisition, in order to obtain and increase both specific and contextual knowledge. It can then be used to generate new theory or influence the understanding of current theory, with the expressed aim of informing the design process. The experimental and research-based techniques that have been chosen will be detailed and justified in the following section.

3.2 Justification for Experimental Approach

A thorough review of literature helped to initially develop and solidify understanding of the research area and gauge the current research activity. This, in turn, led to the development and proposal of a methodology for a pilot study to elicit information about what occurs in the context of learning and interaction, particularly when individuals are presented with novel products about which they possess limited preconceptions. Specific experimental tools and approaches were identified and selected for use in the studies, as their ability to obtain objective data in these scenarios is well documented (McClelland, 1999). The methodology thus involved the use of:

- Verbal/talk aloud/concurrent protocol
- Semi-structured interviews
- Questionnaire administration
- Video-recorded observation

These verbalisation and data capture techniques have been found to be particularly effective when conducting experimental investigations, which provide an excellent opportunity to study communication between products, designers and users (Jarke et al., 1998, Rouse & Morris, 1986). The concurrent or talk-aloud protocol – a narration of thought and action – was chosen as literature suggests the alternative retrospective protocol (where participants return to view and comment upon their recorded experience) may not accurately reveal participants actual task performance experience. It is thought retrospective protocols place less emphasis on negative events, while responses given *during* task completion are more representative of the behaviour and problems users have during assessment (Hands, et. al., 1997). Furthermore, concurrent protocol participants have been found to go into greater detail and provide more of an in-depth evaluation, pointing out usability problems and places where their expectations fail to be met (Teague et al., 2001). The experimental approach was also sympathetic to the financial, experimental and practical resources available, and the combined methodology, in conjunction with the tools used, was successful in ascertaining both useful contextual information and quantifiable and analysable data (Wilkinson & Dix, 2010, Wilkinson et al., 2009, 2010a).

3.3 Experimental Theory and Rationale

From an Inclusive Design perspective the intention of this experimentation is to determine how well current designers are considering the needs not only of the mass-market, but also those users and consumers that are often neglected in the design process. By assessing both the learning effects that occur whilst a user interacts with a novel product freely available on the High Street, it is possible to observe any difficulties users experience. If these difficulties can be directly attributed to the product in question, the opportunity lies to improve the design and enhance the products ease of use.

Regardless of whether the participant is interacting with an established product with which the user is familiar, or a new, novel, device that the user has not previously encountered, the product's design can significantly influence the ease with which both the product and situation is correctly perceived, understood, and an appropriate response initiated (Kletz, 2001). In these terms, the experiments conducted were predominantly designed to elicit information regarding user experience and the effects of prior experience upon interaction.

3.4 Cross-Experimental Consistencies

A number of deliberate consistencies are apparent within the experimentation conducted. The recurring facets will be introduced here, in order to avoid future repetition. Where differences occurred, specific referral will be made within each experimental report.

3.4.1 Hazard Analysis, Risk and Ethics Assessment

Prior to all experimentation, a comprehensive Hazard Analysis and Risk Assessment were performed to ensure no participants or practitioners were placed in an unsafe environment or situation. This involved discussions between the Department of Engineering Health & Safety Officer, the Chairman of the Health & Safety Committee, and the Researcher. A Risk Assessment Record was subsequently drafted and approved (Appendix 1). The record specified issues regarding data collection and protection and these were made explicit within a Consent Form (Appendix 2) that was developed in accordance with the Cambridge University Engineering Department Official Consent Form Guide (Camtools, 2011). This was signed by each individual prior to participation, and informed participants that although a recording would be made, only members of the research team would have access to the recordings and collected data. The consent form also reinforced that participants were able to discontinue participation at any time without comment and that confidentiality would be protected at all times. Ethically, it was imperative that a sensitive and person-centred approach to the research was adopted as the research involved issues affecting individuals from a myriad of backgrounds, possessing different capabilities, experiences and expectations. Whilst it was important to determine the abilities of older and younger people, it was not pursued at a cost to their personal well-being or to the detriment of their self-belief.

3.4.2 Experimental Protocols

Protocols were developed for each experiment to maintain consistency and minimise the encroachment of extraneous variables (Appendix 3). All experimental sessions occurred in a laboratory setting, the set up for which can be observed in the following experimental reports. Every effort was taken to ensure that the participant experience was identical, to ensure the only differences in performance were due to the individual differences of participants.

The tasks participants were given to complete were randomised in the second and third experiments to minimise any order effects or learning that could occur as a by-product of exposure to the tasks and the interactional requirements of the product. This development was pursued following the initial pilot study where, although practice effects were not directly observed with such a small number of participants (3), it was realised this was an extraneous variable that could encroach when conducting the larger experiments.

The nature and requirement of each task was conveyed, and with the participants verbalised and written consent, experimentation began. The conclusion of each session provided a further opportunity for discussion, and allowed the experimenter to place the current research in the context of the overall subject area and the contributions made by participation. All experiments shared the same methodological approach and data capturing tools.

3.4.3 Cantabeclipse Cognitive Assessment Tool

The Cantabeclipse Cognitive Assessment Tool (Cambridge Cognition, 2011) is a system offering assessment of short-term memory ability, coordination and motor skills and it was possible to subsequently examine the results according to age group membership. Further, as a tool, it was capable of verifying that age differences in performance were not limited to the product interaction experiment alone. Two tests were used. The Motor Screening (MOT) test is intended to relax participants and introduce them to the touch screen interface and provides a stimulus-response reaction time. The Spatial Span (SSP) test is a computerised version of the Corsi Block Task - a visuospatial analogue of the verbal-memory span task (Milner, 1971) and can be used to assess short-term memory and neuropsychological impairment (Figure 12).

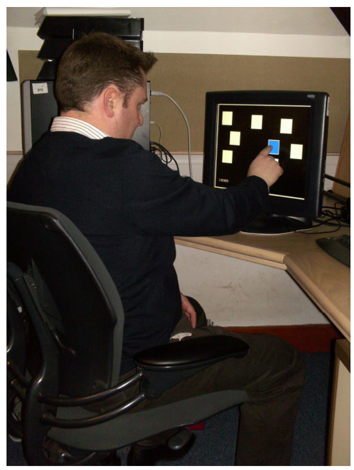

Figure 12: Participant completing the Cantabeclipse SSP test

The test presents nine block items to individuals in a specific order. The spatial memory span refers to the number of items for which an individual can correctly remember and repeat the sequence of block presentation: the maximum possible within the test being nine items. This conforms to Miller's (1956) observation that the memory span or length of adults is on average seven (plus or minus two) items. Hence, a 'low' of 5 or 'high' of items 9 items are well within the normal range, but performance can be subject to age effects (Clark et al., 2006).

Experimental control was maintained by conducting the experiments within a usability laboratory, capable of providing consistent lighting, noise and temperature levels and the apparatus used was arranged identically for each participant to prevent the encroachment of perceivable extraneous variables.

3.4.4 Data Capture Video Recording Equipment

A Sony Super Steady Shot Digital HandyCam (DCR-PC101E PAL) with 120x Digital Zoom was used to record participant verbalisations and interactional behaviour in conjunction with Verbatim Digital Video Cassettes. The recorded video-data was analysed to verify how the concurrent protocols provided by participants corresponded to their behaviour. The subsequent interview-phase material was intended to yield qualitative data upon user perception of interaction to confirm overall levels of product understanding. For reference, the concurrent protocols, interview material and observed interactional behaviour are reproduced in the technical report *User Experiences of Product Interaction* (Wilkinson, 2011), published by the Engineering Department, University of Cambridge.

3.4.5 Other Equipment

In all studies, a table lamp with 60 watt bulb was used for experimental purposes. Initially, the household product under investigation monitored and calculated the cost of energy it consumed. Latterly, it facilitated the second product under investigation detecting the flow of electricity to it. In this experiment three jigs were also developed behind which were located a metal and wooden stud, and an electrical cable. A fourth jig was developed to facilitate and simulate hanging the product as intended, on a wall. A universal stand supported each jig in question.

3.4.6 Experimental Sample Acquisition

For the purposes of efficiency and speed, the initial pilot study utilised a small number of Cambridge University graduates and a member of staff from a local college. It is acknowledged in terms of ecological validity and the opportunity to generalise the findings to a larger proportion of the population, this should be seen as imperfect (Howitt & Cramer, 2007). Although not necessarily representative of the 'average' user, it was, however, deemed appropriate to gain relevant data for the purpose of the preliminary study and to justify further, more empirically valid sampling and investigation. This was focussed upon in the latter studies, and a number of recruitment avenues were followed in order to glean a more representative sample of the general population, and thus facilitate a more ecologically sound assessment of the research findings. There was a two-fold criterion for the sample selection process in that there was a required age specification (16-80) and a desire to recruit a mixture of participants from a wide range of different social and educational backgrounds. This encapsulated the aim of approaching a representative sample from which to generalise, although scientific verification was not conducted.

With the experimentation being conducted within Cambridge itself, the focus for participant recruitment fell within the local community, although a number of national and international organisations were involved including social networking sites such as Twitter, Tagged, The Rev Counter, and Bikerbook. Other local organisations whom print in paper-based and online media were also utilised: The Cambridge Network, Hardwick Happenings, Langstanton Life Magazine, Cambridge Older Persons Enterprise, Histon & Impington Online, CamCreative Network, and Girton Village News. The remaining local and national recruitment streams involved advertising within local charity shops and Cambridge University colleges, Age Concern, the University of the Third Age, a number of Higher Education institutions, and on the researchers own Engineering Department Profile Page. The style of recruitment and advertising varied slightly across formats, examples of which can be perused in Appendix 4.

As recompense for participation, a free tour of the Engineering Department was offered with the possibility, if desired, of being rewarded with a £5 Amazon voucher. Rewarding participants in this way is a controversial issue, however the voucher approach is deemed more ethical than a direct financial reward. Often the voucher was declined in return solely for the opportunity to visit the Engineering Department of the University of Cambridge.

Gaining entirely impartial participants possessing no vested interest in participating within research is extremely difficult. However, methods were sought to minimise this as much as possible, and it was felt that the compromise made was justifiable in light of the results and contribution toward the research and the overall research area gained.

3.4.7 Participant Age Ranges

Exploring generational effects upon product interaction involves studying a broad age range of product users. Consistent throughout experimentation, participants were assigned to one of three age groups: 16-25, 26-59 and 60-80. The justification for this approach will follow.

As has been mentioned, for the purposes of this research, older people and the older generation are defined as those belonging to the age-range of 60-80 years of age to allow examination of age-related differences in terms of prior experience and interaction in comparison with younger groups of users. In order to investigate if the generational effects described by Docampo-Rama (2001) and Freudenthal (2001) exist (that those under the age of 25 are capable of adapting and interacting more effectively with technology than those over the age of 25), a younger generational age group was thus formed. This created a mid age group that consisted of participants between the ages of 26-59. This coincides with the fact significant human physical and psychological development takes place from childhood, largely stabilising during the early to mid-twenties (National Institute of Health, 2005, Educational Informatics, 2010). Once attained, there is a period of relative stability in terms of physical and psychological ability or development, until approximately the age of 60 or late adulthood, when physical and cognitive degradation often occurs (Clark et al., 2006).

By separating the sample into three groups: 16-25, 26-59 and 60-80, the intention is to evaluate the results in terms of verifying if cognitive development and ability (having increased from birth and stabilised around the age of 25) may be an additional factor that contributes to those under the age of 25 being able to interact with modern technology products more effectively in comparison with those over the age of 25 in accordance with Docampo-Rama's (2001) and Freudenthal's (2001) proposals. Although Clark et al. (2006) suggest the next phase of cognitive alteration – a decline in cognitive ability – generally occurs due to natural atrophy from the age of 60, no participants were shown to be affected by severe cognitive impairment as verified with the application of the Cantabeclipse Cognitive Assessment Tool (Cambridge Cognition, 2011). Age-related differences were apparent, however, in terms of cognitive assessment performance, technological experience, and interactional ability, according to the separation strategy utilised.

Thus, though these age groups may appear irregular, they have been found to be capable of elucidating differences according to age group membership, in terms of task and interaction performance, and in extent and form of prior knowledge (Wilkinson et al., 2010b).

It is acknowledged that it would be experimentally ideal to separate age groups more granularly and involve larger numbers of participants. However, a realistic approach to considering the financial, experimental and practical resources was also required. It was considered that the increased cost and demand upon time and resources would have been unlikely to provide substantially greater qualitative or quantitative output. Ultimately, the approach adopted has been seen to yield sufficient, effective, and internationally competitive results, as evidenced and verified in the studies themselves and in various, subsequent, peer-reviewed publications (Wilkinson et al., 2009, 2010a, 2011a).

3.4.8 Data Analysis

The raw data gleaned from the studies appear in Appendix 5, and where applicable, all data were analysed using SPSS 17, the Statistical Package for the Social Sciences (SPSS Statistics, 2011). Some analysis was conducted utilising the Log 10 Transform, to stabilise the variance and normalise the data for the purposes of statistical analysis (O'Hara & Payne, 1998, 1999). The SPSS output is reproduced and available in Appendix 6. Finally, some data sets were removed from the studies due to being incomplete or incorrectly completed.

3.5 Remaining Experimental Features

This section details the remaining commonalities between experiments, including the apparatus and approaches, and rationales for their use.

3.5.1 Rationale for Novel Product Use

One overarching research aim was to investigate how product learning occurs and how product conceptualisations develop with exposure. An interest also lay in determining the usability and learnability of an existing household product, particularly from the perspective of older users. A key question was to ascertain if individuals identify familiar interface elements and combine them with experiential learning through skill, rule and knowledge-based behaviour, and whether internalised concepts are facilitatory toward subsequent product interaction performance. New-to-market, high street products were used to minimise the extent of participants' previous exposure and prior experience, and were representative of general products individuals of any age may purchase. This provided the opportunity to investigate how users' mental models and acquisition of knowledge developed over time, exposure and experience. Other areas of interest to this research included the effects of natural atrophy and ageing, generational effects, and the effects of prior experience upon interaction (Figure 13).

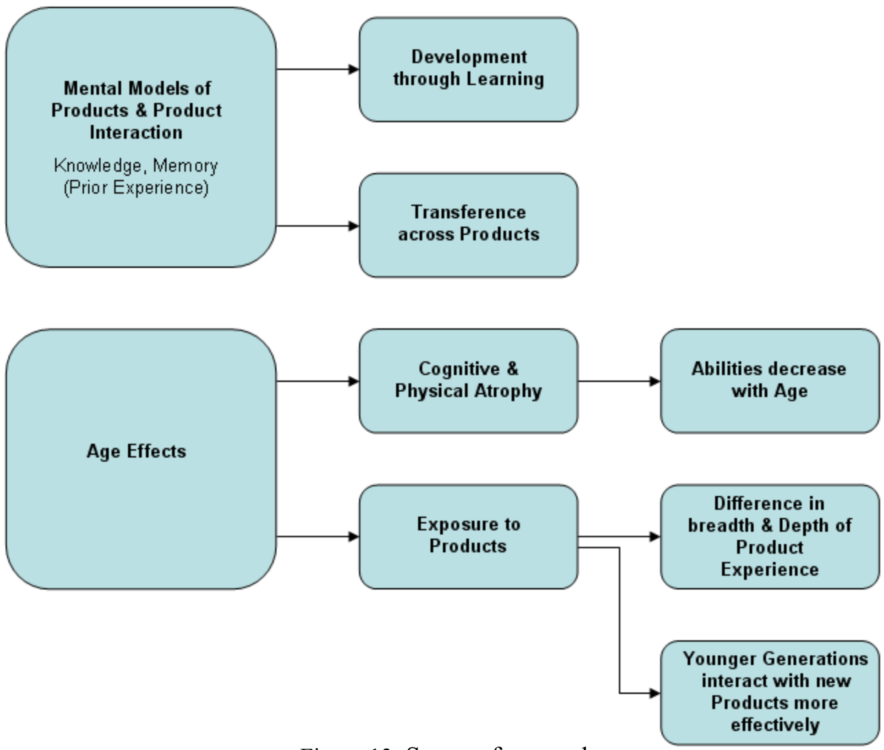

Figure 13: Scope of research

Presenting participants with novel products and asking for their initial understanding of them allowed the identification of pre-conceptions held or initially developed. After completing tasks with the products whilst providing concurrent protocol, the initial questioning was duplicated. Following further product exposure, the questioning was repeated in a post-interaction discussion. This gained clarity on individuals developing understanding and internalised conceptualisations, and ascertained if and how conceptualisations were modified through product exposure and interaction over time. The intention was to elicit information that would allow differentiation between knowledge possessed before product exposure, and the knowledge possessed post-exposure. This would then facilitate the identification of the knowledge acquired *due* to interaction. Efforts were also made to observe knowledge acquisition. Framing behaviour in terms of the SRK structure, allowed the identification and determination of where, when, and what knowledge was acquired during interaction.

The products used possess some similarities but can equally be seen as contrasting. Both are novel, but one presents a traditional, ubiquitous, design form, and the other exudes a unique and bespoke aesthetical design (Figure 14). Regardless of these differences, both products effectively permitted study of knowledge acquisition, the identification of product features and their effects, and participant performance and behaviour (Wilkinson et al., 2010a, 2011a).

Figure 14: Novel Products used in experimentation: Electricity Cost & Usage Calculator and Laserplus Laser-Level

3.5.2 Instruction Manual Prohibition

Within experimentation, the products instruction manuals were not provided to participants. This ensured it was only the devices ability to communicate with the user and vice-versa that was being observed, and allowed assessment of how effectively the product facilitated this aim. This approach mirrors industry sentiment toward designing for product accessibility: “If it requires a manual, maybe it's too complex" (Gerard Kleisterlee, President and CEO, Philips Electronics, 2004). In research that will be outlined in due course, there is also empirical evidence that significant numbers of participants in an online survey admitted their reluctance and avoidance of reading manuals for both new and old products. This is seen as good justification for using novel products without providing participants with instruction manuals, and as an experimental approach, ecologically valid. The research aim then, was to understand and gain evidence for problems experienced in interaction, and by understanding more about how learning occurs, attempt to illuminate how learning can be facilitated and complexity reduced in novel product interaction.

3.5.3 The Administration of the Technological Familiarity Questionnaire

The use of a prior experience questionnaire to elicit information regarding individuals experience with products, the frequency with which they were used and the brands with which they were familiar, is well documented within the work of Langdon (2010). The approach was adopted in this research to determine individuals' experience of specific contemporary products and the features of these products that individuals were familiar with. The 'Technological Familiarity Questionnaire' (TFQ) used originates from the work of Blackler (2006) and was modified slightly in the two former studies, detailing a larger range of both contemporary and less-contemporary products than before (Appendix 7).

In all cases, two general questions are asked about a list of products:

- *How often do you use the following products?*
- *When using the products, how many features of the product are you familiar with and do you use?*

The available responses to the first question ranged from '*Every day'* to '*Never'* and responses to the second question ranged from '*All of the features (you read the manual to check them)*' to '*None of the features – you do not use the product*'. The latter questionnaire also gave participants the opportunity to record any items they may have thought of, or felt they were influenced by, whilst interacting with the novel product. This allowed further exploration into the kinds of technology participants regularly engaged with, and illuminated any potential product features participants felt crossed over from their existing knowledge of products, to the novel device they were presented with.

All responses were analysed following Blackler's rating protocol that provided individual scores for each question and an overall score for Technological Familiarity (Appendix 8). A correlation is observable between score and experience – a high score being indicative of greater experience and familiarity, and a low score representing a lower level of technological experience and familiarity. This approach to identifying products and elements of individuals' prior experience and technological familiarity was capable of efficiently yielding consistent and significant data again evidenced in publication (Wilkinson et al., 2009, 2010a, 2011a).

3.6 Application of the Experimental Approach to the Research Themes

The experimental work was crafted in three stages – a pilot study and two main studies. The pilot study was conducted to validate that the experimental methodology developed would be capable of gleaning suitable information. At this stage the investigation focussed upon mental model development, generational differences, and differences in prior experience of technology. The second study continued these themes, introducing a refined procedure that utilised a larger sample. The third study investigated mental model development, generational differences, and the extent of prior experience with a range of products. It also addressed the concept of learning development and knowledge acquisition during the process of product exposure. Two further investigations were conducted. The initial one administered the TFQ on a larger scale, in an online format. Investigating differences according to age and product experience, it also illuminated the instruction manual reading behaviour adopted by users. The final investigation classifying user behaviour in terms of skill, rule and knowledge-based activity according to the Rasmussen (1993) model, again highlighted differences according to age. The intention of this latter study was to draw out greater information about what occurs during interaction on a more granular level: where, when and what knowledge is acquired during the process of interaction, how design might influence this, and the effects of age upon these processes.

3.6.1 Research Plan

As previously detailed, the overarching research question has been subdivided into three separate research aims. The overarching research question will be reiterated and the subcomponent research aims presented below, prior to the presentation of the overall research plan, over the following pages. The research plan includes the individual questions posed, the methodology used to address the research questions, and the location of the corresponding analysis and discussion.

Overarching research question:

Is there further knowledge to be gained for the design community from the study of generational differences in terms of prior experience and contemporary product interaction?

Subcomponent research aims:

1. *To investigate the existence of age-effects regarding prior experience and any associated effects upon interaction with a number of household products*

2. *To verify if a correlation between product experience and age exists on a larger scale, outside of an experimental setting, and to investigate the extent to which individuals self-report using or avoiding instruction manuals when interacting with products and the associated implications for design and designers*

3. *To investigate the efficacy of framing interaction in terms of Rasmussen's (1993) Skill, Rule and Knowledge-based Model of behaviour and thereby determine how knowledge acquisition is facilitated and identify instances of interactional complexity.*

Subcomponent 1 Research Aim:
To investigate the existence of age-effects regarding prior experience and their effect upon interaction with a number of household products (household electricity monitor and electronic laser-level product).

Research Question	Analysis Method	Analysis	Discussion
1: Is it possible to determine the existence of age-effects regarding physical approaches to interaction?	Assessment of how task-completion-times, number of button presses, erroneous interaction, and mean time for individual button presses vary according to age	5.6.2 6.5.2	9.1.1
2: Is it possible to determine the existence of age-effects regarding the level of icon recognition?	Assessment of initial and subsequent icon identification variance as a factor of age	6.5.2.2	9.1.2
3: Is it possible to determine the existence of age-effects regarding the level of product feature recognition?	Assessment of initial and subsequent feature recognition variance as a factor of age	6.5.2.3	9.1.3
4: Is it possible to determine the existence of age-effects regarding the numbers of products that participants are prompted of during interaction?	Assessment of the number of products participants are reminded of during interaction	5.7 6.5.2.4	9.1.4
5: Is it possible to determine the existence of age-effects regarding the extent of prior technological familiarity?	Assessment of the frequency of specific product interaction, specific feature use, and overall technological familiarity according to age	5.6.3 6.5.3	9.1.5
6: Is it possible to determine the existence of age-effects upon conceptual understanding?	Assessment of Concurrent Protocol Summary	5.6.4 6.5.4	9.1.6
7: Are there other generational or age-related differences in interactional approach observable?	Assessment and interpretation of observed interaction and participant commentary	5.7.1	9.1.7
8: Is learning and interaction facilitated by ease of feature and icon recognition, and age dependent?	Assessment and discussion of findings	6.6	9.1.8
Research Aim Conclusion			9.1.9

Subcomponent 2 Research Aim:
To verify if a correlation between product experience and age exists on a larger scale, outside of an experimental setting, and to investigate the extent to which individuals self-report using or avoiding instruction manuals when interacting with products and the associated implications for design and designers.

Research Question	Analysis Method	Analysis	Discussion
1: Is it possible to determine the existence of age-effects regarding the extent of prior technological familiarity in both an experimental and external setting?	Comparison of overall experimental and online technological familiarity questionnaire survey results	7.7.1	9.2.1
2: Is it possible to determine the existence of age-effects regarding manual reading behaviour in both an experimental and external setting?	Comparison of experimental and online survey results regarding manual reading behaviour	7.7.2	9.2.2
3: Is gender a factor in self-reported manual reading behaviour?	Comparison of experimental and online survey results regarding gender and manual reading behaviour	7.7.3	9.2.3
4: Are there design implications posed by users approaches to manual reading?	Consideration of experimental and literary findings	7.8 7.9	9.2.4
Research Aim Conclusion			9.2.5

Subcomponent 3 Research Aim:
To investigate the efficacy of applying the SRK framework at a granular level toward participant interaction to examine interactional complexity and knowledge acquisition.

Research Question	Analysis Method	Analysis	Discussion
1: Do users operate at different levels of SRK according to age?	Evidence based discussion of Section 8.5.1 and Table 25	8.5.1	9.3.1
2: Do users operate at different levels of SRK according to gender?	Evidence based discussion of Section 8.5.2 and Table 26	8.5.2	9.3.2
3: How and what knowledge is learned during interaction?	Overall assessment of SRK classification focussing upon knowledge acquisition and operation at the knowledge-based level	8.6.1	9.3.3
4: Is there a relationship between age, experience and level of interactional complexity?	Conclusion of SRK classification including reference to data regarding age, experience and interactional complexity	8.7	9.3.4
Research Aim Conclusion			9.3.5

The combined aims of each study have been presented above, including the methodology for addressing the individual research questions posed. Chapters 4 to 6 will detail each experiment, including the rationale, procedure and results. Chapter 7 will present the Online Survey examining prior product experience, and Chapter 8 will focus upon the application of the SRK classification scheme toward product interaction in order to identify instances of interactional complexity. Finally, Chapter 9 will present the overall findings and conclusions of the research in terms of the Research Plan outlined in this chapter.

4: Investigation 1: Pilot Study

The previous section detailed the justification for the experimental approach adopted, explained the techniques that were to be used, and the areas upon which the investigation would focus. This chapter focuses upon the development and assessment of the experimental methodology.

4.1 Introduction

The pilot study was instigated to verify that an appropriate methodology for relevant data capture had been developed. The experiment was designed to determine the development of mental models during product interaction and exposure, the existence of any generational differences in performance or technological prior experience, and to capture differences in knowledge acquisition and learning. The study itself possesses no statistical validity on account of the sample size, and the allocation of participants is merely presented to introduce and convey the development and verification of an appropriate experimental approach.

4.1.1 Participant Sample

By way of example, 3 individuals were assigned to the age ranges that would be used in later studies: 16-25 (25 year old female), 26-59 (26 year old male) and 60-80 (60 year old male).

4.1.2 Novel Product

The household product used was a Plug-in Electricity Cost and Usage Calculator manufactured by Nikkai Power (Figure 14). Capable of monitoring the power consumption of electrical devices attached to it and, once the current unit cost of electricity has been entered, the calculator can display how much the device consumes both electrically and financially. This product was selected due to its novel nature; it being comparatively new to market in the United Kingdom. This was intended to limit the preconceptions participants would bring to the experimentation, allowing focus upon interactional design issues, and to determine how effectively it facilitated learning and the development of appropriate mental models. The Technological Familiarity Questionnaire (TFQ) was designed to identify any participants already aware or familiar with the product, to ensure this could be taken into account during subsequent data analysis.

4.1.3 Research Materials and Equipment

Participants were presented with the novel household product and requested to use it to complete 6 tasks, the optimum interaction technique for which was predetermined (Appendix 9). The apparatus consisted of the novel Plug-in Electricity Cost and Usage Calculator and a desk lamp with a standard 60 watt bulb used in each trial (Figure 15).

Figure 15: Experimental set-up

A Sony Digital HandyCam was used to record participant verbalisations and interactional behaviour. Cantabeclipse software ensured all participants were sufficiently hand-eye coordinated and provided the opportunity to detect other age-related differences in performance. Technological Familiarity Questionnaires and Standardised Interview Protocols were developed to ensure consistency between trials. Participants underwent Cantabeclipse assessment, were initially presented with the product and then asked their understanding of it.

4.2 Data Analysis

The recorded video-data was analysed to verify how the concurrent protocol corresponded to the user's actions, assessment of task completion times, and rates of error. Analysis would also indicate if participants took longer to achieve task completion, according to age-group. The interview-phase material was intended to yield qualitative data upon user perception of interaction to confirm their overall level of product understanding. This would potentially elicit useful information about how individuals internalise understanding or representations of products and their interaction, and how in conjunction with their perceptions, interaction is influenced. The Task Familiarity Questionnaire administered asked two questions regarding a list of contemporary products; "How often do you use the following products?" and "When using the products, how many features of the product are you familiar with and do you use?" Answers were then rated according to Blackler's (2006) protocol which provided individual and overall TFQ scores (Appendix 8).

4.3 Procedure

Participants were initially presented with the product and asked their views upon it to gauge any pre-experimentation conceptions they possessed about it. At mid-way and end points this was repeated in an attempt to ascertain if their conception of the product had been developed or modified through interaction, and potentially to determine if their conception was accurate and therefore assistive toward task completion. Further discussion in this phase centred upon each participant's recognition of any familiar features observed in the product and at what stage (if at all) the participants felt they understood the product and interaction.

Protocol:

- Explain experimental requirements and administer consent form
- Administer pre-test Cognitive Assessment using Cantabeclipse
- Video-record participant exposure to the product and ask them to complete six tasks with it whilst providing a verbal commentary or concurrent protocol. The tasks were:
    - Find the lowest wattage reading for the device attached to the product.
    - Find the current reading for the device attached to the product.
    - Set Unit Cost Price to 99.50 £/kWh.
    - Find the frequency reading for the device attached to the product.
    - Find out how much the device attached to this product has consumed.
    - Find the highest wattage reading for the device attached to the product.
- Record participant reaction to the product at initial exposure, mid-way through the completion of tasks, and after the task completion phase.
- Administer the Technology Familiarity Questionnaire (TFQ).
- Participant Debrief

4.4 Results

4.4.1 Cantabeclipse Cognitive Assessment Summary

The initial test (MOT) based upon reaction time data and screening for vision, hearing, movement and comprehension impairment, highlighted no issues. The second test (SSP), designed to assess working memory capacity, indicated minimal differences between age groups, the participant in the 26-59 age group performing slightly better.

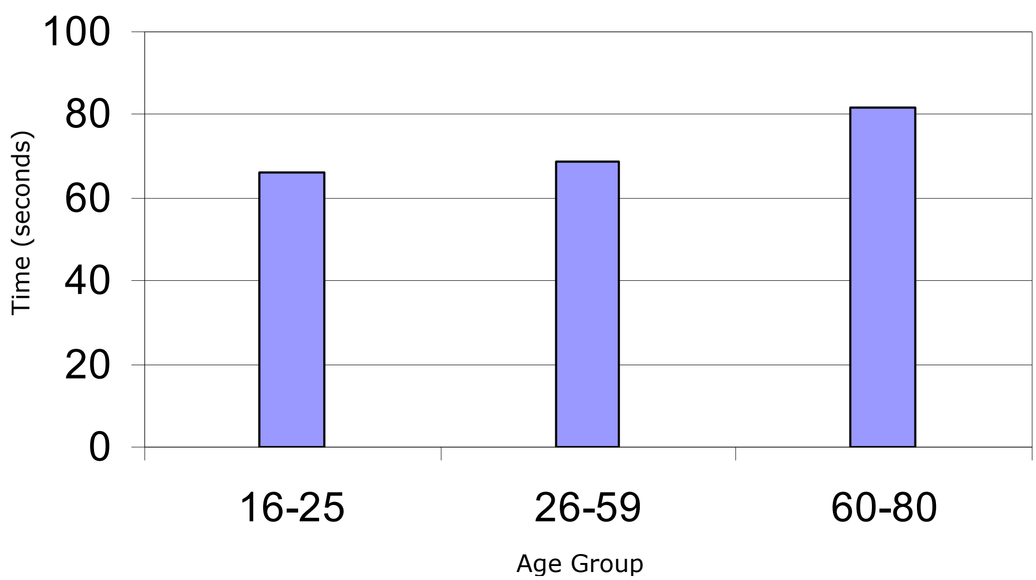

Figure 16: Reaction times according to age group membership (n = 3)

The participant in the 16-25 age group completed the task the quickest, and the participant in the 60-80 age group took the longest: the 16-25 age group completed the task in 66 seconds, and the participants in the 26-59 and 60-80 age groups in 69 and 78 seconds (Figure 16).

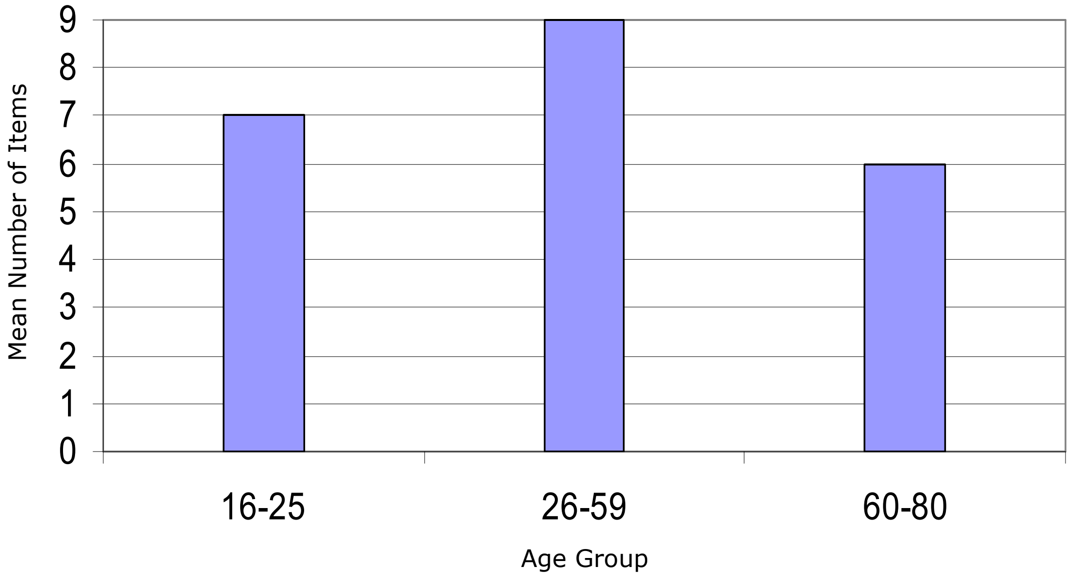

Figure 17: Number of remembered items according to age group membership (n = 3)

The SSP Test designed to assess working memory capacity indicated that the participant in the 26-59 age group remembered 9 items in comparison with the participant in the 16-25 group whom remembered 7 items and the participant in the 60-80 age group, who remembered 6 (Figure 17). All results fell within Miller's (1956) expected range of 7 +/- 2 items, the maximum possible within the test being 9 items.

4.4.2 Interaction Data

It is evident that the participant in the 16-25 age group had a lower average number of button responses than either of the other age groups, with the participant in the 26-59 age group recording the greatest average number. This trend was repeated regarding rates of error. Task completion times were more variable; the participant in the older age group completing tasks quicker than both the participants in the 16-25 and 26-59 age groups. The participant in the 60-80 age group also exhibited the lowest average time per button press, followed by the 26-59 age group and the 16-25 age group respectively (Table 1).

Mean Data	16-25	26-59	60-80
1. Mean number of button presses	24.6	44.5	40.5
2. Mean rates of error	19.6	39.5	35.5
3. Mean task completion times (seconds)	121.6	203.3	103.1
4. Mean times per button press	4.13	2.98	2.28

Table 1: Interaction Data Results Overview

1: Total number of button presses divided by the number of tasks.
2: Error calculated by subtracting the theoretically-possible minimum number of button presses required to achieve desired state from the number of button presses made (Rasmussen, 1990b).
3: Total task completion times divided by the number of tasks.
4: Total number of button presses divided by time taken.

4.4.3 TFQ Score Comparison

The administration of the TFQ provided an opportunity for experimentation to establish the extent to which each participant interacted with technology on a regular basis, and the number of different products and interfaces they are familiar with (Table 2).

	16-25	26-59	60-80
Question 1: Frequency of specific product interaction	28	20	28
Question 2: Frequency of product feature usage	13	16	18
Overall TF Score	41	36	46

Table 2: Technological Familiarity Questionnaire (TFQ) Results

Although literature would suggest younger generations have greater familiarity with new technology than older generations, in this pilot study it is the older generation that yield the highest technological familiarity score, indicating they have a greater knowledge of different devices and interact with them more regularly. However, the minimal sample may account for this and hence it would be inappropriate to draw major conclusions in this particular instance.

4.4.4 Concurrent Protocol Summary

All participants referred to the Function button, particularly in the early stages. They rapidly learned the functionality it represented but all exhibited and voiced difficulty in attempting to complete Task 3, as the functionality represented by the alternative buttons appears to have been less apparent. All participants were able to reference other products they felt held a degree of similarity with the novel product presented, and a consensus centred around watches in particular. Participants stated this was because watch interaction often presents multi-functionality through a single button clicked multiple times, as does the novel product. In the case of the novel product, there is a requirement to depress button 1 (Function) and to hold-down the remaining buttons in a specific order to set the device. The outward aesthetic of the device was also mentioned, being referred to as reminiscent of an old mobile phone and the display appeared: "dated like an early seventies calculator". The response of the participants regarding their overall concept of the product was largely similar. Relevant and accurate inferences about the product were made from the beginning, all participants correctly assuming that the product was electrical in nature, and something into which an electrical device was inserted. By the mid-way questioning phase, the participant in the 16-25 age group correctly identified the purpose of the product, stating that: "…you're setting up the cost price – pound per kilowatt hour and then it records how much has been spent on electricity – it's basically just recording your usage". The remaining test and final discussion stage confirmed the development of participants' internal concepts of the device. For further reference, please refer to the technical report *User Experiences of Product Interaction* (Wilkinson, 2011, pp.5-10).

4.5 Discussion

It is evident from Table 1 that the participant in the 16-25 age group had a lower average number of button responses than either of the other age groups. This participant also had a lower rate of error than either of the participants in the 26-59 or 60-80 age groups. In both instances the participants in the 26-59 and 60-80 age groups were similarly matched for number of average button presses and rates of error. Task completion times were more variable, with the participant in the older generation age group completing tasks quicker than both the participants in the 16-25 and 26-59 age groups. The concurrent protocol yielded revealing information about the formation of internalised concepts regarding the product presented. Uniformity was noted with regard to the fact that although all participants were unfamiliar with the novel product, all were aware Button 1 (Function) would adjust the cost setting; it was the sole button selected to achieve that specific goal. By the end of the testing phase participants belonging to the younger age groups had both accurately modified their concepts of, and identified, the actual product's purpose. It is arguable that the concept described by the participant in the 60-80 age group had been modified, although perhaps not as accurately. The frequent admission by participants that they were adopting a random button press approach toward goal achievement, with little or no intention to think about a plausible solution to task achievement, is acknowledged as a significant experimental problem. However, this is often the approach adopted by individuals in the real world and reported in literature, and so maintains ecological validity (Sarker & Wells, 2003). The Cantabeclipse Cognitive Assessment results, indicating that participants in the younger age groups performed better than the 60-80 age group, concur with Lewis et al.'s (2008) and Blackler's (2007) findings regarding age and performance, although within the product interaction phase this was uniformly not upheld. A summary detailing the development of participants interactional and product knowledge over the course of exposure and time is presented below (Figure 18).

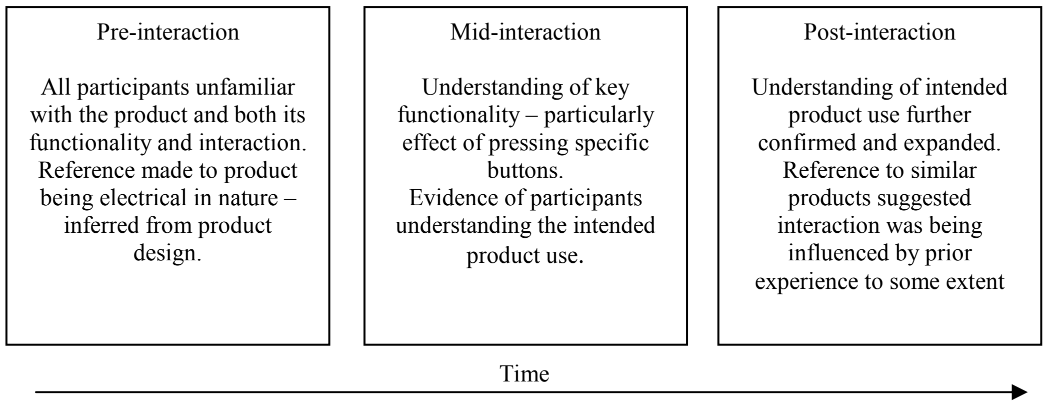

Figure 18: Summarised development of understanding over time, influencing product concept

4.6 Conclusion and Summary

The aim of the Pilot study was to verify a methodology capable of determining the existence (or otherwise) of age-effects regarding prior experience and their effect upon interaction. The experiment was also designed to examine the development of conceptual understanding during product interaction. The older age group's approach to task completion saw them produce neither the largest number of button presses, or attempts toward task completion, nor possessing the greatest rate of error. Task completion times for the 60-80 age group were the quickest within the study. The subsequent larger-scale study would investigate if this was a consistent effect and one that correlated with technological familiarity, as this age group also possessed the highest technological familiarity score. The results contributed to not only verifying the approach was experimentally sound, but also in providing justification for the further investigation of how and where design may hinder or compromise product usability. The next chapter details the subsequent study of these themes through experimentation that utilises a more appropriate sample of some 30 participants.

5: Investigation 2: Full Scale Study 1

The previous chapter detailed the developed methodology applied within a pilot study. Investigation 2 was largely identical, but utilised a larger and more representative study sample.

5.1 Introduction

Full Scale Study 1 sought to obtain information regarding the development of internalised concepts through product interaction and how interaction may have been influenced by design. Generational differences were examined and a larger sample size used in an attempt to present a more representative overview of the intricacies involved in interaction with the product.

5.1.1 Participant Sample

30 individuals from a variety of backgrounds were recruited to minimise educational biases and maximise ecological validity, although this wasn't verified. Participants were assigned to three age groups: 16-25 (10 participants), 26-59 (10 participants) and 60-80 (10 participants). The sample consisted of 18 males and 12 females. The age distribution is shown below (Figure 19).

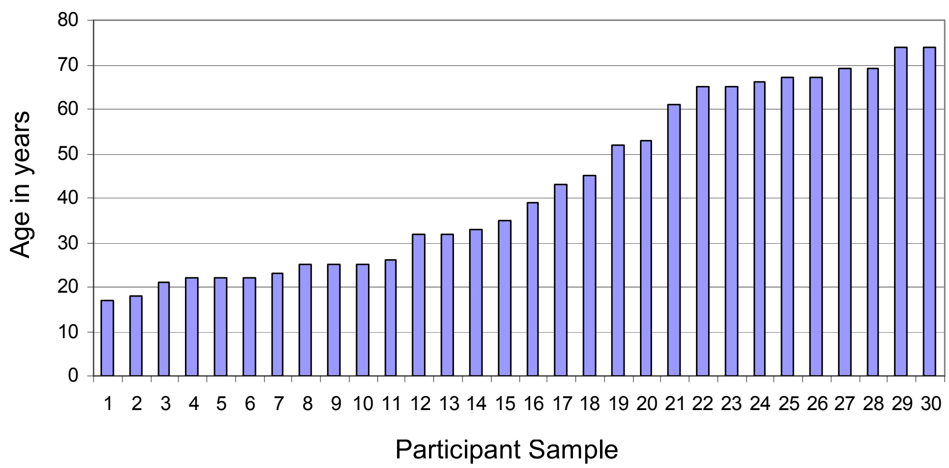

Figure 19: FSS1 Sample Age Distribution (n = 30)

Age Group	Mean	Standard Deviation
16-25	22	2.79
26-59	39	9.04
60-80	67.7	4.03

5.1.2 Research Materials and Equipment

Participants were presented with the novel household product and requested to complete 6 tasks that were randomised to minimise any order or learning effects. The most efficient interaction technique (minimum number of button presses, errors and task completion times) had been predetermined for later comparison. Again, the apparatus consisted of the Electricity Cost and Usage Calculator that was used to monitor the electrical consumption of a desk lamp with a standard 60w bulb.

The Sony Digital HandyCam was used to record participant verbalisations and interactional behaviour, and running the Cantabeclipse assessment ensured all participants possessed sufficient hand-eye coordination and motor skills, and allowed the investigation of other potential age-related differences. The Technological Familiarity Questionnaires (Appendix 7) were reused and standardised interview material developed to maintain consistency between trials. Again, following Cantabeclipse assessment, participants were initially presented with the product and then asked their understanding of it, throughout the course of experimentation.

5.2 Experimental Design

The experiment was a 2-factor mixed design comparing people's performance and mental model development according to observation of their interaction with a novel device and their expressed knowledge of technology. 30 participants were assigned to one of three groups according to age: 16-25 (10), 26-59 (10) and 60-80 (10).

The factors were:

- Between Subjects Factor: Age Group Membership
- Within Subjects Factor: Task Completion

The different aspects of performance and mental model development being measured as dependent variables were:

1. Task completion times
2. Number of Button Presses
3. Error Rate
4. Mean Time per Button Press
5. Technological Familiarity Questionnaire (TFQ) Score

Participant verbalisations, interactional behaviour, and semi-structured interview responses, were used to cross-reference participant understanding and mental model development.

5.2.1 Hypotheses

The expectation was that prior experience with similar products would affect users ability to interact with the product and that this might be age-related. To investigate this, the following hypotheses were proposed:

- There will be an effect of age upon task completion time
- There will be an effect of age upon number of button presses
- There will be an effect of age upon number of errors
- There will be an effect of age upon overall TFQ score or prior experience

5.3 Task Design

The six tasks (Appendix 9) were presented as follows:

1. Find the lowest wattage reading for the device attached to the product.
2. Find the current reading for the device attached to the product.
3. Set Unit Cost Price to 99.50 £/kWh.

4. Find the frequency reading for the device attached to the product.

5. Find out how much the device attached to this product has consumed.

6. Find the highest wattage reading for the device attached to the product.

Tasks were randomised, although as task 5 could only be achieved after completion of task 3, task 3 was provided during the first half of the experimental procedure and task 5 during the second half. Tasks remained numbered solely for identification purposes.

5.4 Data Analysis

Each participant's interactional behaviour was recorded to allow post-experimental analysis. Task completion times, total number of button presses, and button press error rates (the number of button presses made above the minimum required) were measured by subsequently reviewing the video-footage, and mean times per button press calculated. Errors in this context were viewed as unnecessary steps taken. This was in accordance with Rasmussen's (1990) views on task analysis, where discrete and specific steps toward task completion can be identified, and omission or ignorance of these steps are counted as errors. The recording of the session allowed the notation of participants' verbal responses during interaction and particularly the pre, mid, and post-experimental discussions. Verbalisations were noted in full and then analysed to extract information according to common themes. This included the quantification of the product concept: its purpose and operation as considered by participants initially, at the mid-way stage, and at the end. Interview material also yielded qualitative data upon user perception of interaction to confirm overall level of product understanding, and how this influenced interaction. The Technological Familiarity Questionnaire posed the same two questions as presented in the pilot study, regarding a list of contemporary products: "How often do you use the following products?” and “When using the products, how many features of the product are you familiar with and do you use?”. Responses were then rated according to Blackler’s (2006) protocol which provided individual Question TFQ Scores and an overall combined TFQ score (Appendix 8).

Other points of interest included which product interface features, if any, were deemed familiar to participants, and from which products these features originated. The aim being to determine any transference of knowledge from one product or interface to another. It was possible to formulate a list of frequently referenced products that either shared or possessed similar design features to also consider if feature familiarity facilitated learning, akin to the findings of Langdon et al. (2010).

5.5 Experimental Procedure

Participants were presented with the product and asked their views upon it to identify initial conceptions possessed. At mid-way and end points this was repeated to ascertain if these had been modified through interaction, and to determine the extent to which they had been assistive toward task completion.

Procedure:

- Explain experimental requirements and administer consent form
- Administer pre-test assessment using Cantabeclipse
- Video-record initial exposure to the product and ascertain participant understanding
- Record participant performing 3 randomised tasks whilst delivering concurrent protocol
- Record participant understanding of product and interaction at mid-way stage

- Continue recording the performance of the 3 remaining randomised tasks whilst the participant delivers the concurrent protocol
- Record participant understanding of product and interaction at task completion stage
- Commence semi-structured interview regarding participants' interaction experience
- Administer Technology Familiarity Questionnaire
- Debrief Participants

5.6 Results

5.6.1 Cantabeclipse Cognitive Assessment Summary

5.6.1.1 MOT Task Completion Time Assessment

The initial (MOT) reaction-time test that also screens for vision, hearing, movement and comprehension impairment, highlighted no neuropsychological issues, but indicated differences in performance times between the 26-59 and other age groups (Figure 20).

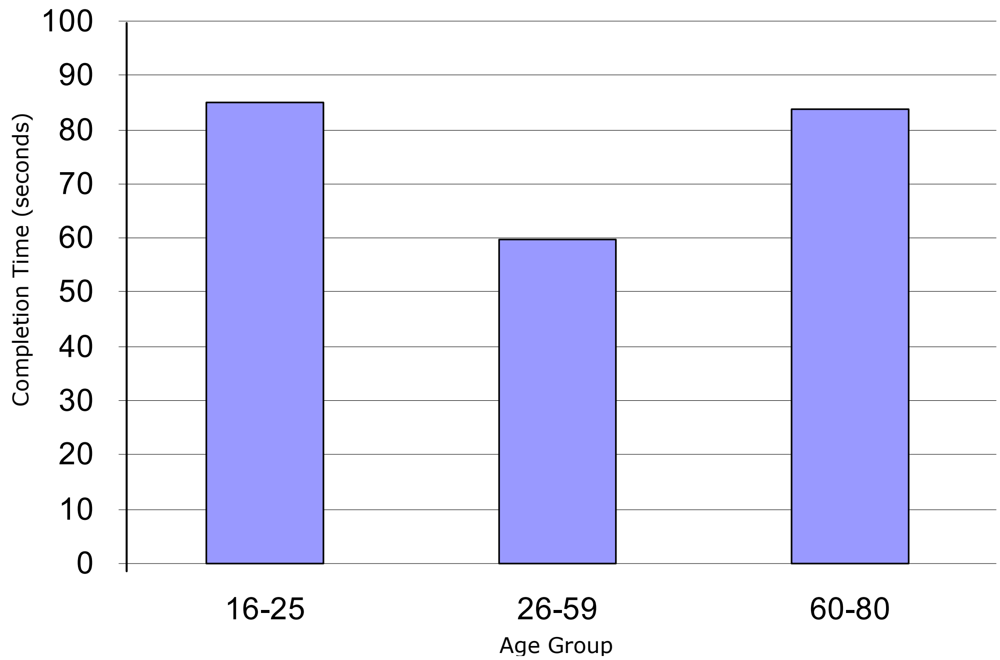

Figure 20: MOT task completion time comparison (n = 30)

A 1-way analysis of variance (ANOVA) showed no significant effect of age on MOT task completion time: $F (2, 27) = 0.865$, $p>0.01$. The 26-59 age group completed the MOT task the quickest, and the 16-25 age group took the longest; the 26-59 age group completing the task in 59.7 seconds, and the 16-25 and 60-80 age groups in 85 and 83.7 seconds respectively.

The relationship between Age and MOT task completion time was also investigated using Pearson product moment correlation coefficient, but no significant correlations were found.

5.6.1.2 SSP Memory Capacity Assessment

The SSP Test designed to assess working memory capacity indicated that the 26-59 age group on average remembered 7 items in comparison with the 16-25 group whom remembered 6.5 items and the 60-80 age group, who remembered 5 (Figure 21).

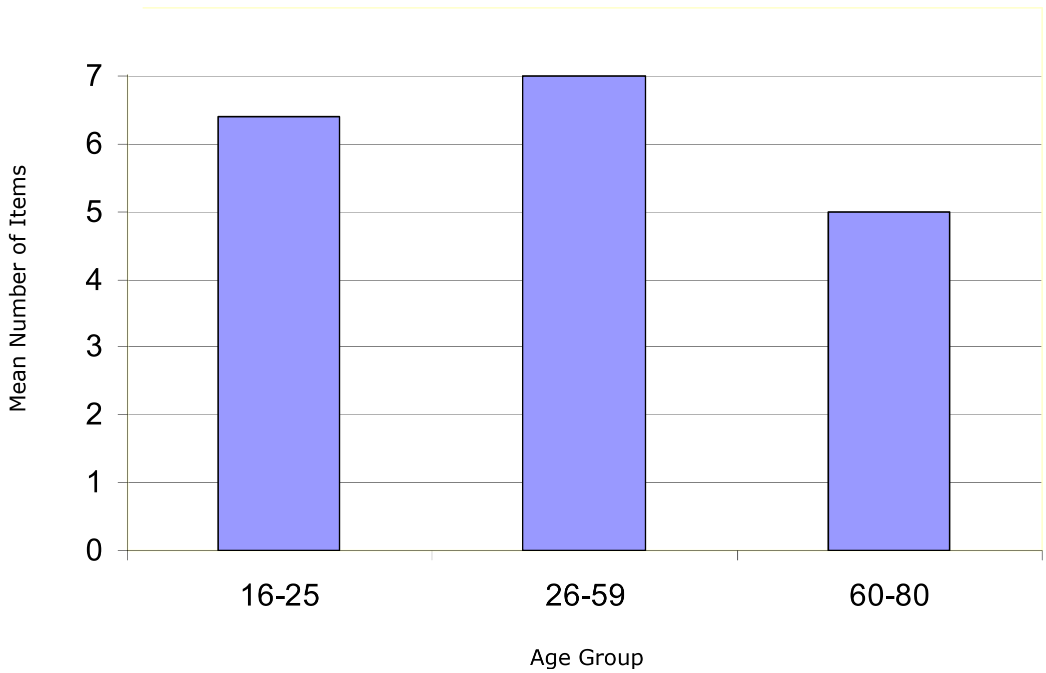

Figure 21: Memory span comparison (n = 30)

Assessing the effect of age upon SSP Memory Capacity, Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group (M = 5.0, SD = 1.24) was significantly different from the 26-59 age group (M = 7, SD = 1.33). However, the 16-25 age group results (M = 6.4, SD = 1.57) did not significantly differ from either the 26-59 or 60-80 age groups.

The relationship between Age and SSP Score was investigated using Pearson product-moment correlation coefficient. There was a moderate negative correlation between the two variables with a high level of Age associated with a low level of SSP Score (Table 3).

		Age		
		r	*p*	
FSS1	SSP Score	$r = -0.450$	0.013	$r = -0.450$ (30), $p < 0.05$

Table 3: Correlation coefficient results

This suggests that age is a factor in memory capability, and that as we age our memory capability decreases. Older participants recalled fewer items than the other age groups, although overall, the results fell within Miller's (1956) expected range of 7 +/- 2 items, the maximum possible within the test being 9 items.

5.6.2 Interaction Data

5.6.2.1 Task Completion Time Comparison

The older generation took longer to complete tasks 1 – 6 than both the younger age groups, with the 16-25 age group completing tasks in the quickest overall times (Figure 22).

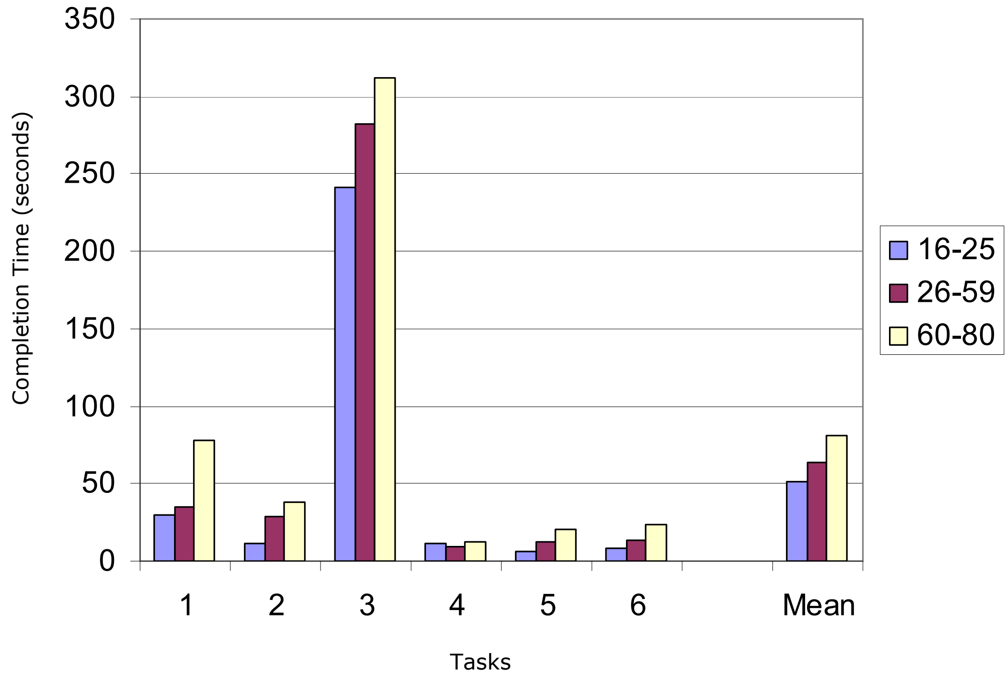

Figure 22: Task completion time data comparison

A multivariate analysis of variance (MANOVA) showed a significant effect of age on Task Completion Time (TCT): $F (2, 27) = 7.153$ $p<0.01$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 1.45$, $SD = 0.41$) was significantly different from that of the 16-25 age group ($M = 1.13$, $SD = 0.35$). However, the 26-59 age group results ($M = 1.34$, $SD = 0.30$) did not significantly differ from either of the remaining groups.

An anomaly clearly exists with regard to Task 3 task completion time in that it took much longer for all participants to complete this specific task in comparison with the remaining tasks. It should be noted that the results of Task 3 have thus skewed the overall task completion time mean values. Whilst the mean values are legitimate, their inclusion may have a misrepresentative or misleading effect upon the interpretation of the average task completion time, and the reader is urged to take this into consideration.

The relationship between Age and Task Completion Time was investigated using Pearson product-moment correlation coefficient on each of the individual tasks and the mean (Table 4).

		Age		
		r	*p*	
FSS1	TCT: T1	$r = 0.364$	0.048	$r = 0.364$ (30), $p < 0.05$
	TCT: T2	$r = 0.401$	0.028	$r = 0.401$ (30), $p < 0.05$
	TCT: T5	$r = 0.400$	0.028	$r = 0.400$ (30), $p < 0.05$
	TCT: T6	$r = 0.339$	0.034	$r = 0.339$ (30), $p < 0.05$
	TCT Mean: T1-6	$r = 0.482$	0.007	$r = 0.482$ (30), $p < 0.01$

Table 4: Correlation coefficient results

There were no other significant correlations.

In five instances there was a moderate positive correlation between the two variables with a low level of Age associated with a low level of Task Completion time. This suggests that age is a factor in the speed with which tasks were completed: as age increased, the speed with which these specific tasks were completed also increased.

5.6.2.2 Button Press Comparison

Figure 23 indicates that the older generation made a greater number of button presses toward task completion and the 16-25 age group made the fewest.

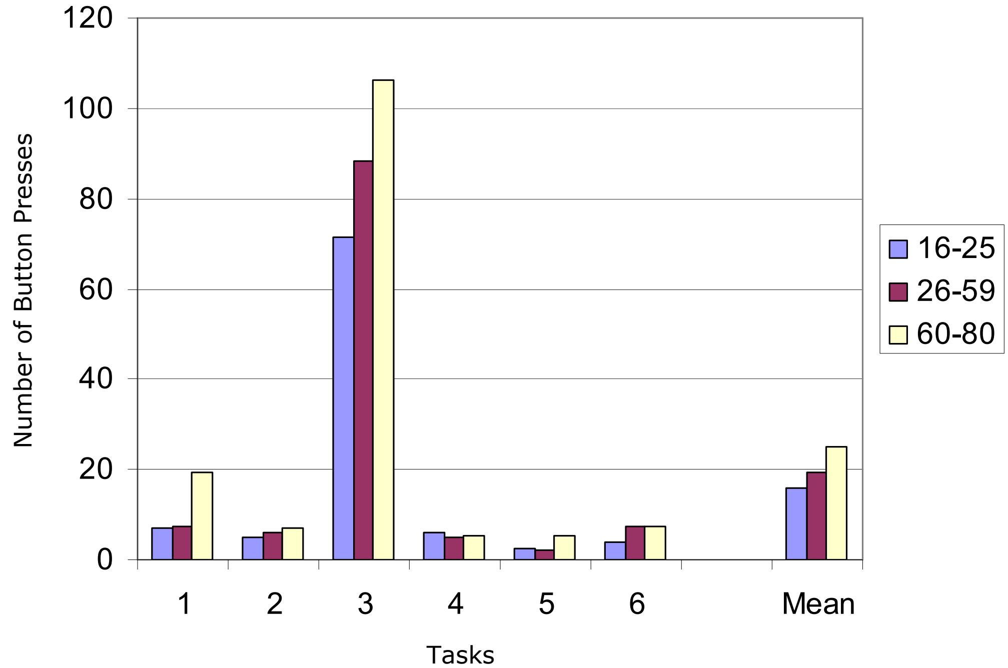

Figure 23: Button press data comparison

A multivariate analysis of variance (MANOVA) showed a significant effect of age on Number of Button Presses made to complete tasks: $F(2, 27) = 3.417$ $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 0.93$, $SD = 0.36$) was significantly different than the 16-25 age group ($M = 0.75$, $SD = 0.26$). However, the 26-59 age group results ($M = 0.56$, $SD = 0.30$) did not significantly differ from the remaining groups.

An anomaly clearly exists with regard to the number of button presses taken to complete Task 3 in that it required many more button presses for each participant to complete this specific task in comparison with the remaining tasks. It should be noted that the results of Task 3 have therefore skewed the mean values for number of button presses. The reader is urged to consider that whilst the mean values are legitimate, their inclusion may have a misrepresentative or misleading effect upon the interpretation of the average number of button presses made.

The relationship between Age and Button Press data was investigated using Pearson product-moment correlation coefficient and the significant correlations are presented below (Table 5).

		Age		
		r	*p*	
FSS1	NoBP/C: T1	$r = 0.398$	0.029	$r = 0.398$ (30), $p < 0.05$
	NoBP/C: Mean: T1-6	$r = 0.323$	0.041	$r = 0.323$ (30), $p < 0.05$

Table 5: Correlation coefficient results

There were no other significant correlations.

Increases in age correlate to a significant increase number of button presses made to complete task 1. Those in the older age group made more button presses to complete the task than the mid age group who, in turn, made more than the younger age group. There is also a positive correlation between age and average number of button presses, showing the same trend. This indicates that the older generation, in this instance, is not being as efficient interactionally as they might be or as design might facilitate them being.

5.6.2.3 Error Rate Comparison

The data regarding Error Rates indicated that the older generation made more errors during product interaction, followed by the 26-59 and 16-26 age groups respectively making fewer errors and exhibiting greater accuracy in their approaches (Figure 24).

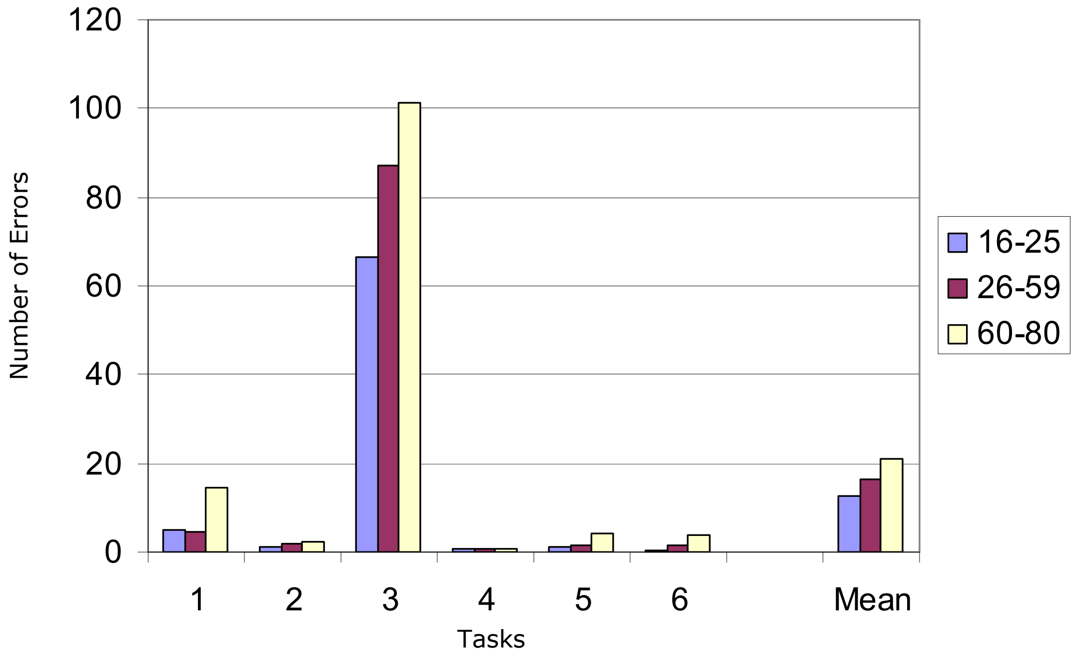

Figure 24: Error rate data comparison

A multivariate analysis of variance (MANOVA) showed a significant effect of age on Number of Errors made whilst completing tasks: F (2, 27) = 3.440 $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group (M = 0.61, SD = 0.42) was significantly different than the 16-25 age group (M = 0.40, SD = 0.32). However, the 26-59 age group results (M = 0.48, SD = 0.33) did not significantly differ from the remaining groups.

Again, an anomaly clearly exists with regard to Task 3 error rate data in that far more errors are apparent for this task in comparison with the remaining tasks. It should be noted that these results for Task 3 have thus skewed the overall error rate mean values. Whilst the mean values remain legitimate, their inclusion may have a misrepresentative or misleading effect upon the interpretation of the average rate of error, and the reader is urged to take this into consideration.

The relationship between Age and Error Rate was investigated using Pearson product-moment correlation coefficient and the significant correlations are presented below (Table 6).

		Age		
		r	*p*	
FSS1	Number of Errors: T5	$r = 0.316$	0.044	$r = 0.316$ (30), $p < 0.05$
	Number of Errors: Mean: T1-6	$r = 0.315$	0.045	$r = 0.315$ (30), $p < 0.05$

Table 6: Correlation coefficient results

There were no other significant correlations.

There is a positive correlation between age and the number of button press errors made to complete task 5, and age and the overall average number of button presses. The correlation indicates that in these instances, increases in age correlate to increases in the number of button presses made to achieve task completion. This indicates that again, as the participants age increases, the design appears to impair interaction, causing it to be less accurate or efficient, and placing such users at an interactional disadvantage.

5.6.2.4 Mean Time per Button Press Comparison

The Mean Time per Button Press data indicated that, overall, the older generation took slightly longer to make button presses during product interaction than the 26-59 age group and 16-26 age group took less time still, which may be indicative of a slower interactional approach being adopted by the older generation (Figure 25).

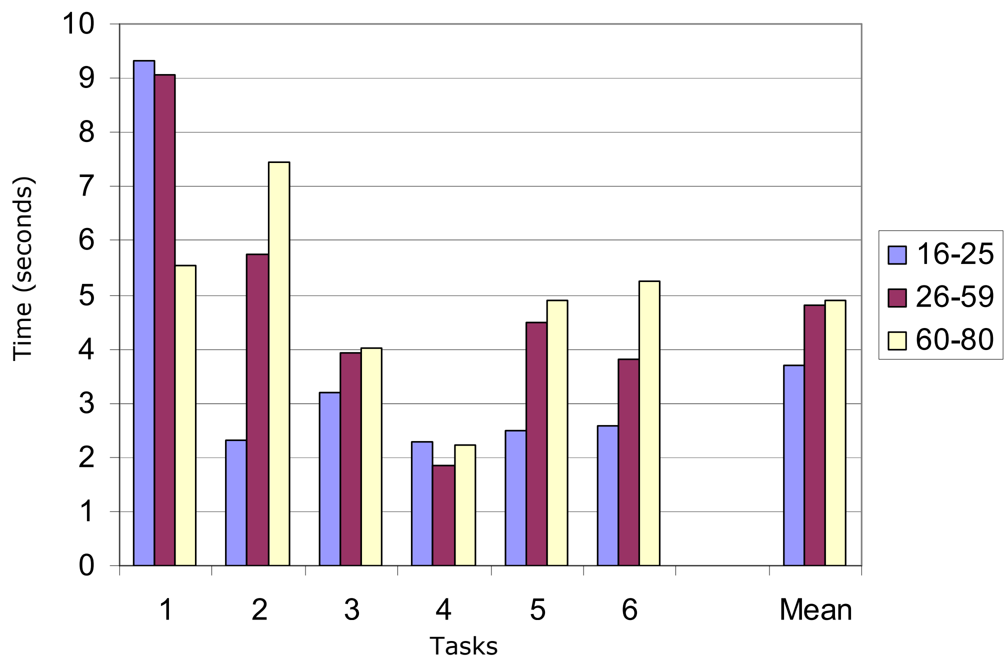

Figure 25: Mean time per button press comparison

A multivariate analysis of variance (MANOVA) showed no significant effect of age on the time per button press data whilst participants completed tasks: $F\ (2, 27) = 1.714\ p>0.05$.

It is worthy of note, however, that in Task 1 (find the lowest wattage reading) the older age group exhibited quicker average button response times. Task 1 rates of error, number of button presses and completion times were almost double for the older age group, indicating that although this group made more attempts, these attempts were more erroneous. This individual instance of faster mean button response times is counter to the overall results which suggest that, in general, as individuals age they take longer to physically interact with products, devices, or systems.

The relationship between Age and Mean Time per Button Press was investigated using Pearson product moment correlation coefficient and the significant correlations are presented below (Table 7).

		Age		
		r	*p*	
FSS1	TpBP: T2	$r = 0.445$	0.014	$r = 0.445$ (30), $p < 0.05$
	TpBP: T5	$r = 0.343$	0.032	$r = 0.343$ (30), $p < 0.05$
	TpBP Mean: T1-6	$r = 0.346$	0.031	$r = 0.346$ (30), $p < 0.05$

Table 7: Correlation coefficient results

There were no other significant correlations.

The effects identified above indicate a positive correlation between the two variables, with increasing age being associated with greater amounts of time taken per average button press. These correlations indicate that as individuals age they take longer to physically interact with products, devices or systems. This may be due to age-related physical dexterity issues, a decline in cognitive ability, or exposure to age-related design phenomenon that preclude or compromise efficient interaction.

5.6.3 TFQ Score Comparison

The overall results of the Technological Familiarity Questionnaire indicated that the 26-59 age group were most familiar with contemporary forms of technology; closely followed by the 16-25 age group, with the older generation exhibiting the lowest familiarity (Figure 26).

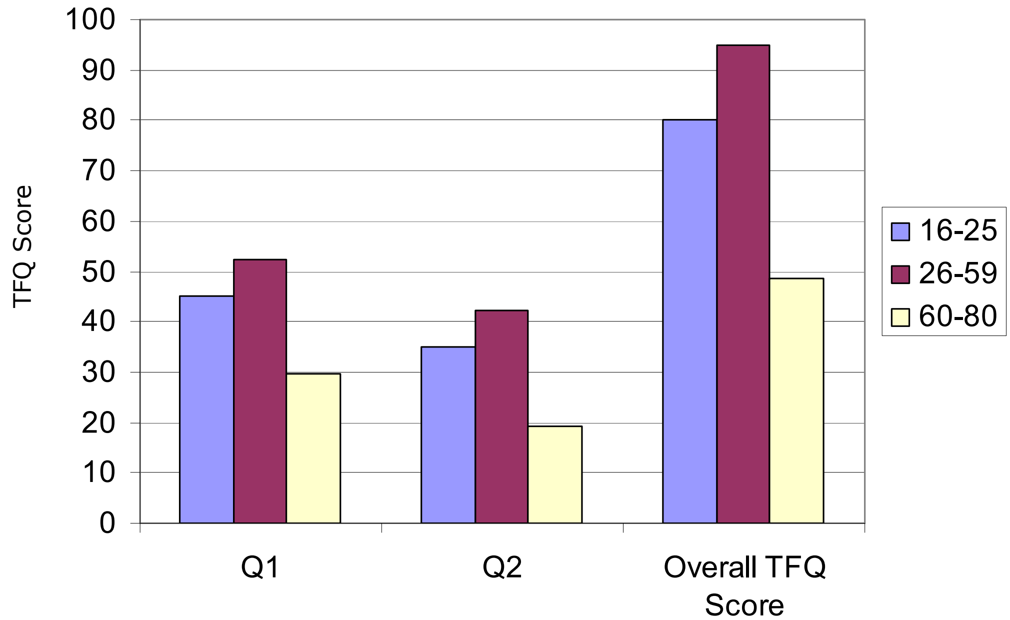

Figure 26: TFQ score comparison

A 1-way analysis of variance (ANOVA) showed a significant effect of age on Technological Familiarity Questionnaire Question 1 Score: $F (2, 27) = 10.278$, $p<0.01$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 1.43$, $SD = 0.18$) was significantly different to the 26-59 age group ($M = 1.70$, $SD = 0.07$) and significantly different to the 16-25 age group ($M = 1.63$, $SD = 0.13$). However, the 16-25 and 26-59 age groups did not significantly differ from each other.

There is a significant difference between older age group and the young age group and there is a significant difference between the older age group and the mid age group. This result indicates that the older participants were less familiar and interacted with the products less frequently than the younger and mid-age groups.

A 1-way analysis of variance (ANOVA) showed a significant effect of age on Technological Familiarity Questionnaire Question 2 Score: $F(2, 27) = 14.858$, $p<0.01$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 1.21$, $SD = 0.26$) was significantly different to the 26-59 age group ($M = 1.62$, $SD = 0.06$) and significantly different to the 16-25 age group ($M = 1.52$, $SD = 0.13$). However, the 16-25 and 26-59 age groups did not significantly differ from each other.

Post-hoc Tukey analysis indicates that there is a significant difference between the older age group and the younger age group and that there is a significant difference between the older age group and the mid age group. This result implies that older individuals are significantly less aware or use fewer features of the examples of the technological products presented upon the TFQ questionnaire than the younger age group, and than the mid-age group.

A 1-way analysis of variance (ANOVA) showed a significant effect of age on Technological Familiarity Questionnaire Overall TFQ Score: $F(2, 27) = 13.706$, $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 1.64$, $SD = 0.20$) was significantly different to the 26-59 age group ($M = 1.96$, $SD = 0.05$) and significantly different to the 16-25 age group ($M = 1.88$, $SD = 0.12$). However, the 16-25 and 26-59 age groups did not significantly differ from each other.

There is a significant difference between the older and the young age group (Sig = 0.002) and there is a significant difference between the older age group and the mid age group (Sig = 0.000). This suggests that the older age group were familiar with significantly fewer examples of the technological products presented upon the technological familiarity questionnaire than the younger age group, and the older age group were familiar with significantly fewer examples of the features of the products presented upon the TFQ than the mid age group.

There is a strong negative correlation between Age and TFQ Q1, Age and TFQ Q2 and Age and TFQ Total Score (Table 8).

		Age		
		r	*p*	
FSS1	TFQ: Q1	$r = -0.424$	0.020	$r = -0.424$ (30), $p < 0.05$
	TFQ: Q2	$r = -0.563$	0.001	$r = -0.563$ (30), $p < 0.01$
	TFQ: Total	$r = -0.509$	0.004	$r = -0.509$ (30), $p < 0.01$

Table 8: Correlation coefficient results

There were no other significant correlations.

Increases in age significantly correlated to decreases in the frequency with which participants interacted with the technology identified in the Technological Familiarity Questionnaire, and to a decrease in the use and awareness of product features. Overall, this indicates another strong generational effect – ageing equates to less feature awareness and product interaction.

5.6.4 Concurrent Protocol Summary

Mirroring the pilot study reports, all participants initially recognised that the product was electrical in nature, and the majority surmised that it was used in the measurement of electricity itself. All participants identified and made reference to plug devices and measuring tools in the initial phase of questioning and, if anything, it was evident that the 26-59 age group provided the most accurate and elaborate descriptions at this stage. By the mid-way stage participants had confirmed their original ideas and nearly all confirmed that it was designed to measure the flow of electricity through it, and that it could be set to indicate how much that usage cost. Again however, the 60-80 age group were the vaguest, having not (unlike other age groups) solidified their understanding of the product or it's interaction at this stage. Likewise, all age groups voiced disquiet at the complexity of setting the electrical cost function (Task 3). Again, in the latter stage, the older generation provided the vaguest descriptions of the device and what it was designed for. The 16-25 and 26-59 age groups provided at this point, more concrete, thorough, and accurate descriptions of the purpose, function, and interaction of the product.

The scrolling menu feature of the product was learned and understood rapidly by all age groups, and was cited as being a design feature with which many were familiar. The most frequently cited product resemblance was to digital watches and alarm clocks, both featuring multi-button press requirements, scrolling menus, and up and down adjustment controls. The 60-80 age group provided the fewest number of familiar devices, followed by the 16-25 age group. The 26-59 age group cited the highest number of similar devices. For further reference, please refer to the technical report *User Experiences of Product Interaction* (Wilkinson, 2011, pp.11-56).

5.7 Discussion

The performance data indicates that with regard to task completion times, the younger generations exhibited faster responses and overall task completion times than the older generation (Figure 22). Indeed, the older generation took considerably longer to complete tasks in comparison with the other age groups. Although it may be that the older generation took more time to consider each move for a variety of reasons, it would appear they made more attempts (Figure 23) and consequently made a greater proportion of erroneous attempts (Figure 24). Observed in conjunction with each groups TFQ Scores, it is evident that the 26-59 age group possess the greatest awareness and level of interaction with contemporary technology. Overall, it appears a greater level of familiarity may correspond to increased task performance.

In relation to interaction and learning, there is evidence of participants understanding a connection between both the effects of their interaction with the novel product and effects within their environment in accordance with the views of Clark (1997). All participants were aware that the lamp influenced the energy monitor, or vice-versa. As all participants performed fewer button presses in the latter stages of the test than at the beginning, and made fewer references to not understanding how to proceed, it could be concluded that learning of interactional behaviour had occurred. In the latter stages the method of achieving task completion by repeatedly pressing the Function button was learnt in all conditions. Again, this was seen as being performed automatically, and thus verged upon the skilled or rule-based levels of processing according to the Wickens et al. (1998) model of Skill, Rule and Knowledge-based processing.

As in the pilot study, all participants quickly consolidated their understanding of the Function button, rapidly learning its scrolling functionality. Task 3 presented some difficulty to all participants. If anything, it would appear that those in the 26-59 age group were most used to the multi-button press approach and multi-button functionality model required, but all groups indicated that it was at this stage their understanding, or the adequacy of the design, was lacking. This feature of the product was most likened to alarm clocks, digital watches and DVD controllers by 14 out of 30 participants (Table 9). Although individuals were familiar with the model or mode of interaction required (as stated post-experimentation), there were obviously some issues with its implementation as indicated during experimentation.

	16-25	26-59	60-80
Trivial Pursuit Game Controller	1		
DVD Controller	**2**	**1**	**1**
Alarm Clock	**2**	**4**	
Digital Watch	**1**	**3**	
Circuit Breaker	1		
Timer	1	1	
Multi-meter	1	1	
Energy Monitor	1	1	
Video		1	
Mobile Phone (text)		1	1
Radio		2	
Microwave		1	1
Automobile dashboard			1
Laser printer			1
Chlorinator			1
Total	10	16	6

Table 9: From the number of products referenced during post-interaction discussions it is evident that alarm clocks, digital watches and DVD controllers were the most frequently cited products

5.7.1 Generational Differences

It would appear participants of the older age group were reticent and reluctant to try new things with the device, as Dewsbury et al. (2007) suggested:

"*I would have thought you should only have to press any of them once (the buttons) not multiple times. You're afraid and think pressing the buttons quickly will break it*."

Participant 15 (60-80 Age Group)

Accordingly, the average time per button press data revealed that those in the 60-80 age group took longer to make individual or combinations of moves, as opposed to the younger age groups who were noticeably quicker in their average times per button press. In conjunction with each groups level of technological familiarity, it is evident that the younger generations possessed a greater awareness and level of interaction with contemporary technology than the older generation. This greater level of familiarity may correspond to an increase in overall task performance, and perhaps a notable observation is that the younger generations were the most economical in their interaction – making the least number of errors in the shortest time. The concurrent protocol indicated that the younger generation were convinced, given time, they would obtain the solution. Conversely, the older generation quickly became frustrated when the product would not respond in an intuitive fashion:

"*Young people would know about multi-button pressing and holding buttons, and have the patience to try different combinations, until they get the response they want. I just don't have the patience. I would try what I know, and if it didn't do what I wanted it to, I'd just go mad and give up with it*."

Participant 16 (60-80 Age Group)

The Cantabeclipse data revealed that the older age group possessed the shortest short-term memory span and those in the 26-59 age group the longest. Also observed were differences in the quantity of referenced products according to age. The older generation again indicated fewer points of reference than the younger age groups, with the 26-59 age group reporting the highest number. This may be because the 26-59 age group have a wide spectrum of device knowledge across a significant technological time period. This device experience, coupled with a recall ability that should be unaffected by the affects of ageing, should increase the potential information available that could be useful in subsequent novel situations.

5.7.2 Hypothesis Acceptance

In this experiment the hypothesis that prior experience would affect users' ability to interact with products was supported, as was the hypothesis that differences might be age related.

Hypothesis 1: There will be an effect of age on task completion time. Task completion times varied significantly according to age, the youngest age group completing tasks quickest and the older age groups taking the longest time [$F(2, 27) = 7.153$, $p < .01$]

Hypothesis 2: There will be an effect of age on number of button presses. The number of button presses made by participants differed significantly as a factor of age, the younger group recording the least number of button presses and the older group recording the most [$F(2, 27) = 3.417$, $p < .05$]

Hypothesis 3: There will be an effect of age on number of errors. Errors varied significantly according to age, the younger age group making the fewest errors in comparison with the other age groups, the older age group making the most errors[$F(2, 27) = 3.44$, $p < .05$]

Hypothesis 4: There will be effect of age on TFQ Score or prior experience. The amount of prior experience possessed as determined by overall TFQ Score again varied according to age. In this instance, the 26-59 age group recorded the greatest experience with the products listed upon the TFQ, followed by the 16-15 age group, the older age group recording the least familiarity with the products listed [$F(2, 27) = 13.706$, $p < 0.05$]

5.8 Inclusive Design Observations

With regard to the products design itself, there was some expectation voiced that with so few buttons, the interaction of the device must be specific and as it appeared to offer considerable functionality, complicated. The utilisation of up and down arrows was recognised, almost universally, although accessing their function was not deemed intuitive. From a generational perspective, a number of observations were made:

1. The display digits were considered large and assistive toward older individuals' perception. However, the units of measurement were deemed too small to ease recognition and this directly contributed in increases in task completion time, particularly for older participants. Although the measurement was perceived, it was often indeterminable which is indicative of poor user centred design (Rogers et al., 1997)
2. Colour could improve the products intuitive interaction, having the up and down arrows and square icon differentiated from the devices background would also assist their observation and the labels above buttons would be better discriminated had they been coloured
3. Screen illumination was insufficient: in low lighting conditions, the display itself appeared difficult to read and this factor has high probability in the home with plug sockets at floor level

4. An older participant explained that with increasing arthritis, they rarely felt the end of their fingertips, and thus, successfully manipulating the device was made increasingly awkward, given the button size. This led to increased errors and supports reports in literature that decreasing manual dexterity impacts upon ease of use for older people (Osman et al., 2003)
5. Button design also limited the size, ease of recognition, and ease of finger-tip touch recognition of the icons embossed upon the buttons

The interaction and observational evidence presented would suggest that simple alterations to the physical design and the method of interaction would enhance individuals' ability to learn and use this product. Difficulty in interaction was highlighted in attempts to complete Task 3 – setting the unit cost, regardless of age (Figure 22).

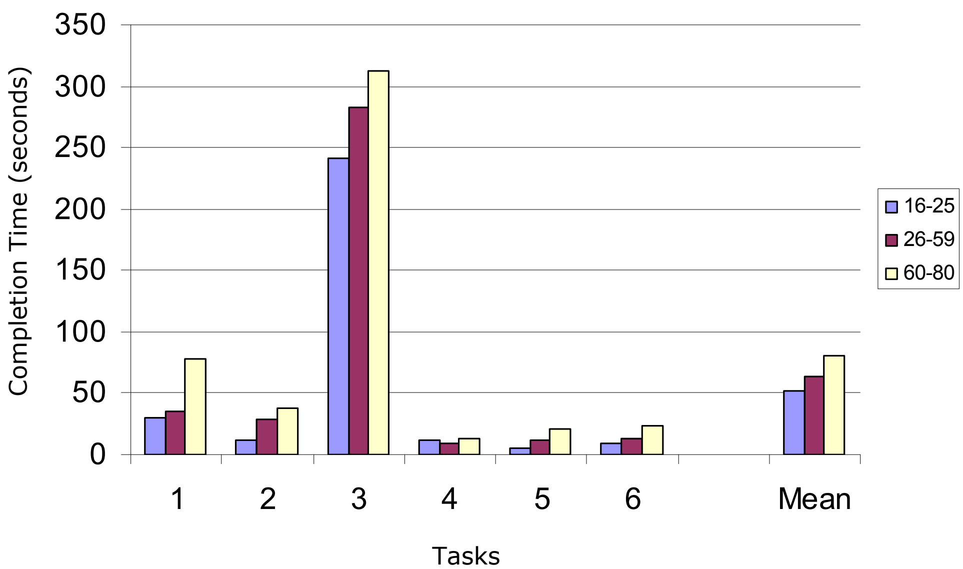

Figure 22: Task completion time comparison

Altering this procedure and reducing the level of complexity required to achieve task completion to that required when interacting with the other available functions would reduce the level and extent of initial learning required and increase its intuitive usability. The setting of the cost could have been improved by simply providing more effective feedback. From the verbal protocol and interview material it was evident that participants consistently recognised elements of the overall product concept, comprising of individual components, and outward aesthetic elements (Figure 27). The findings remain in line with Norman's (1988) views that internalisations are created and developed by the accurate perception of a device's function and likely behaviour through its design.

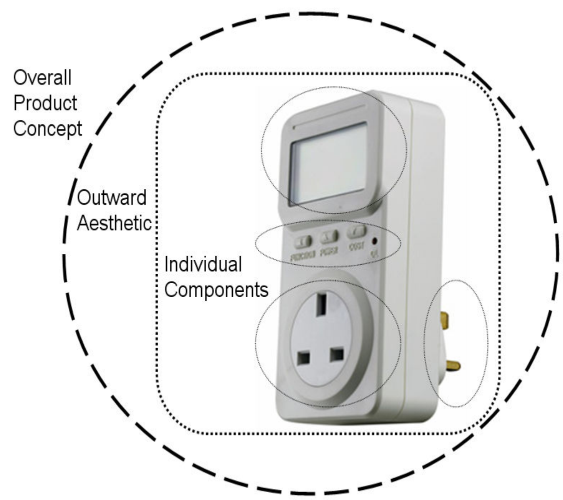

Figure 27: Overall product concept and constituent parts

There are financial and manufacturing reasons for producing products in the way this new-to-market energy monitor appears on the shelves. Ensuring a minimum number of components do a multitude of tasks may be cheaper initially. However, this economy may compromise usability as users struggle to engage with such products, promoting the sluggish adoption of technology by all users – not only the older generation. Thus, in this instance, the economy of design does not translate well into simplicity, or user friendliness, of design. In fact, it appears to have produced the opposite effect.

5.9 Conclusion and Summary

This chapter has detailed a larger study that followed the same principles and used the same product and experimental set-up as the pilot study. The performance data indicated that the younger generations performed faster and that the older generation made greater numbers of errors and attempts toward product interaction. The TFQ data suggest a correlation between age and level of familiarity, and this appears to be associated with increases in task performance. Mental model and understanding development were observable during the course of experimentation and exposure, and the application of the Rasmussen's SRK classification suggested that for the most part, interaction was occurring at a skill-based level, requiring little cognitive effort and being achieved rapidly and almost automatically.

With the experimental approach verified, the overall investigation then attempted to determine on a more granular level the type of knowledge and learning that occurs during product interaction. This was the focus of Full Scale Study 2, detailed in the following chapter.

6: Investigation 3: Full Scale Study 2

The next step regarding the overall project was to investigate the notion of learning through interaction. This was achieved by taking snapshots of knowledge possessed before and after product exposure, to reveal the knowledge acquired through experience.

6.1 Introduction

The overall approach was identical to that used in the previous studies, but utilised a different novel product that was available from high-street suppliers. This experiment set out to evaluate, not only the further existence of generational effects within interaction with household products, but also to evaluate the product itself in terms of its usability, user-friendliness and learnability.

6.1.1 Participant Sample

30 individuals from a variety of backgrounds were recruited to minimise educational biases and maximise ecological validity, although this wasn't verified. Participants were assigned to one of three groups according to age: 16-25 (10 participants), 26-59 (10 participants) and 60-80 (10 participants). The total sample consisted of 13 males and 17 females. The age distribution of the samples is represented in Figure 28. Further information regarding the sampling methodology is available in section 3.4.6 and 3.4.7.

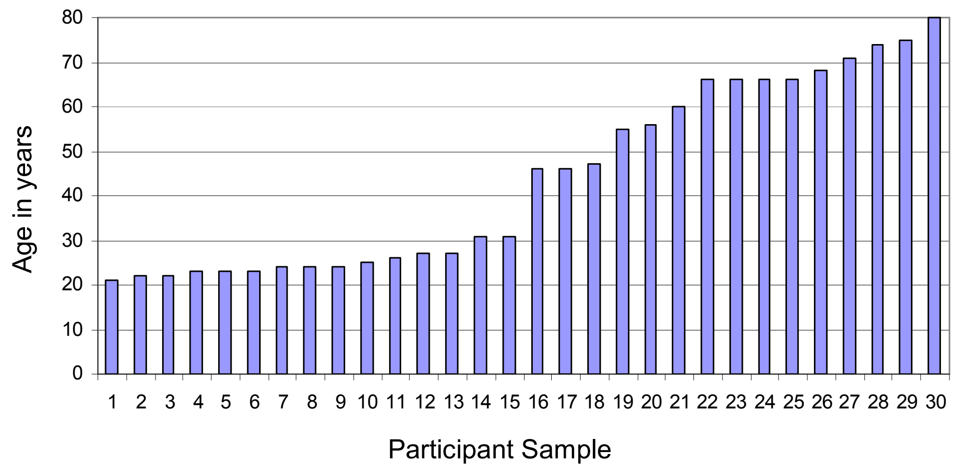

Figure 28: FSS2 Sample Age Distribution (n = 30)

Age Group	Mean	Standard Deviation
16-25	23.1	1.20
26-59	39.2	11.98
60-80	69.2	5.81

6.1.2 Novel Product

The Black & Decker Laserplus laser-level (Figure 29) is a multifunctional device contained within a unique and bespoke aesthetical design and is used to detect wooden and metallic studs or pipes and electricity cables obscured behind walls or fascias. It is also capable of emitting a laser beam to provide a straight level line. To operate the device successfully, users set the device to detect wooden studs indicated by a wooden block icon, or metal studs/pipes indicated by an icon of a beam representing a metallic object.

Figure 29: Black & Decker 'Laserplus' laser-level

Setting is done by pressing a red toggle switch on the front of the device. Users must then calibrate the device by pressing and holding down the button on the right side of the device. Once calibrated the device emits an audible ‘beep’ and requires the button remain depressed whilst the user passes the device across the wall surface or fascia. The detector itself is located in a ‘Detector Zone’ and thus for accuracy it is this area of the device that must be considered during operation. As the device is passed nearer to a stud, vertical lines converge on the display and an audible ‘beep’ occurs when the device is directly above the stud itself. The display reflects this by showing the converging lines meeting in the centre. As the stud is passed, the beep ceases and the vertical lines separate and retract.

The detection of electrical cables follows an identical procedure, although there is no ‘setting’ of the device required. Once calibrated, the device can be immediately passed across walls or fascias. The feedback provided is identical with the addition of the electrical warning LED illuminating when the device detects live electrical cables in the vicinity. The laser-level functionality is accessed by inserting a hanging tool into the rear of the device and pushing the slider button on the left side to the ‘Laser On’ position. The hanging tool in this instance was to be located upon a protruding screw, and thus could easily pivot until the laser line was at its strongest, indicating a true, level, straight line.

Whilst the device may have only four functions, the level of conceptual development required to understand and operate it successfully appears significant. The devices bespoke and novel nature also affords more direct study of understanding-development as the likelihood of prior specific product experience is minimal. For further justification for the usage of novel products in experimentation, please refer to section 3.5.

6.1.3 Research Materials and Equipment

6.1.3.1 Warning Icon Assessment Sheet

An icon assessment sheet was developed to test participants' recognition or understanding of warning icons appearing either upon the packaging of the device or upon the device itself (Figure 30).

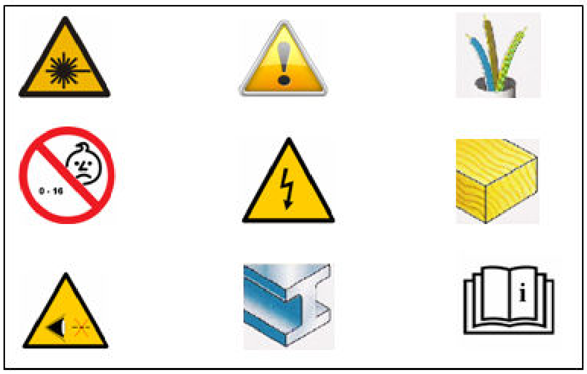

Figure 30: Icon assessment sheet

Figure 31: Modifying responses on the assessment sheet

This was presented before and after product exposure, to both verify participants' levels of prior experience, and determine knowledge and understanding acquired during the process of interaction (Figure 31).

6.1.3.2 Product Feature Assessment Sheet

Studying the video-data and verbal report allowed assessment of feature recognition during initial exposure, and the development of the Product Feature Assessment Sheet (Figure 32) permitted the assessment of product features each participant recognised post exposure (Figure 33). This approach allowed the determination of product features, usage and understanding development over the course of exposure.

Figure 32: Product feature assessment sheet

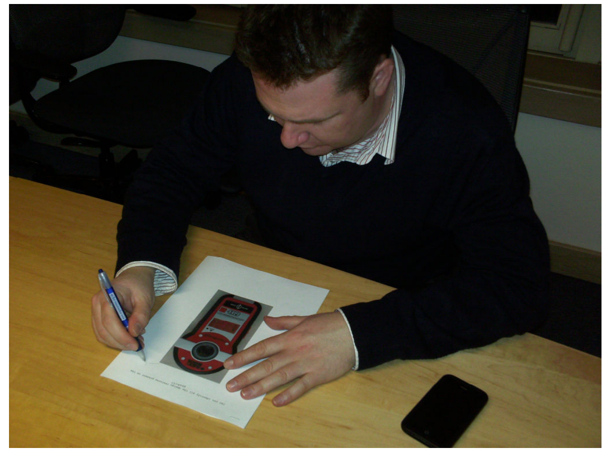

Figure 33: Completing the product feature assessment sheet

6.1.3.3 Revised Technological Familiarity Questionnaire

The Technological Familiarity Questionnaire (TFQ) was a modified version of that used in a previous study (Wilkinson et al., 2010a), which itself has origins within the work of Blackler (2006). The modified Technological Familiarity Questionnaire posed the same two questions: “How often do you use the following products?” and “When using the products, how many features of the product are you familiar with and do you use?” but detailed a larger range of both contemporary and less-contemporary products than before (Appendix 10). Again, rating the answers provided produced an overall participant TFQ score.

6.2 Experimental Design

Between-subjects design, assigning a total of 30 participants (13 male and 17 female) to one of three groups according to age: 16-25 (10), 26-59 (10) and 60-80 (10).

Independent Variable:

Age: 3 levels: 16-25, 26-59, 60-80.

Dependent Variables:

1. Cantabeclipse cognitive assessment performance
2. Icon pre/post exposure recognition
3. Task performance times
4. Product feature pre/post exposure recognition
5. Technological familiarity questionnaire performance

6.2.1 Hypotheses

Based on the research conducted, the following three hypotheses were proposed:

- Iconic knowledge is increased through interaction and increased exposure
- There will be a correlation between age and technological familiarity or experience
- There will be a correlation between age and task completion time performance

6.3 Data Analysis

The recorded video-data verified how the concurrent protocol corresponded to the users' actions, assessment of task completion times, and understanding of the products design and function before, during, and after product exposure. Interview material provided qualitative and quantitative data upon user perception of interaction to confirm overall level of product understanding, and how this influenced interaction. Other data recorded included: MOT and SSP scores, overall two-stage TFQ scores, the quantity of products recalled during interaction, and warning icon and product feature recognition initial and subsequent scores (Appendix 11).

6.4 Experimental Procedure

The following procedure was adopted as the experimental protocol to maintain consistency between of each and every participant's experience:

- Explain experimental requirements and administer consent form
- Administer pre-test assessment using Cantabeclipse Cognitive Assessment Tool
- Assessment of warning icon recognition
- Record initial exposure to the product and participant understanding
  (including initial product exposure feature recognition)
- Record participants performing randomised tasks with the product whilst verbalizing actions: 1: Fit Battery, 2: Find Wooden Stud, 3: Find Metal Pipe, 4: Find Electric Cable, 5: Fit Hanging Tool, 6: Hang and operate laser-level
- Reassess participant understanding of product and interaction, and warning icon recognition
- Assess post exposure product feature recognition
- Administer technological familiarity questionnaire
- Debrief

6.5 Results

6.5.1 Cantabeclipse Cognitive Assessment Summary

6.5.1.1 MOT Task Completion Time Assessment

The initial (MOT) reaction-time test that also screens for vision, hearing, movement and comprehension impairment, highlighted no neuropsychological issues, but indicated differences in performance times between age groups (Figure 34).

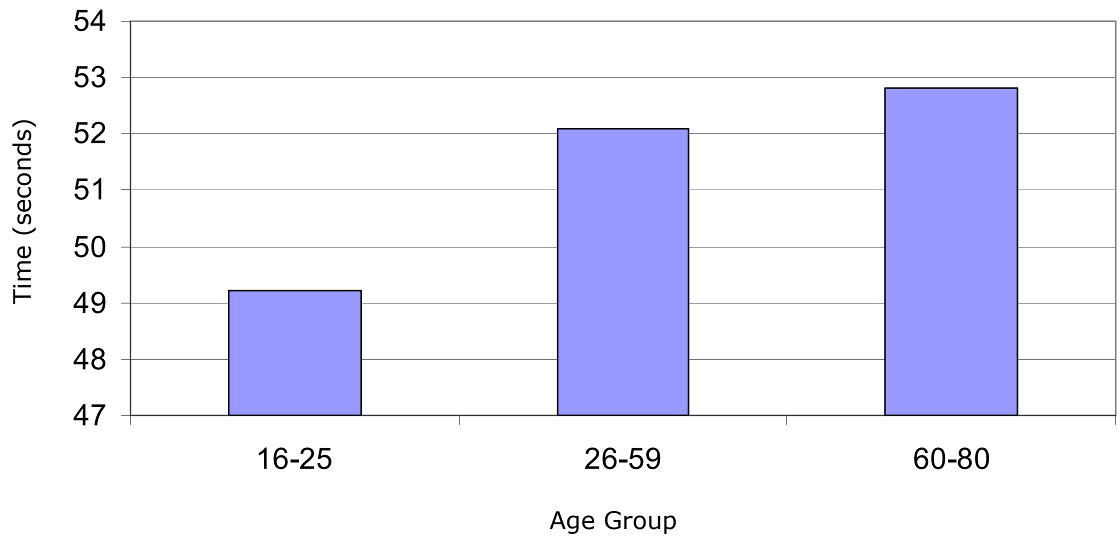

Figure 34: Cantabeclipse MOT reaction times according to age group membership (n = 30)

A 1-way analysis of variance (ANOVA) showed no significant effect of age on MOT Task Reaction Time: F (2, 27) = 0.594 p>0.05. The 16-25 age group completed the MOT task the quickest, and the 60-80 age group took the longest; the 16-25 age group completing the task in 49.2 seconds, and the 26-59 and 60-80 age groups in 52.1 and 52.8 seconds respectively.

The relationship between Age and MOT Task reaction time was investigated using Pearson product-moment correlation coefficient. There was a moderate positive correlation between the two variables with a high level of age associated with a high level of reaction time (Table 10).

		Age		
		r	*p*	
FSS2	MOT R-Time	$r = 0.317$	0.044	$r = 0.317$ (30), $p < 0.05$

Table 10: Correlation coefficient results

There were no other significant correlations.

Increases in age correlate to a significant increase in MOT Task completion time. Thus, those in the older age group will take longer to complete the task than those of a younger age. This correlation indicates that the older generation's interaction is somehow being compromised as they are unable to perform as efficiently as their younger counterparts.

6.5.1.2 SSP Memory Capacity Assessment

Memory Span Length decreased with age: the 16-25 group recording 6.9 items, the 26-59 age group recording 6.4 and the older age group recording 4.9 (Figure 35).

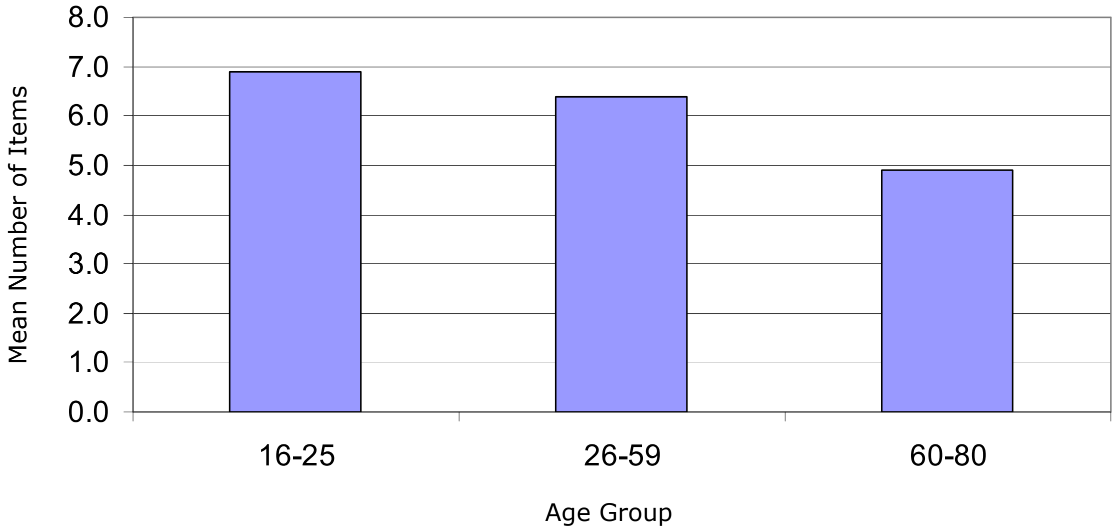

Figure 35: Cantabeclipse SSP (Memory Span Length) results: Number of remembered items (n = 30)

A 1-way analysis of variance (ANOVA) showed a significant effect of age on SSP Memory Capability: $F(2, 27) = 5.205$, $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 4.9$, $SD = 1.19$) was significantly different than the 16-25 age group ($M = 6.9$, $SD = 1.44$). However, the 26-59 age group results ($M = 6.4$, $SD = 1.64$) did not significantly differ from either of the remaining groups.

The relationship between Age and SSP Score was investigated using Pearson product-moment correlation coefficient. There was a moderate negative correlation between the two variables with a high level of Age associated with a low level of SSP Score (Table 11).

		Age		
		r	*p*	
FSS2	SSP Score	$r = -0.664$	0.00	$r = -0.664$ (30), $p < 0.01$

Table 11: Correlation coefficient results

This suggests that age is a factor in memory capability, and that as we age our memory capability decreases. Thus, older participants recalled fewer items than either of the younger age groups. Results fell within the expected range (Miller, 1956, refer to section 3.4.3 for a reminder), the maximum possible within the test being the correct recall of 9 items.

6.5.2 Interaction Data

6.5.2.1 Task Completion Time Comparison

Figure 3 indicates time taken to complete tasks 1 to 6 (1: Fit Battery, 2: Find Wooden Stud, 3: Find Metal Pipe, 4: Find Electric Cable, 5: Fit Hanging Tool, 6: Hang and operate level).

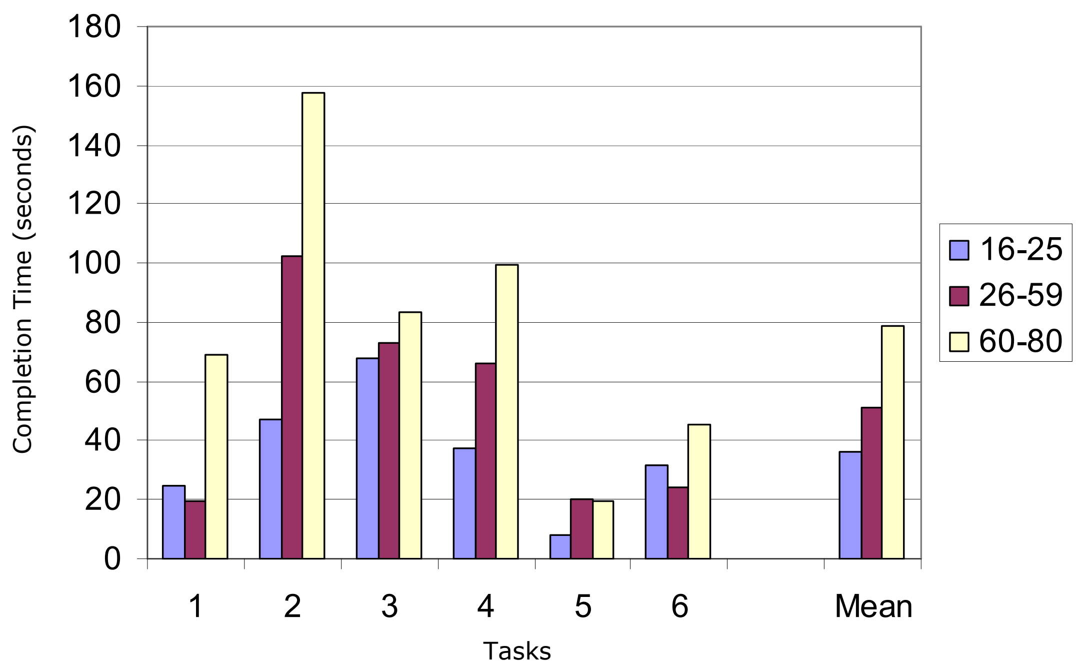

Figure 36: Task performance times according to age group membership (n = 30)

A multivariate analysis of variance (MANOVA) showed a significant effect of age on Task Completion Time (TCT): $F(2, 27) = 8.146$ $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group ($M = 1.71$, $SD = 0.30$) was significantly different than the 16-25 age group ($M = 1.37$, $SD = 0.33$). However, the 26-59 age group results ($M = 1.49$, $SD = 0.32$) did not significantly differ from either of the remaining groups.

The relationship between Age and Task Completion Time was investigated using Pearson product-moment correlation coefficient on each if the tasks and the mean (Table 12).

		Age		
		r	*p*	
FSS2	TCT: T1	$r = 0.554$	0.002	$r = 0.554$ (30), $p < 0.01$
	TCT: T2	$r = 0.431$	0.017	$r = 0.431$ (30), $p < 0.05$
	TCT: T4	$r = 0.508$	0.004	$r = 0.508$ (30), $p < 0.01$
	TCT: T6	$r = 0.451$	0.012	$r = 0.451$ (30), $p < 0.05$
	TCT Mean: T1-6	$r = 0.575$	0.001	$r = 0.575$ (30), $p < 0.01$

Table 12: Correlation coefficient results

Although there were no other significant correlations, in five instances there was a moderate positive correlation between the two variables with a lower age associated with a lower task completion time. The visible fluctuation in performance between tasks is predicted to have been due to differences in task complexity. Overall, the results suggest that age is a factor in the speed with which tasks were completed: as age increased the speed with which these specific tasks were completed also increased.

6.5.2.2 Warning Icon Identification Comparison

Warning Icon Identification Pre and Post Experimentation (Figure 37).

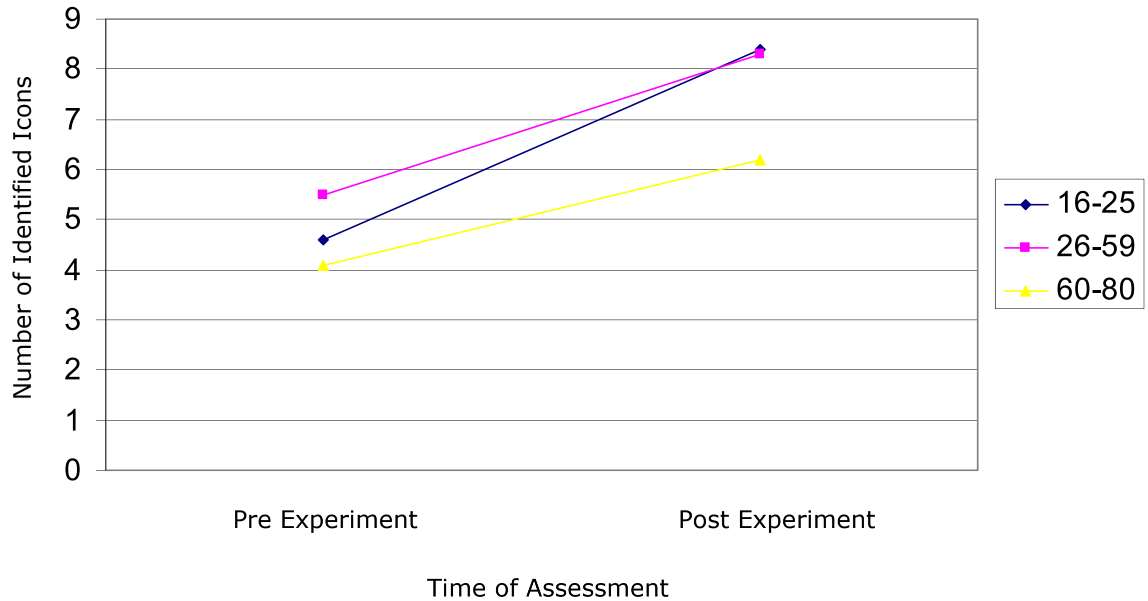

Figure 37: Comparison of number of warning icons identified pre and post experimentation (n = 30)

A multivariate analysis of variance (MANOVA) indicated a significant effect of time of assessment and age group on the number of icons identified: $F(2, 27) = 415.969$, $p<0.01$. Analysis indicated no significant difference between the age groups at the pre-experiment exposure stage, but a significant difference between the 60-80 age group ($M = 6.20$, $SD = 2.34$) and the 26-59 age group ($M = 8.20$, $SD = 1.93$) and between the 60-80 age group ($M = 6.20$, $SD = 2.34$) and the 16-25 age group ($M = 8.40$, $SD = 0.84$) in the post-experiment stage. Thus, although initially age was not a significant factor in identification, it is a factor in the amount of iconic knowledge gained during exposure.

The relationship between Age and Icon Identification was investigated using Pearson product-moment correlation coefficient. There is a strong negative correlation between Age and pre-experiment icon identification, Age and post-experiment icon identification, and Age and difference between pre and post-experiment icon identification (Table 13).

		Age		
		r	*p*	
FSS2	Pre-Exp Icon ID	$r = -0.335$	0.035	$r = -0.335$ (30), $p < 0.05$
	Post-Exp Icon ID	$r = -0.613$	0.000	$r = -0.613$ (30), $p < 0.01$
	Post – Pre Icon ID (diff)	$r = -0.394$	0.031	$r = -0.394$ (30), $p < 0.05$

Table 13: Correlation coefficient results

There were no other significant correlations.

Increases in age correlate to a significant decrease in icon recognition at the pre and post-product exposure stage. Increases in age also correlate to decreases in iconic information acquisition, providing evidence of another generational effect – in this instance that as we age our ability to acquire iconic information decreases as a correlational factor of age.

6.5.2.3 Product Feature Identification Comparison

Product Features Identified Pre and Post Experimentation (Figure 38).

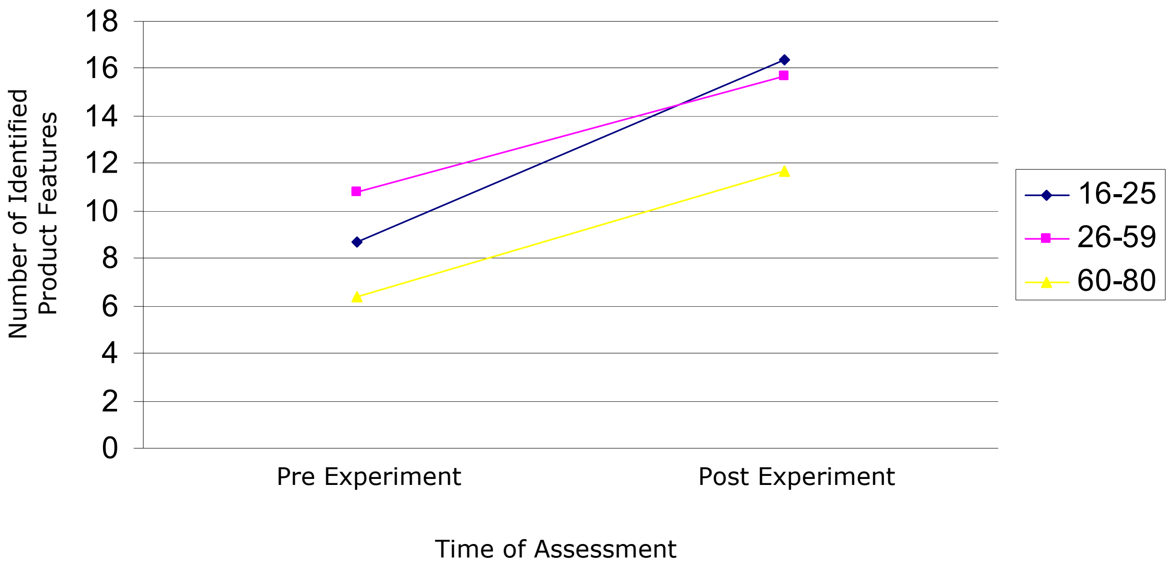

Figure 38: Comparison of number of product features identified pre and post experimentation (n = 30)

A multivariate analysis of variance (MANOVA) indicated a significant effect of time of assessment and age group on the number of features identified: $F(2, 27) = 268.518$ $p<0.01$.

In the pre-experiment exposure stage, analysis indicated that there was a significant difference between the 60-80 age group (M = 6.40, SD = 3.50) and the 26-59 age group (M = 10.80, SD = 5.18). The 16-25 age group results (M = 8.70, SD = 3.09) did not significantly differ from either of the remaining groups.

However, in the post-experiment exposure stage, analysis indicated a significant difference between the 60-80 age group (M = 11.70, SD = 3.19) and the 26-59 age group (M = 15.70, SD = 6.05) and between the 60-80 age group (M = 11.70, SD = 3.19) and the 16-25 age group (M = 16.40, SD = 2.91). In both stages age was a significant factor in feature identification. Thus, age is a factor in the amount of product feature knowledge gained, and the older age groups ability to acquire information and learn is adversely affected.

The relationship between Age and Icon Identification was investigated using Pearson product-moment correlation coefficient. There is a strong negative correlation between Age and pre-experiment icon identification, Age and post-experiment icon identification, and Age and difference between pre and post-experiment icon identification (Table 14).

		Age		
		r	*p*	
FSS2	Pre-Exp Icon ID	$r = -0.384$	0.036	$r = -0.384$ (30), $p < 0.05$
	Post-Exp Icon ID	$r = -0.544$	0.000	$r = -0.544$ (30), $p < 0.01$
	Post – Pre Icon ID (diff)	$r = -0.394$	0.031	$r = -0.394$ (30), $p < 0.05$

Table 14: Correlation coefficient results

There were no other significant correlations.

Increases in age correlate to a significant decrease in feature recognition at the pre and post-product exposure stage. Increases in age also correlate to decreases in the ability to acquire product feature knowledge: in this instance that as we age our ability to acquire feature related information decreases as a correlational factor of age.

6.5.2.4 Product Recall Comparison

Mean Number of Products Participants reminded of during Interaction (Figure 39).

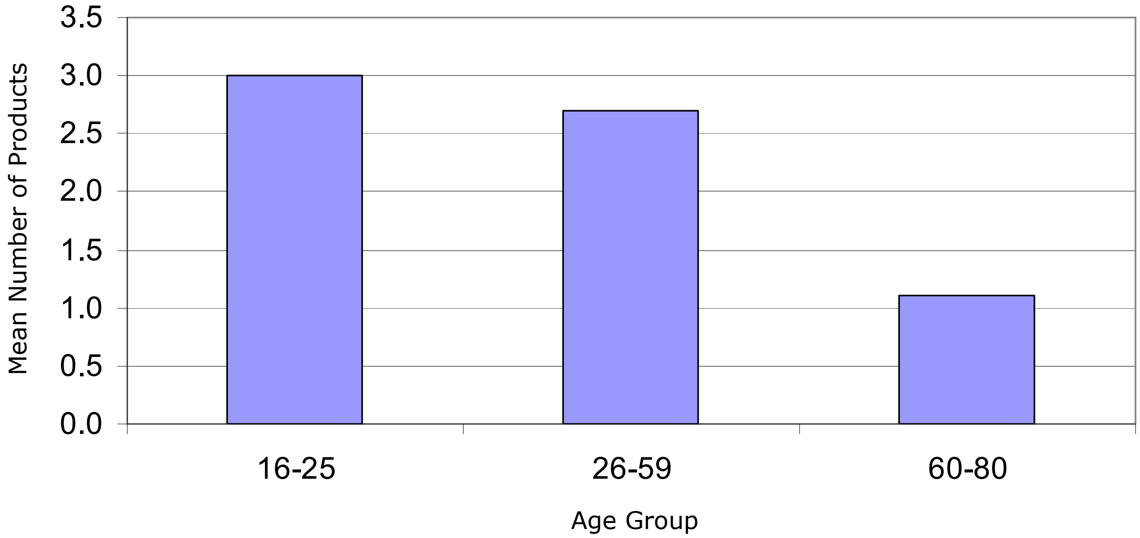

Figure 39: Mean number of products participants were reminded of during interaction (n = 30)

A 1-way analysis of variance (ANOVA) showed no significant effect of age on the mean number of products recalled during exposure: $F\ (2,\ 27) = 2.965$, $p>0.05$. Although there appears to be a generational trend of older participants scoring lower and younger participants scoring higher in terms of products recalled, the effect is not significant.

The relationship between Age and mean number of products recalled during exposure was investigated using Pearson product-moment correlation coefficient. There was a moderate negative correlation between the two variables with a higher levels of age associated with a lower levels of recalled products (Table 15).

		Age		
		r	*p*	
FSS2	Prompted Product Recall	$r = -0.383$	0.037	$r = -0.383$ (30), $p < 0.05$

Table 15: Correlation coefficient results

Although differences between groups are not significant, increases in age correlate to a significant decrease in prompted product recall. This indicates the existence of a generational effect – our ability to recall products is significantly negatively correlated to increases in age. Natural atrophy in terms of reduced cognition and memory access may also play a role, but this and subsequent findings contribute to the notion that increasing age equates to a reduction in regularity of interaction with modern products. This may be a key factor causing poorer performance in terms of age related icon and feature recognition, with such icons and features being common characteristics of the types of contemporary products examined. This apparent, age-induced, reduced familiarity with modern products and designs would also account for older users reduced ability to recall other, similar, contemporary products.

6.5.3 TFQ Score Comparison

The Technological Familiarity Questionnaire results represented below (Figure 40) indicate that differences are observable between groups, the 16-25 age group possessing the highest overall TFQ Scores and the older age group the lowest.

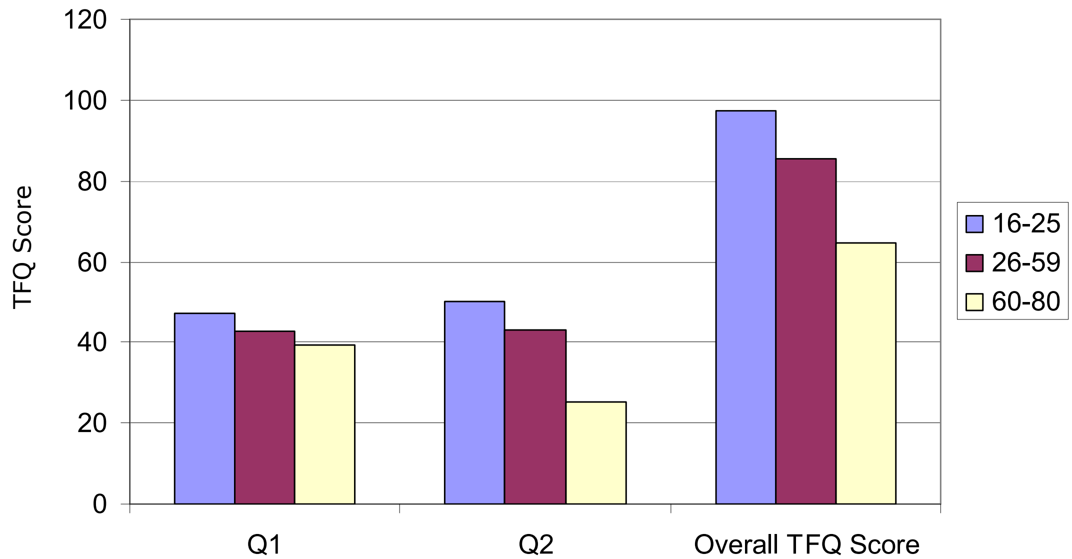

Figure 40: Technological familiarity questionnaire scores according to age (n = 30)

A 1-way analysis of variance (ANOVA) showed no significant effect of age on TFQ Q1 Score (frequency of product interaction): $F(2, 27) = 0.890$, $p>0.05$.

A 1-way analysis of variance (ANOVA) showed a significant effect of age on TFQ Q2 Score (awareness and use of product features): $F(2, 27) = 4.973$, $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group (M = 25.4, SD = 11.21) was significantly different to the 16-25 age group (M = 50.1, SD = 17.12). However, the results for the 26-59 age group (M = 43.0, SD = 23.58) were not significantly different from either of the remaining groups.

A 1-way analysis of variance (ANOVA) showed a significant effect of age on Overall TFQ Score: F (2, 27) = 3.470, $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group (M = 64.8, SD = 22.36) was significantly different to the 16-25 age group (M = 97.3, SD = 16.32). However, the results for the 26-59 age group (M = 85.6, SD = 39.69) were not significantly different from either of the remaining groups.

There is no significant difference between the frequency of interaction with the products identified upon the questionnaire according to age. There was an effect of age upon the awareness and use of product features, however. Post-hoc Tukey analysis indicates that there was a significant difference between the older age group and the younger age group. This implies older individuals are significantly less aware or use fewer features of the examples of the technological products presented upon the TFQ questionnaire than the younger age group.

The relationship between age and technological familiarity was investigated using Pearson product-moment correlation coefficient. There was a strong negative correlation between Age and TFQ Q2, and Age and TFQ Total Score (Table 16).

		Age		
		r	*p*	
FSS2	TFQ: Q2	$r = -0.509$	0.001	$r = -0.509$ (30), $p < 0.01$
	TFQ: Total	$r = -0.462$	0.004	$r = -0.462$ (30), $p < 0.05$

Table 16: Correlation coefficient results

There were no other significant correlations.

Increases in age significantly correlated to decreases in the frequency with which participants interacted with the technology identified in the Technological Familiarity Questionnaire, and to a decrease in the use and awareness of product features. Overall, this indicates another strong generational effect – ageing equates to less feature awareness and product interaction.

6.5.4 Concurrent Protocol Summary

Analysing the concurrent protocol in combination with the experimental data – task performance times, icon recognition, product feature recognition, understanding of product function, functionality, and conceptual awareness – revealed increases in knowledge and understanding over the duration of product exposure. Design features appeared fundamental to the creation and development of product understanding and formation of an internalised mental model, and the mental model of the product was significantly developed in the latter stages of the experimentation from a basic initial concept to an accurate post-exposure conclusion:

Early conceptualisation

"*Device to detect a solid wall, or hollow wall. It's got a solid here (participant points to the solid block icon on the device) and an I-block (icon on the device). I've used something like this before, like a finder and you go around the wall*."

"*I haven't the faintest idea what it is, but it may be for levelling something. An "I" and "end of block" icon – these are the main functions, but I don't know what they mean*."

(Participant FSS2P04)

Increasing understanding during interaction

"*The red light stayed on, so is this all electricity (participant points)? Ah, now it went off, ok. I'm thinking this is the indicator for the electrical line (pointing to the symbol and LED). So it's electric all through here (passing the device back across the jig right-to-left) – the LED illuminates and as the run of cable is crossed, the interface 'beams' indicate the crescendo point, or lie of the cable. Ah, these elements work in combination – the beep, the light and the interface beams*."

Post exposure conclusion

"*Well, it's not just for use as a spirit level, which presumably the laser is mainly for that. You can detect where pipes or electric cable are so if you're drilling a hole in the wall (you can avoid them), and you can tell if they're vertical or horizontal*."

(Participant FSS2P04)

Feature familiarity was also a key factor as Okeye (1998) suggests. For example, the On/Off switches including the sliding switch to operate the laser function was felt to have been seen before by a number of participants in such devices as mobile phones, including the tactile requirement to hold specific buttons for a time period to activate a particular response or function. However, the LCD display contents were not so well understood as it was felt the design of the feedback provided failed to tap into users' conscious awareness of other products/design:

"*I'm partly familiar with this type of tool to find a stud in the wall and the knob (laser-slider switch) on this and (the press-and-hold button), to do that (calibrate and detect). And I'm familiar with a tool to line things up, but I've never seen it together like that.*"

(Participant FSS2P01)

There was also an expectation-led focus of attention and interaction:

"*Viewfinder area seems like the focus of attention, but maybe I should have been looking elsewhere.*"

Designers themselves may be unaware how the design of an artefact will affect both perception and use of a product, particularly in the initial stages of exposure. 50% of participants verbally referenced the device's 'viewfinder element' during the initial product feature assessment: six participants in both the 26-59 and 60-80 age groups, with just three participants in the 16-25 age group. The ‘viewfinder’ is actually an almost redundant feature of the product, and yet with users’ preconceptions of design and associated use, it appears to have had an adverse effect upon learning, understanding and interaction. As the younger age group referenced this element the least and performed the most effectively, we can propose that this design feature may have interfered with the development of an accurate model of interaction and contributed to the older age groups poorer performance.

Two participants, who expressed being visual people, admitted their approach to interaction was very object orientated – searching for familiar objects and features. They tended to ignore written information and adopted a pattern recognition technique that reduced the amount of effort required. Their initial searches focused upon locating recognisable and familiar elements of the product to achieve task completion.

These reports indicate that the mental models developed are dependent upon observations of features, icon recognition, and the product design as a whole, as well as its designed interaction. Younger age groups recognised greater numbers of both icons and product features, and these elements contributed to the depth, accuracy and content of their mental models of the product. This superior knowledge or awareness, it would appear, also correlates to both the younger age groups greater familiarity with modern products and designs, and in this instance correlates to their superior performance with the laser detector.

The complete protocol analysis is reproduced in the technical report: *User Experiences of Product Interaction* (Wilkinson, 2011, pp.57-190).

6.6 Discussion

The trend of the younger age group performing the quickest is evident within the Cantabeclipse MOT results included within Table 18.

		Age Group		
		16-25	**26-59**	**60-80**
Cantab MOT Completion time	(seconds)	49.2	52.1	52.8
Cantab SSP Memory Span Length	(items correctly recalled)	6.9	6.4	4.9
Interaction Task Completion Times (1-6)	(seconds)	36.1	51.0	79.0
Icon Recognition (pre-exposure)	(number of icons)	4.6	5.5	4.1
Icon Recognition (post-exposure)	(number of icons)	8.4	8.3	6.2
Product Feature Recognition (pre-exposure)	(number of features)	8.7	10.8	6.4
Product Feature Recognition (post-exposure)	(number of features)	16.4	15.7	11.7
Prompted Product Recall	(number of products)	3.0	2.7	1.1

Table 18: Overall means per age group, representing the results of Cantab MOT and SSP tests, task completion times, icon and product feature recognition, and prompted product recall.

In this instance, the younger age range (16-25) performed the MOT task the quickest, followed by the 26-59 and 60-80 groups respectively. The older age group performed the slowest of all. Likewise, the Memory Span Length (SSP) results also reflect that the older age groups possessed the shortest memory span and the younger age group the largest. The averages of task completion during the interaction phase of the experiment show that the younger age group completed tasks in the shortest timeframe, followed by the mid and older age groups. It was noted that all age groups were not fully aware from the beginning or able to make completely accurate inferences regarding warning icon meaning and design, as no individual recognised the maximum number of 9 warning icons initially. The younger age group developed this understanding the most during the course of exposure. This in itself has ramifications for designers attempting to convey important (in this case potentially safety-critical) information to users. The results for product feature identification are similar; knowledge of product features increased during the course of exposure, influencing participants overall understanding of product functionality and intent. These are all elements that have inclusively contributed to the formulation of overall product concepts or mental models. Likewise, the number of recalled products varies uniformly with age – older participants recalling fewer than the other age groups, and the younger age group recalling the most (Figure 39). This is considered a factor of prior experience – younger individuals appearing more familiar and aware of a greater number of products whilst interacting with the novel device, and is further supported by the TFQ data that confirms the younger generations were more familiar with the technology specified in the questionnaire (Figure 40). This may be beneficial: if not in learning to interact with a novel product, certainly in understanding more about its functionality.

Individual task performance times are more varied and whilst trends can be seen according to task, they are not evident in all tasks (Figure 36). Battery fitment (Task 1) was completed most efficiently by the 26-59 age group, and not the 16-25 group as might be expected. Interacting successfully with the product and locating the wooden stud (Task 2) did reflect the expectation with the younger age groups completing the task significantly quicker than older age groups. Locating the metal pipe (Task 3) and the electric cable (Task 4) mirrored this finding. The 16-25 age group took the least time to successfully secure the products 'hanging tool' (Task 5) and the 26-59 age group the least time to operate the laser-level function (Task 6).

6.6.1 Hypotheses Acceptance

Participant knowledge was clearly enhanced through interaction and exposure. Correlations were found to exist between age and experience and task completion time performance.

Hypothesis 1: Increases in age were correlated with decreases in amounts of knowledge acquired during product exposure/interaction; $r = -.394$, $n = 30$, $p = 0.031$ and the effect of age on differences in amounts of pre and post exposure knowledge or awareness of icon design was significant [$F (2, 27) = 415.969$, $p = 0.01$]. The mean number of increases in warning icon recognition/understanding over the course of exposure was 2.97 items. The overall average number of increases in features identified over the course of exposure was 5.97 items.

Hypothesis 2: There is a correlation between age and technological familiarity or experience supported by the TFQ data. Increases in age were significantly correlated with decreases in overall TFQ score: $r = -.462$, $n = 30$, $p = 0.004$.

Hypothesis 3: There is support for the hypothesis that there will be correlations between age and task completion time evidenced by the results presented. Task completion time positively correlated with age in 5 out of 7 instances, indicating that a lower age was associated with a quicker task completion time.

6.7 Inclusive Design Observations

A number of design issues were voiced during the course of interaction, which directly affected participant performance and user experience. These included the LCD display timing-out too quickly for individuals to fully comprehend the information available, and it was felt this contributed toward participants finding it difficult to realise the functionality and purpose of the different modes in searching for wood and metal objects. This in turn affected task success and extended the time taken to complete tasks, as multiple efforts were required to obtain the information. Continually pressing the detector button was demanding and fatiguing particularly for older people. The provision of visual and audible feedback was considered beneficial in highlighting object detection, but the audio frequency raised issues for older people with deteriorating hearing. It was felt that more comprehensive and coherent icon design on the product and packaging would enhance the accuracy and detail of product understanding and interaction. During battery fitment, significant conscious attention was observable in locating the battery compartment cover and inserting the battery correctly. This might be improved by contrasting the colour of the compartment cover from its surroundings and labelling it *Battery*. Differentiating the battery insertion diagram (Figure 41) from its background would also reduce the amount of time and effort involved. The current design (left) appeared to particularly disadvantage the older generation and significantly increased their task completion times.

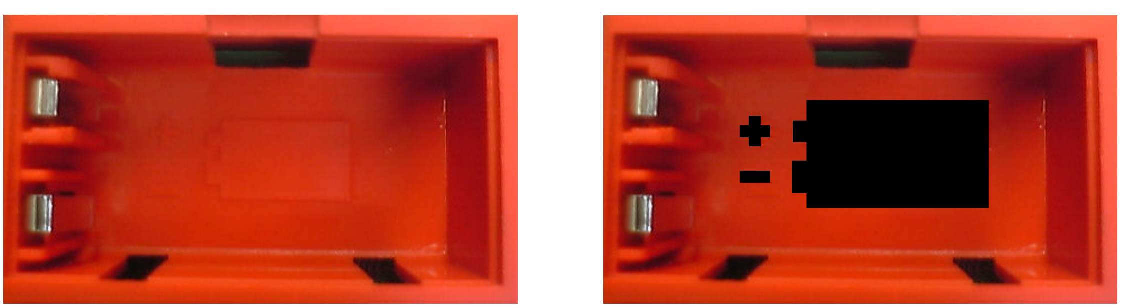

Figure 41: Although embossed, the lack of contrast affects accurate battery polarity perception

The design of the device and particularly its side-grips caused the LCD display to often be occluded by the users' hand (Figure 42). Equally, due to this issue, it would be easy to overlook the illumination of the LED that indicates the detection of an electrical cable (Figure 43). Ambiguity was also cited over the multi-functionality of the LED, as it illuminated both during calibration and when detecting a live electrical cable. Misinterpretation could lead to the misdiagnosis of a safety-critical situation by the user, with the potential to result in electrocution. Equally, the fact that the device only detects *live* cables is another safety critical factor, especially if they cables *become* live during or after wall drilling for example.

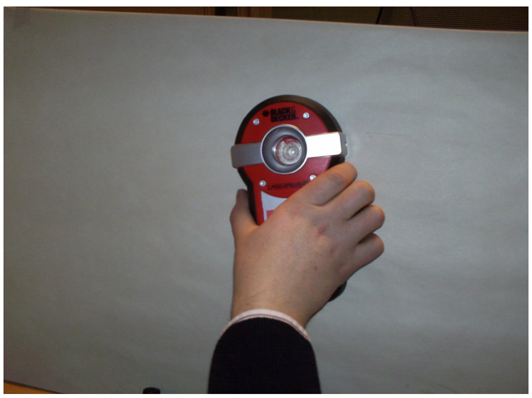

Figure 42: Implication of grip-design

Figure 43: LED and screen occlusion

6.8 Conclusion and Summary

Through the course of this latter experiment, it has been possible to establish differences in performance according to age-group membership, and identify outcomes of learning through product experience and indicate how successfully this design facilitates learning. Some of the key findings have been that;

- Participant knowledge was increased through interaction and exposure. This was evidenced with increases in 1) iconic knowledge and awareness, and 2) feature recognition and understanding

- Increases in age were correlated with decreases between amounts of knowledge acquired during product exposure/interaction
- The effect of age on differences in amounts of pre and post exposure knowledge or awareness of warning icon and feature design was significant
- There is a negative correlation between age and technological familiarity/experience
- Task performance was also correlated to age in 4 out of 6 instances, the remaining two still being marginally significant
- Accurate mental model development hinges upon accurate perception and interaction with the product, and the success of the product, in facilitating learning and understanding, hinges upon the designers ability to convey the correct message and communicate effectively, through design

Exploration of the Technological Familiarity Questionnaire data revealed that 14% of the sample reported intentionally avoiding reading instruction manuals or quick-start guides accompanying the products listed. This poses an implication upon product design and designers to convey *all* the required information through the product itself, especially when there is a safety critical element to the operation of the product in question. The next chapter details the administration of the TFQ on a larger scale, to determine the extent to which this manual reading behaviour was commonplace.

7: Investigation 4: Online Technological Familiarity Survey

This chapter introduces and details the development of an online survey, based upon the Technological Familiarity Questionnaire (TFQ) utilised throughout the experimental studies. There are three main areas of focus, namely; the effects of age and technological familiarity, the effects of age and self-reported manual reading behaviour, and the effects of gender and self-reported manual reading behaviour. Initially a recapitulation of the TFQ and its development is presented, followed by the rationale for the development of an online survey, and the subsequent results of its administration.

7.1 The Technological Familiarity Questionnaire

As mentioned, prior experience questionnaires have been used to determine individuals' product experience and feature familiarity (Langdon et al., 2010, Wilkinson et al., 2009). The 'Technological Familiarity Questionnaire' (TFQ) used originates from the work of Blackler (2006) and was modified slightly in the initial two studies and revised again in the latter study to detail a larger range of products (Appendix 10). In the online survey as no product interaction occurred, the instruction to indicate any products that participants may have thought of during interaction was removed.

Two general questions were asked about the list of products:

- How often do you use the following products?
- When using the products, how many features of the product are you familiar with and do you use?

The available responses to the first question ranged from ‘Every day’ to ‘Never’, and likewise responses to the second question ranged from ‘All of the features (you read the manual to check them)’ to ‘None of the features – you do not use the product’.

The results were rated according to Blacker’s rating protocol, the answers providing an individual score for each question posed above, and an overall participant TFQ score (Appendix 8). A relationship exists between score and experience – a high score being indicative of greater experience and a low score representing a lower level of technological familiarity. It was possible to analyse the resultant data in terms of Technological Familiarity (Prior Experience), Gender, Age and Manual Reading Behaviour.

7.2 Why Develop the Online Technological Familiarity Survey

One intention of conducting an online survey was to verify if the trend of product experience decreasing as a factor of age was replicable on a larger scale, outside of the experimental setting. If so, it might validate the original findings and allow greater generalisability of results to a larger population. Another aspect that the performance of the TFQ in an experimental setting highlighted was the extent to which individuals self-reported using manuals when interacting with products. 14% (n = 30) reported that they didn’t use instruction manuals to interact with the products and devices listed and this included product manuals, instruction booklets and quick-start guides. The online survey was thus developed based solely upon the experimental TFQ and administered on a larger scale (n = 74).

Some explanations for this behaviour were born out of the interview and discussion material during Investigation 3, a brief summary of which is documented below.

7.3 Reasons for Avoiding Manual Reading

The verbal reports and interview material gave illuminating insights into why manual reading behaviour may be avoided. Some individuals are simply of a more visual persuasion, preferring icon and image visualisation over text (Participant 22I3). Such participants preferred more visual information available on the product, feeling this would have enhanced their product interaction performance and fitted well with their desire to learn product function directly from the interface, in accordance with the work of Shneiderman (1983) and Norman (1988). This participant considered it to be simply a cost (in terms of time) versus benefit analysis - reading instructions was considered time consuming and cognitively involving. There was also an emotional element: according to one participant new items need to be played with, there and then, for immediate gratification. The participant had made an association between enjoyment derived through direct manipulation and interaction with the product and negativity derived from reading the instruction manual which interrupted the enjoyment experience. This is supported by the notions of Physio, Ideo, Psycho and Socio Pleasure put forward by Tiger (2000) and Porter et al. (2007) who proposed that there is a reciprocal relationship between emotion and interaction, and that product design can affect emotion and thus enhance the return of pleasure from interaction. Similarly, participants reported an apparent information/time trade-off – participants in the study tended not to read (or want to read) all the information available. The immediacy of access to information also appeared be a factor - if the information is easily accessible (within the immediate environment) there appears a greater likelihood of it being read or accessed. If the manual is required it is considered a laborious activity for which there is less motivation. The association of the manual as a laborious artefact was perhaps summarised neatly by Imeson (2011) who observed that modern manuals were more concerned with avoiding litigation, as they were about assisting toward successful interaction:

"Don't you love the three pages of disclaimer information sheets and one picture of how to put up Ikea stuff?"

Some participants were less concerned about reading manuals for household products, but when using more industrial products such as chainsaws or drills, were happy to invest in the activity to minimise the danger of impairment or injury (Participant 19I3).

Another participant concurred with the concept of being a visual person who sought object recognition, rather than searching for textual information in the environment (Participant 17I3). This particular individual adopted such an approach both when looking at and selling products. Knowing what the product and packaging looked like, and basing visual search strategies on this approach, was cognitively less demanding than reading either text on the packaging itself or accompanying documentation. This is not uncommon, and can be considered as a basic pattern recognition technique, reducing the extent of cognitive loading experienced to achieve task resolution (Reason, 1990). It is not unfair to conclude individuals may be capable of adopting similar approaches to product interaction – to search for recognisable and familiar elements of the product to achieve task completion.

7.4 Procedure and Sampling

The TFQ used (Appendix 10) was converted into an anonymous, electronic, online survey using 'SurveyMonkey'; a free online survey software and questionnaire tool that allows the rapid creation of online surveys and is capable of displaying results graphically in real time

(SurveyMonkey.Com, 2011). Appropriately, the survey was designed to feature a welcome page explaining and thanking individuals for participating toward the research about how the use, awareness and experience of technology and specific products may vary according to age. Anonymous age group and gender data were captured on the second page, and participants were again categorised according to the age groups specified in the experimental studies: 16-25, 26-59 and 60-80. The third page was entitled 'Frequency of specific product usage' and provided the same products and response options as in the paper-based version, asking how often the participant used the products listed. The fourth page was entitled: 'Product Feature Usage' and asked participants to indicate when using the products listed, how many features of the product were they familiar with and did they use. Finally, a fifth page thanked participants for sparing the time to complete the survey. The results were then accessible to the researcher online via the SurveyMonkey Analyze Results Interface.

As in the experimental studies, and mentioned previously in the cross-experimental consistencies section (3.4.6 and 3.4.7), a number of recruitment avenues were followed in an attempt to glean responses from a representative sample of the general population. Invitations to participate were sent out across a number of mediums including Twitter, University of the Third Age, Cambridge College Mailing Lists, and local publications, with the intention of ensuring a varied response in terms of age, social and educational background, although these factors were not expressly verified. Those wishing to participate in the research that couldn't be directly involved in the experimental studies, were emailed a link to the EDC Researchers Department Profile Participation Page (EDC People, 2011) that, in itself, contained a link to the electronic version of the Online TFQ Survey (SurveyMonkey TFQ Survey, 2011).

74 individuals from a variety of backgrounds were recruited to minimise any educational biases and maximise ecological validity. Participants were assigned to one of three groups according to age: 16-25 (21 participants), 26-59 (33 participants) and 60-80 (20 participants). The total sample consisted of 34 males and 40 females.

7.5 Data Analysis

Explanation of how the data were analysed to reveal the effects of trends regarding age and gender on experience, interaction and manual reading behaviour will now follow.

7.5.1 Age

During both experimental and online investigations, participants were required to indicate their age. Thus overall TFQ Scores could be assessed and analysed for correlations between age and TFQ Score (level of experience or familiarity).

7.5.2 Gender

Another requirement was to specify the gender category participants felt they most alluded to and this allowed assessment in terms of gender and TFQ Score.

7.6 Manual Reading Behaviour

This was extrapolated from the results and particularly focused upon participants' responses to the question posed on the second page of the Technological Familiarity Questionnaire (Appendix 10): *How many features on the product are you familiar with and do you use on a regular basis?*

As can be seen in Table 18, answers to this question range from 'All of the features (you read the manual to check them) to 'None of the features – you do not use this product'.

Product	**All of the features (you read the manual to check them)**	**As many as you can figure out without the manual**	**Just enough to get by with**	**Your limited knowledge of the features limits your use of the product**	**None of the features – you do not use this product**	
Television				•		
Video Recorder		•				
Satellite Television		•	•			
Camcorder						
(TV) DVD Recorder		•				
Mobile Telephone				•		
Each Column assigned a number	**4**	**3**	**2**	**1**	**0**	
Number of responses multiplied by the column number	**0**	**9**	**2**	**2**	**0**	**13**
TFQ 2 Score						**13**

Table 18: TFQ 2 scoring system: Each column is assigned a number, and this is multiplied by the number of responses the participant has in that category

It was *only* noted when participants had *not* indicated they read the manual to check the features of a product for *any* of the 24 products listed (as in the reduced example above).

Any figure or score in this column would indicate that the participant *had* read the manual for *at least* 1 of the 24 products. Where this occurred, they were subsequently categorised as being manual readers.

The intention was to identify cases when the total in the first column was equal to 0, thus permitting categorising participants as non-manual readers (it is acknowledged this approach doesn't allow for differences according to individual products). The inference from this analysis was that participants' with 0 in this column interacted without referral to the instruction manual for all 24 products.

For example, in the experimental condition (n = 30); 4 people out of 30 participants showed 0 in Column 1 indicating they didn't read the manual and it was then possible to investigate this in terms of Gender (Table 19).

Male Read	Female Read	Male Don't Read	Female Don't Read	Total
11	15	2	2	30
37%	49%	7%	7%	100%

Table 19: Manual Reading Behaviour according to Gender

Although a rudimentary method of analysing manual reading behaviour, it does indicate the presence of particular effects and, at worst, this approach under-represents the extent to which users avoid reading product instruction manuals. With the procedure for extracting age, gender and manual-reading behaviour presented, the experimental and online results follow (it should be noted that only correctly completed questionnaires were used, as a number of online versions were incomplete and it was necessary to remove them from the study).

The age group and gender breakdown used in the study is represented in Table 20 below.

Condition	Age Group	Number of Participants	Gender Breakdown
Experiment	16-25	10	2m 8f
Experiment	26-59	10	8m 2f
Experiment	60-80	10	3m 7f
Online Survey	16-25	20	9m 12f
Online Survey	26-59	34	18m 15f
Online Survey	60-80	20	7m 13f

Table 20: Age Group and Gender Analysis

7.7 Results

7.7.1 Effects of Age on Technological Familiarity

Figure 44 represents the TFQ score comparison between the experimental and online survey results. A similar trend is observable in both instances with the 16-25 age group possessing a higher score than the 26-59 age group who possess a higher score than the 60-80 age group.

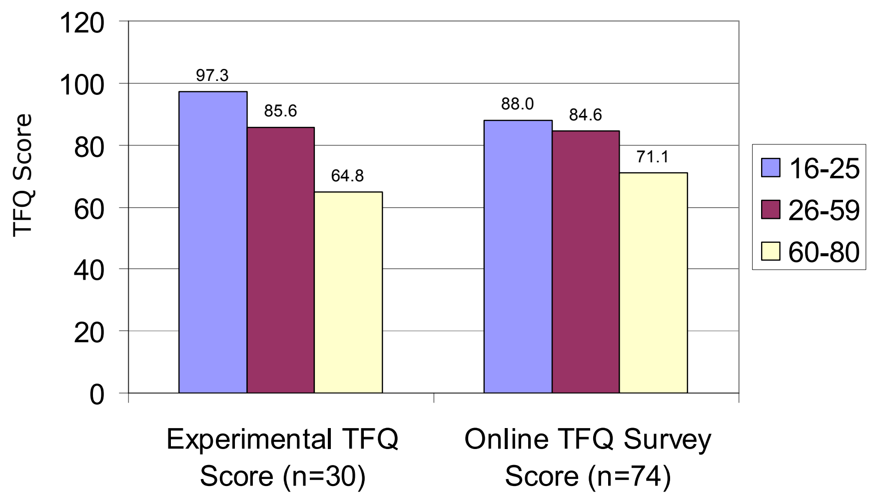

Figure 44: Technological familiarity questionnaire scores according to age

A 1-way analysis of variance (ANOVA) showed a significant effect of age on Overall TFQ Score in the experimental condition: $F(2, 27) = 3.470$, $p<0.05$. Tukey HSD post-hoc analysis indicated that the mean score for the 60-80 age group (M = 64.8, SD = 22.36) was significantly different to the 16-25 age group (M = 97.3, SD = 16.32). The results for the 26-59 age group (M = 85.6, SD = 39.69) were not significantly different from either of the remaining groups.

A 1-way analysis of variance (ANOVA) showed no significant effect of age on Overall TFQ Score in the online condition: $F(2, 71) = 2.552$, $p>0.05$. The variation between groups in this condition is not sufficient to provide significance, so that overall, only the identical trend of younger people possessing higher TFQ scores than older people can be reported.

7.7.2 Effects of Age on Manual Reading Behaviour

Figure 45 represents the number of people who self-reported not reading manuals for any of the 24 products listed within both the Online Survey and the Experimental TFQ.

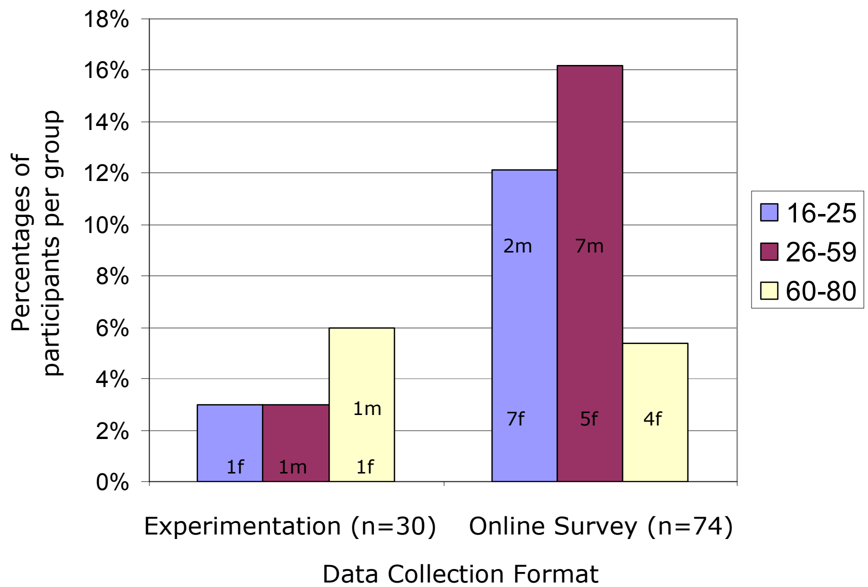

Figure 45: Age and self-reported manual reading avoidance behaviour

A 1-way analysis of variance (ANOVA) showed no significant effect of age on the avoidance of reading instruction manuals in the experimental condition [F (2, 29) = 2.65, p>0.05] or in the online survey condition [F (2, 73) = 1.277, p>0.05]. However, it is observable that 14% (n = 30) in the experimental condition and 34% (n = 74) of participants in the online survey condition reported not reading manuals to interact with products.

In the experimental condition, out of the three age groups, more participants in the older age group reported not reading instruction manuals. In the online survey condition, the greatest reportage of instruction manual avoidance was by the 26-59 age group, with fewer older people reporting avoiding manuals than the younger age groups. This indicates that the younger age groups are more prepared to 'learn-as-they-go' than the older generation, of whom greater proportions use manuals to successfully interact with products.

The data on manual reading behaviour has further been analysed in terms of gender in Figure 44. In the experimental condition it indicates that one female in the 16-25 age group reported not reading manuals, one male in the 26-59 age group, and one male and one female in the 60-80 age group. In the online survey condition two males and seven females in the 16-25 age group, seven males and five females in the 26-59 age group and four females in the 60-80 age group report not reading manuals when interacting with products. More females report not reading manuals than males according to the online survey, and this analysis is expanded in the following section.

7.7.3 Effects of Gender on Manual Reading Behaviour

The data on gender and manual reading behaviour indicates in the experimental condition equal numbers of males and females self-reported avoiding reading instruction manuals (Figure 46).

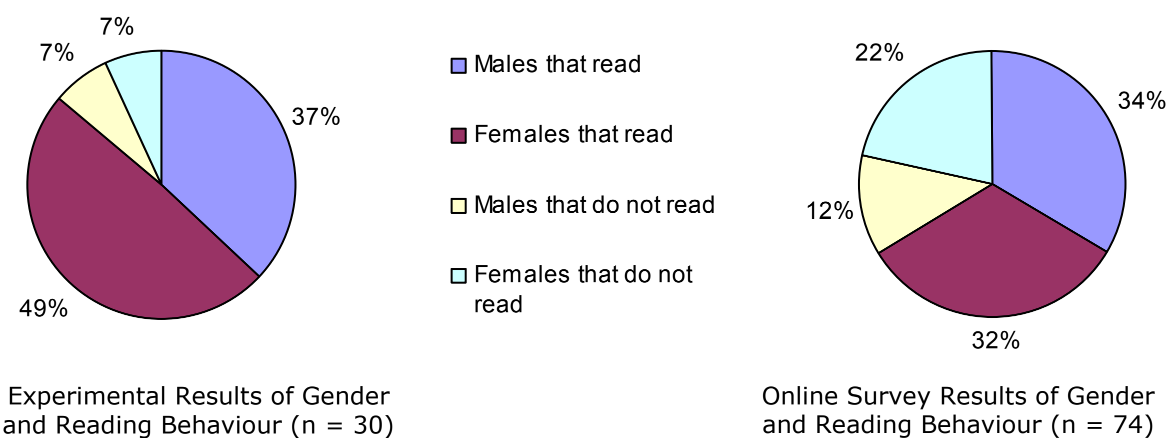

Figure 46: Comparison of experimental and online results of Gender and Reading Behaviour

Almost half of the experimental sample that reported reading manuals were female (49%) and a smaller proportion of males in comparison reported reading manuals (37%). The results of the online survey were conversely more equally distributed regarding those that reported reading instruction manuals (32% female: 34% male), and more females reported avoiding reading manuals (22%) than males (12%). Overall, it is evident that a considerable proportion of participants confessed to avoiding reading instruction manuals and in the online survey more females did this than males (Table 21).

	Male Read	Female Read	Male Don't Read	Female Don't Read	Total
Experiment	11	15	2	2	30
	37%	49%	7%	7%	100%
Online	25	24	9	16	74
	34%	32%	12%	22%	100%

Table 21: Experimental and Online Survey Comparison of Reading Behaviour

7.8 Discussion

The administration of the experimental TFQ indicated 14% (n = 30) of users ignored product manuals. Thus the TFQ was developed into an online survey and administered to a larger sample (n = 74). This revealed a conservative estimate of 34% of users self-reported ignoring instruction manuals. It is worthy of note, that the TFQ Score Data followed the same trend online as experimentally, and the fact that fewer older people self-report not reading manuals may indicate the presence of a further a generational effect. Reasons for this were hinted at by a number of older users who commented that when they were younger, products and technology were not as robust or reliable as today's products. Therefore, based upon this prior experience, they were reluctant to misuse or abuse products through what they perceived to be inappropriate interaction, and were more likely to follow instructions to the letter.

7.8.1 Implications for Design

If a significant number of users ignore manuals, design must faultlessly convey the required information – especially in safety critical situations. Industry appears to be following this trend in terms of increasing usability/intuitiveness, as suggested by the President and CEO of Philips Electronics, Gerard Kleisterlee, who considered that if a product was released that required a manual, it could actually benefit from redesigning and simplifying (Kleisterlee, 2004).

It is important to recall, that no users understood *all* the icons and warnings presented initially in the latter experimental study, although some increases were apparent through exposure and learning. There is a very real potential for electrocution/gas leakage/boiling water leakage if the laser-level detector is incorrectly operated and a user inadvertently damages or drills through pipes or cables hidden behind walls or fascias.

Older people experienced greater difficulty in operation and understanding, and therefore learning, as highlighted by the warning icon recognition, product feature awareness and interaction performance data. Although learning occurred, the older age groups level of knowledge developed peaked at a similar point to that at which the younger age groups awareness and recognition began. Clearly in these instances, product design can and should be improved to facilitate and encourage ease of learning. A generational effect is evident that either hampers learning through exposure, or places the older generation at an immediate disadvantage with regard to learning, operating and interacting with these particular products.

7.9 Conclusion

The Online TFQ Survey indicated that significant proportions of participants and users regularly avoid reading instruction manuals and guides (34%). Kleisterlee's (2004) observation justifies and supports the prohibition of instruction manuals in experimental investigation as an ecologically valid approach. The findings themselves highlight and reinforce some implications for design: if product users are not utilising instruction manuals, then design needs to bridge the gap and facilitate communication between the user and the device. Viewed in conjunction with the previous findings, particularly of Full Scale Study 2 involving the laser-level detector, these notions enhance concerns that not only are designers failing to understand the needs of the user base, but that this is also impacting safety. Furthermore, it would appear the older user in particular is being placed at a disadvantage in this respect. By establishing that there is a fundamental problem that is alienating potential product users, the next chapter introduces the notion of categorising interactional behaviour in terms of the SRK structure which will allows us to assess the extent of cognitive load placed upon users due to product design. By determining where within interaction, greater levels of cognitive demand are a consequence of design, a new method can be used to identify product features that cause increased cognitive loading, impede learning and understanding, and increase interactional complexity. The method will then advocate addressing these issues by directing a redesign focus to these areas. Increasing the ease of interaction and learning by ensuring greater amounts of activity occur at the skill-based, automatic and unconscious level, to a broader age range of users, will widen subsequent product inclusivity, and thereby widen the potential product market.

8: Classifying Observed Interaction in terms of Skill, Rule and Knowledge Based Behaviour

Frequent mention has been made throughout this work to the notion of Skill, Rule and Knowledge based interaction. This chapter will introduce the concept in greater detail, and will then report how the experimental interactions were classified according to the definitions of each activity based on Rasmussen's (1993) work. Following a brief elaboration regarding the SRK Model itself, and provision of the working definitions, the procedure by which interaction with a novel product was framed is provided and the results and conclusions presented. This chapter makes particular reference to the transcribed concurrent protocols and observed behaviour that were created after participants undertook the experimental elements of the research. For complete reference, the reader is directed toward the technical report '*User Experiences of Product Interaction'* (Wilkinson, 2011, pp.57-190) published by the Engineering Department, University of Cambridge.

8.1 The Skill, Rule and Knowledge Based Behaviour Model

As mentioned previously, Rasmussen's model accounted for fluctuations in the level of consciousness required during interaction, based on the assumption that individuals operated at a level appropriate to the familiarity of the situation (Thomas & van-Leeuwen, 1999). The model was developed by Wickens et al. (1998) to incorporate the type of cognitive processing that occurs (Figure 8). In this context, it will be used to classify human behaviour during interaction and simultaneously assess the extent of interactional complexity users experience as a consequence of product design.

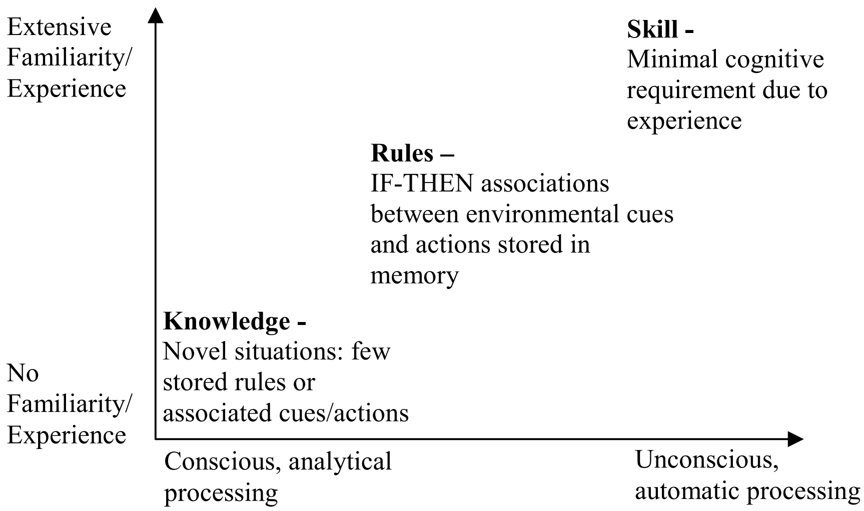

Figure 8: Wickens' (1998) expanded version of Rasmussen's skill, rule and knowledge-based processing model

By determining where, within interaction, greater levels of interactional complexity exist, the suggestion would be to redesign or design-out the features causing confusion or difficulty, thereby increasing the ease of use of the product.

8.1.1 Definitions of Skill, Rule and Knowledge-based Behaviour

Skill-based activities are often highly rehearsed procedures of behaviour: increasing the automaticity of behaviour through repetition (making a cup of tea for example) reduces cognitive loading and allows attentional and cognitive resources to be directed toward other aspects of interaction (Wickens & Hollands, 2000). Such actions can be identified as being highly practiced and fluently executed, requiring a minimal amount of conscious effort in their implementation. Considered almost automatic, these actions are often swiftly repeated or repeatable (Embrey, 2003, Sicart, 2008). Skill-based activity is susceptible however, to attentional errors – skipping or repeating steps in well rehearsed action sequences, or when stimuli trigger an inappropriate automatic response.

The application of rules in the scenario to achieve the desired outcome is indicative of Rule-based behaviour – the scenario may be familiar but to achieve task completion may require the application of conscious attention to execute the associated rule-based response (Rasmussen, 1993). Rule-based mistakes refer to the application of ineffectual rules or rules that are no longer appropriate. These are often short-cuts developed from experience that work most of the time (Wogalter, 2006).

Knowledge-based behaviour is characterised by the exhibition of advanced reasoning (Wirstad, 1988, Reason, 1990). This approach often occurs in novel scenarios, where the situation is unfamiliar: cognitive effort and resources are deployed in understanding the current situation and developing pathways to the desired end-goal scenario which must also be conceptualised. A consequence of exhausting all the options or behaviours at the skill or rule-based level is increased cognitive element and situational demand. Resultant interactional response times are usually greater than either skill or rule based interaction activity (Reason, 1990). Thus, interaction typically requires greater attention and situational awareness, and is often prone to error (Alario & Ferrand, 1999). Knowledge-based errors are failures in the mental models people use or manipulate, or are based on erroneous perception of current stimuli states:

"*...mistakes result from changes in the world that have neither been prepared for nor anticipated…errors arise from the fact that the problem solver has encountered a novel situation for which he or she possesses no contingency plan or preprogrammed solutions*."

(Reason, 1990, p61).

8.1.2 The Interaction of Perception, Error and Action

Lehto (1991) developed Rasmussen's early model of processing to encapsulate human behaviour and its implications in warning system design, indicating how perception, processing and action interconnect and influence each other. To show how the skill, rule and knowledge-based approach will be conceptually applied, and the corresponding error types that may be observed to aid the classification of behaviour, Lehto's model and Rasmussen's concept of cognitive performance levels and error types have been combined in the following diagram (Figure 47).

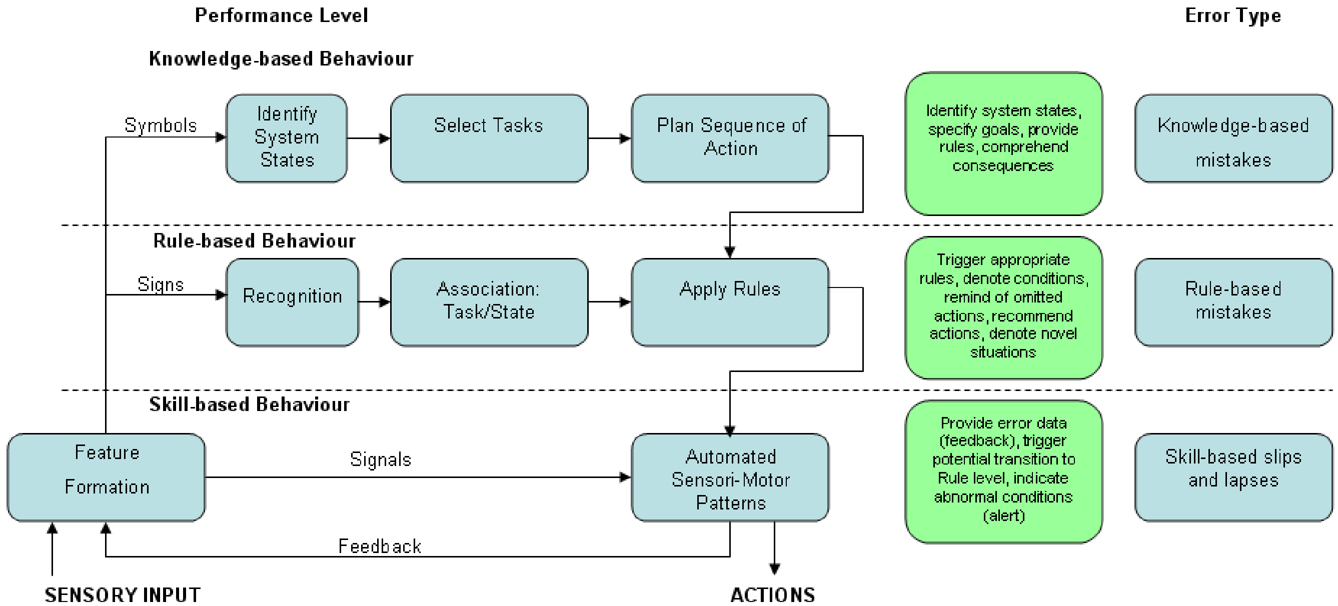

Figure 47: Lehto's (1991) model of human behaviour combined with Rassmussen's (1990) performance levels and Reason's error types (1990)

These notions will directly determine what level of interactional behaviour is being adopted by individuals. To reiterate the overall intention of this study, the aim is to apply the SRK framework at a granular level toward the observed and documented participant behaviour. It will further be used to examine interactional complexity and knowledge acquisition. In inclusive design terms this will allow interactional and product design enhancements to be suggested that would support skill and rule-based behaviour, reducing the cognitive resources required for successful interaction and the occurrence of error.

8.2 Applying SRK Classification to Novel Product Interaction

By way of introduction, an overview of the interactional findings of the first full-scale study (FSS1) have been analysed in terms of the SRK framework. This is prior to the subsequent studies' more rigorous and granular classification of human behaviour in terms of SRK activity.

8.2.1 Classifying an Overview of Interaction

Based upon the definitions of Skill, Rule and Knowledge-based interaction, it is possible to propose that observing the design of the first novel product – the electricity monitor – and physically interacting with it via its button controls, is both a common activity and one that only requires basic input from the user to be accomplished. Therefore *with experience* this can be classified as skill-based behaviour. Accessing and utilising the scrolling-menu system eventually *became* a skill-based activity, but initially participants would have operated at a knowledge, then rule-based, level.

Interacting with the cost-setting function and the scrolling menu system was initially an unfamiliar activity as participants had not developed skill or rule-based procedures or sequences of behaviours. The interaction required the user to use their cognitive ability to enter the correct form of information, and to understand that by entering specific information certain results were obtainable. It also required users to actively review their input and the system's output, and therefore required greater conscious awareness in order to complete the activity. That issues remained regarding the cost-setting functionality, even post-exposure, highlights that it may be an area that would benefit from an inclusive redesign. It was clearly an aspect that demanded much conscious activity even after initial exposure, where users continued to operate at a knowledge or rule-based level. The intention would be to show how a redesign of this interaction procedure or individual features of the product may reduce it's interactional complexity and increase its usability.

8.3 The Classification Procedure applied to Full Scale Study 2

To reiterate, the research aim is:

> *"To investigate the efficacy of applying the SRK framework at a granular level toward participant interaction to examine interactional complexity and knowledge acquisition."*

Figure 48 indicates the element to which the SRK classification procedure was applied.

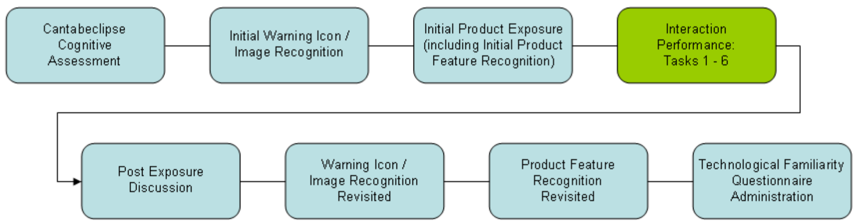

Figure 48: FSS2 experimental procedure

The aim of this approach is to collect qualitative data that can be quantified and evaluated to reveal interactional behaviour in context. It is used to investigate and observe how individuals learn to operate technological products through experience, and to identify where product design may enhance or impede this process. In this instance, the qualitative data consists of the complete video-footage of each individual's user experience of interacting with the product within the experiment. The footage was observed, documented and presented in transcript form. The actions of each individual were interpreted with regard to which category of SRK behaviour the participants' behaviour was most indicative of. To ease discrimination, each of the three categories were assigned a different colour and participants responses highlighted accordingly. Skill-based (automatic) behaviour was highlighted in Green, Rule-based in Blue, and the Knowledge-based (slow, conscious-processing) behaviour highlighted in Red.

The following is a summary of the formal procedure set out by Chi (1997, p.8) for assessing and interpreting qualitative data:

1) Reduce or sample the protocols (transcripts)
2) Segment the reduced or sampled protocols – optional
3) Develop or choose a coding scheme or formalism (SRK)
4) Operationalise evidence in the coded protocols that constitutes a mapping to a chosen formalism
5) Depict the mapped formalism
6) Identify patterns in the mapped formalism
7) Interpret the patterns
8) Repeat the process – optional

Interactional behaviour was documented in transcript form and, as will be subsequently detailed, the protocols have been segmented into 180 individual data sets. The coding scheme adopted is the classification of behaviour according to the observation of Skill, Rule or Knowledge-based activity, and the 180 individual data sets have been classified accordingly.

Chi (1997, p.17) proposes further justification for depicting the coding of the data;

1) As a way of presenting the data to the audience, (just) as quantitative data would be presented graphically or in tabular form
2) To verify if patterns can be detected in the depicted data

Furthermore, Chi suggests that obtaining separate quantitative data from studies also provides a confirmation of the qualitative analysis (p.7). The remainder of this chapter will expand upon this approach, presenting the patterns found in the data and proposing an interpretation that highlights how individuals learn through experience, and identifies where design may enhance or impede this process.

8.3.1 An Example of Classifying FSS2 Interaction

This example focuses upon the insertion of a battery into the household product (Table 22). This was Task 1 of FSS2 and included locating and removing the battery compartment cover, determining the correct orientation of the battery, correctly fitting the battery and replacing the battery compartment cover. The total time taken to correctly insert the battery is 17 seconds. The initial behaviours are swift and automatic – grasping the device and removing the battery compartment cover located on the rear of the device. Hence, these behaviours are demarcated in Green following the key definition of Skill-based behaviour discussed in section 8.1.1.

Time	Product feedback	Observed behaviour	Participant verbalisation	SRK Decision rationale	Knowledge Acquisition / Learning component
39.33		Device picked up in right hand and turned over, cover facing up		Skill-based motor action	
39.37		Battery cover removed with left hand		Skill-based motor action	
39.39		Polarity checked – scan of terminals in product and on battery		Application of rule regarding battery fitment	
39.41		Device checked more consciously and in greater detail for battery polarity instructions		No prior experience / search for knowledge or information	**Knowledge acquisition/affirmation** – new knowledge of interaction is learned or imparted
39.47		Battery inserted		Application of rule regarding battery fitment	
39.49		Cover replaced		Skill-based motor action	
39.50		End			

Table 22: SRK Classification applied to the transcript of observed behaviour

More conscious activity is observed whilst the participant scans and refers to the internal diagram indicating the correct orientation of the battery. There is evidence of the application of a rule as the participant checks for the polarity of the device, relying partly on expectation that the battery will have to be inserted in a specific orientation. This activity is therefore highlighted in Blue. Unable to complete the task at this stage, activity develops into a search for further information as the participant visually scans between the battery and polarity instruction diagram within the battery compartment. Taking on a more conscious feel, this activity is considered most akin to the key definition for Knowledge-based activity, and is demarcated accordingly, in Red. This also highlights an element of interactional complexity, as the individual is not operating at a fluid, skill-based level of interaction, but has had to intentionally search for specific information in order to successfully interact with the product and complete the task. Having acquired this information, the participant is considered to have implemented or affirmed a rule regarding battery insertion. The new information acquired contributes to the creation and implementation of this rule and this activity is demarcated in Blue indicating operation at the rule-based level. The action of replacing the battery cover, being swift and fluid-like, permits activity to be recorded in Green indicating operation at the skill-based level.

As can be observed, the classification goes further by detailing:

- The timings of interaction
- The visual and auditory feedback produced by the device during interaction
- The observed behaviour of participants
- The justification for the skill, rule or knowledge-based classification decision
- The knowledge acquired, sought or affirmed during interaction
- Instances of misapplied rules, correctly applied rules, and incorrectly applied rules, are also determined through interpretation of verbalisation, behaviour and contextual observation

Interactional complexity is identified as episodes within interaction that require the acquisition or affirmation of knowledge, under the premise that if no knowledge is sought or affirmed, or rule applied, the individual will be operating with comparative ease at a skill-based level. Thus, it is possible to frame interaction in terms of SRK activity and identify instances of interactional complexity. Due to the chronological nature of the documented reports, this approach also determines where, when, and what, knowledge is acquired within interaction.

8.4 Applying SRK Classification to the Complete Study Sample

The procedure was applied to the 6 tasks completed by all 30 participants, providing 180 individual data sets. To review the complete application of SRK classification to the observed behaviour of participant interaction, the reader is directed toward the technical report *'User Experiences of Product Interaction'* (Wilkinson, 2011, pp.57-190).

8.4.1 Analysis of SRK Classification

The analysis focussed upon differences between age groups in terms of skill, rule, and knowledge-based activity participants were engaged in during interaction. An additional 'Other' behaviour category was developed to allow for situations where there was no observable interaction, no verbalised thought, extended pauses in speech, or when participants were merely engaged in the activity of listening to product feedback. Studying the timeline of interaction in each of the reports, it was possible to extrapolate the percentage of interaction each participant was engaged in, performing a particular skill, rule, knowledge-based, or other behaviour. This provides a straightforward method of determining each individual's engagement in a specific form of activity.

Table 23 represents the analysis performed upon the previous battery insertion example (see *User Experiences of Product Interaction,* p. 73).

Behaviour Type	Skill	Rule	Knowledge	Other	
Time (Seconds)	4+2+1	2+2	6	0	17
Total (Seconds)	7	4	6	0	17
Percentage of task interaction	41%	24%	35%	0%	100 %

Table 23: Analysis of SRK framed interaction identifying the predominant behaviour type

The task completion time was 17 seconds, and it is evident that this individual predominantly operated at a skill-based level (41% of the interaction), applied rule-based behaviour for 24% of the interaction, and engaged in knowledge-based activity for 35% of the interaction. Observing the report itself, it is evident the participant needed to acquire information relating the correct orientation of the battery in order to complete the task successfully, and this was particularly an area where increased interactional complexity was experienced.

8.5 Complete Study Results

The complete study results of all 30 participants completing each of the 6 tasks were combined to produce the following tables of overall percentages of time spent engaged in skill, rule, knowledge-based, or other activity, according to age group membership and gender. For reference, a more granular breakdown is available in Appendix 12.

8.5.1 Results of SRK Classification according to age

It is evident from both Figure 49 and Table 24 that the overall predominant behaviour type participants engaged in was skill-based in nature.

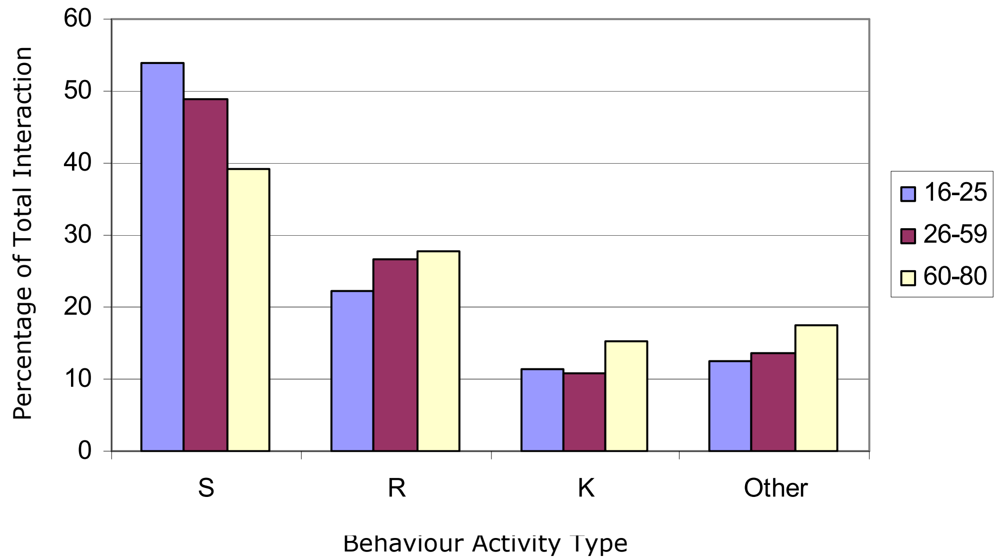

Figure 49: Behaviour Activity Type Classification according to age group membership (n = 30)

	Behaviour Type			
Age Group	**Skill**	**Rule**	**Knowledge**	**Other**
16-25	54%	22%	11%	13%
26-59	49%	27%	11%	13%
60-80	39%	28%	15%	17%

Table 24: Complete Analysis of SRK classification identifying the predominant behaviour type as a percentage of overall interaction according to age group

Rule-based behaviour was the next most commonly occurring type of activity with both knowledge-based and other activity showing comparatively minute differences in terms of overall percentages of behaviour participants were engaged in. Differences according to age group membership are also apparent: the 16-25 age group engage in greater amounts of skill-based interaction (54%) than either of the 26-59 age group (49%) or the 60-80 age group (39%) who indulge in higher rates of rule and knowledge-based activity.

8.5.2 Results of SRK Classification according to gender

Figure 50 and Table 25 indicate that the product has a marginal gender bias regarding skilled operation, in favour of males.

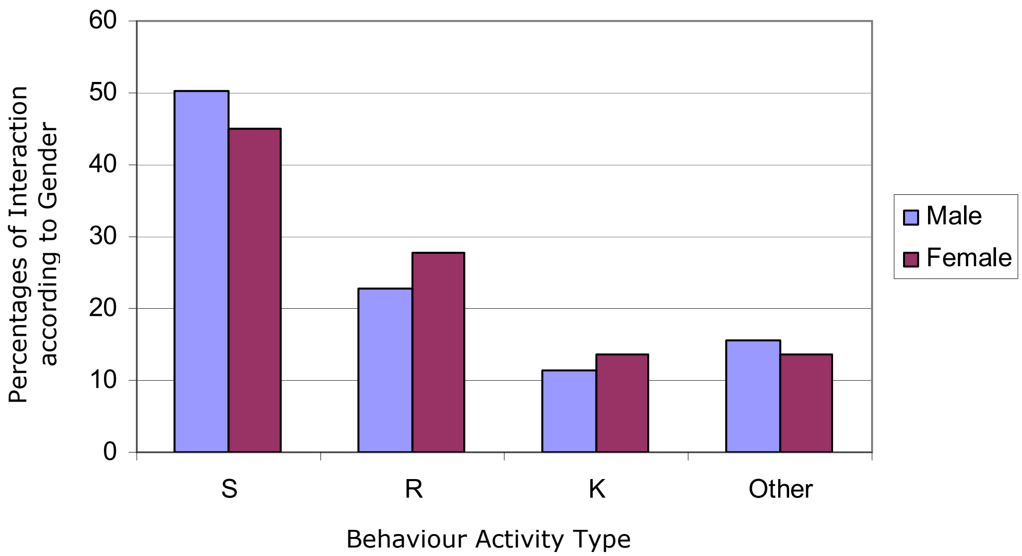

Figure 50: Behaviour Activity Type Classification according to gender (n = 30)

	Behaviour Type			
Gender	**Skill**	**Rule**	**Knowledge**	**Other**
Male	50%	23%	11%	15%
Female	45%	28%	14%	14%

Table 25: Complete Analysis of SRK classification identifying the predominant behaviour type as a percentage of overall interaction according to gender

Table 26 indicates that 50% of males as opposed to 45% of females operated the product at a skill-based level. The results suggest that females exhibit marginally higher levels of rule and knowledge-based interaction than males as a percentage of overall interaction (28% to 23% and 14% to 11% respectively) but these results were not significant.

8.6 Highlighting Interactional Complexity within SRK Classification

The interactional issues highlighted in framing behaviour in terms of SRK activity centre around some key areas that are both related to individuals' and their personal capability, and issues inherent in the design, that were interrelated:

- Physical problems affecting interaction –
    - Participant movement capability – manifest in accessing the battery compartment cover
    - Sight capability in terms of both locating the battery compartment cover and the internal battery polarity diagram
- Design problems affecting interaction –
    - Lack of detailing/differentiating the battery compartment cover from its surroundings
    - Lack of detailing of the battery polarity diagram from its surroundings

A total of 16 participants had issues either with coordinating their physical movement toward successful interaction or had difficulty in visually recognising either the battery compartment location or internal battery polarity diagram. Again these results are age-related (Figure 51).

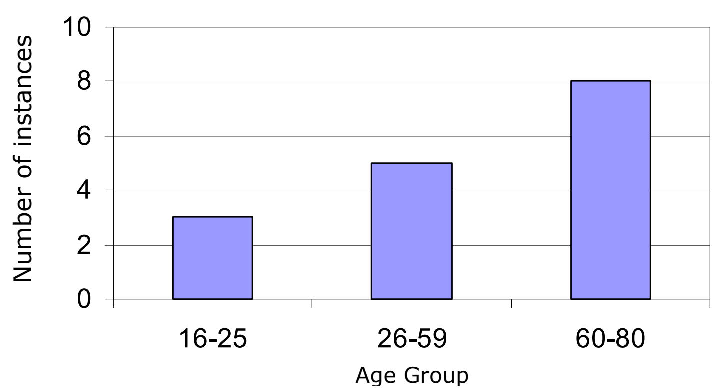

Figure 51: Instances of interactional difficulty in physical movement or visual recognition (n = 30)

It is evident the older age group experience more difficulty interacting with the device, particularly in relation to inserting the battery correctly and locating and manipulating the battery compartment cover, although these issues affect users regardless of age.

8.6.1 Identifying Knowledge Acquisition within SRK Classification

The data also allow examination of the type of knowledge sought by users when interacting with the product. Reflected within instances of interactional complexity, Figure 52 indicates when users were reduced to a knowledge-based level of interaction. These are key points when knowledge was both required and acquired to continue successful interaction with the product. Thus, this identifies what, when, and where, within interaction, knowledge is sought and learned, as well as identifying the issues causing users the greatest interactional complexity.

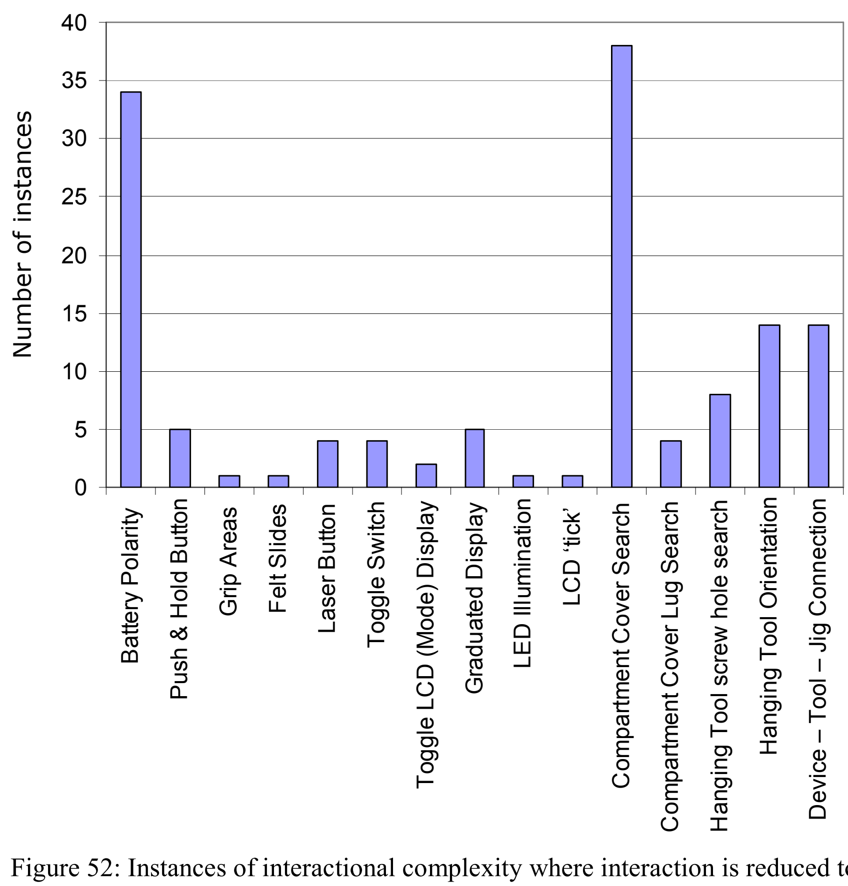

Figure 52: Instances of interactional complexity where interaction is reduced to a knowledge-based level, indicating the features of interaction involved (n = 30)

Clearly the two features of interaction causing the most challenge and greatest interruption to operation at skilled, or rule-based levels of interaction regardless of age or gender, revolve around determining Battery Polarity and the location of the Battery Compartment Cover. The next most frequently occurring design implications centre upon the use of the Hanging Tool that is attached when operating the laser-level function.

With regard to learning and ease of knowledge acquisition, the overall analysis indicates that further consideration of how the information regarding battery polarity and battery insertion, and battery compartment cover location and removal is conveyed to users would be well justified. The compartment cover itself is quite understated and was frequently overlooked because of this. The use of colour and labelling to highlight the cover and the internal battery diagram would improve the ease of knowledge acquisition and learning considerably. The analysis indicates that these elements were the information being sought most during interaction, and indeed, these are elements that are required for successful interaction. Thereby the current design is actively preventing users from interacting with the product intuitively, which limits the product's ease of use and potentially affects user perception and product and brand loyalty. Alienating any consumer makes poor commercial sense, and a simple redesign or rethink may overcome the issues currently hampering the product's intuitive interaction.

8.7 Conclusion and Summary

The intention of this chapter was to introduce the classification of behaviour in terms of Skill, Rule and Knowledge-based interaction, based upon Rasmussen's model of cognitive processing. The differences between these levels of processing were defined and used to interpret the behaviour and verbalised thought processes of participants interacting with the novel device during the experiment. Skill-based interaction was effectively positioned on one end of a continuum, representing an automatic and largely unconscious activity, with knowledge-based interaction at the other, indicating activity that occurs in often novel environments requiring much conscious attention. Rule-based interaction is considered to fall somewhere between these extremes, defined by if-then associations between environmental cues and actions. That these associations have already been formed implies previous experience of similar situations that assist in decision making strategies toward task completion.

SRK classification was applied to the complete study sample of Full-Scale Study 2, framing the interaction between user and product, as each of the six tasks in the experiment were completed. The main findings indicated that more members of the younger age group operated the product at a skill-based level. In contrast, a lower number of older participants tended to interact with the product at this level, and showed higher levels of rule and knowledge-based activity. Very slight gender differences were also observed, and these findings were supported by the Technological Familiarity Questionnaire data that found correlations between age, performance and product experience.

The approach of framing interaction in terms of SRK behaviour has highlighted interactional design and complexity issues, as well as analysing learning activity. It is recommended that SRK framing is applied to all tasks a product, design, system or interface is designed to fulfil. This research approach has been capable of identifying how and when learning occurs during interaction, revealing precisely what information is learned, and has indicated the elements that cause interactional complexity for users. The final chapter discusses the overall findings and conclusions of the research in terms of the Research Plan outlined in Chapter 3.

9: Discussion and Conclusions

This chapter discusses the implications of the results presented in Chapters 4 to 8 and how they relate and interconnect with the theories discussed in Chapters 1 to 3. Following the conclusions drawn, a critique of the work conducted and suggestions for future research are presented. To recall, a pilot study was conducted to ascertain that the experimental approach conceived was capable of gleaning the desired information. The first main study examined mental model development, generational differences and differences in performance according to individuals' prior experience of technology. The second main study continued these themes and also addressed the concept of learning development and knowledge acquisition during the process of interaction. Of the two further investigations, the initial one took the form of an online study that administered the Technological Familiarity Questionnaire on a larger scale. This investigated differences according to age and experience, and highlighted findings regarding the use of instruction manuals and manual reading behaviour adopted by users. The final investigation focussed upon generational differences within the classification of user behaviour in terms of skill, rule and knowledge-based behaviour according to the Rasmussen (1993) model. The intention was to draw out greater information about what occurs during interaction on a granular level to determine where, when and what knowledge is acquired during the process of interaction, how design might influence this, and the effects of age upon this process.

To recap, the intention of the overall project was to investigate the effect of prior experience upon interaction and its role within Inclusive Design and toward this aim the overarching research question posed was:

Is there further knowledge to be gained for the design community from the study of generational differences in terms of prior experience and contemporary product interaction?

This research question was subdivided into three main subcomponent research aims, which will be discussed in conjunction with the presentation of their contribution toward answering the overarching research question and their relation to literature:

1. *To investigate the existence of age-effects regarding prior experience and any associated affects upon interaction with a number of household products*
2. *To verify if a correlation between product experience and age exists on a larger scale, outside of an experimental setting, and to investigate the extent to which individuals self-report using or avoiding instruction manuals when interacting with products and the associated implications for design and designers*
3. *To investigate the efficacy of framing interaction in terms of Rasmussen's (1993) Skill, Rule and Knowledge-based Model of behaviour and thereby determine how knowledge acquisition is facilitated and identify instances of interactional complexity.*

9.1 Addressing the first subcomponent Research Aim

This first subcomponent research aim was: '*To investigate the existence of age-effects regarding prior experience and any associated affects upon interaction with a number of household products'*. Subdivided ultimately into 8 components that were developed through experimentation, each of these subcomponent elements will be introduced and the overall findings discussed.

9.1.1 Is it possible to determine the existence of age-effects regarding physical approaches to interaction?

The interaction results were studied to reveal if participants' approaches to interaction differed according to age. In the first main study (FSS1), significant differences between the 60-80 age group and 16-25 age group were revealed regarding task completion times, with numerous correlations suggesting age is a factor in terms of task completion speed. This finding was also repeated in the second main study (FSS2). There was a significant effect of age on task completion time between the older and younger age groups, with age correlating to task completion times in five out of seven instances. Overall, this suggests that age is a factor in the speed with which tasks were completed: as age increased the speed with which these specific tasks were completed also increased.

Differences were also apparent in FSS1 between the 60-80 age group and 16-25 age group regarding the number of button presses made to complete tasks. Increases in age correlated to a significant increase in the number of button presses made to complete task 1, and there was a positive correlation between age and average number of button presses, showing the same trend. Thus, the interactional accuracy of the older generation appeared compromised in this respect. Significant differences between the 60-80 age group and 16-25 age group also were revealed in this study regarding the number of erroneous interactions made. Positive correlations between age and the number of erroneous interactions made to complete task 5 and for the overall average number of button presses were also observed. The correlations indicate that in these instances, increases in age correlate to increases in the number of button presses made to achieve task completion. This indicates that again, as the participants age increases, the design appears to impair interaction, causing it to be less accurate or efficient, and placing such users at an interactional disadvantage. Further correlations indicated that increases in age were associated with higher levels of time taken per individual button press. This indicates that as individuals age they take longer to physically interact with products, devices or systems. This may be due to age-related physical dexterity issues, a decline in cognitive ability or exposure to age-related design phenomenon that preclude or compromise efficient interaction. As a whole, these results indicate that it is possible to determine the existence of age-effects regarding physical approaches to interaction, and are in line with research that suggests generational differences are a factor in terms of product interaction (Docampo-Rama, 2001, Freudenthal, 2001, Langdon et al., 2010, Tarakanov-Plaz, 2005). From a design perspective, these results show that as the participants' age increased, so their interaction with the product was compromised, evidenced in less accurate and efficient interaction, and ultimately placing such users at an interactional disadvantage.

9.1.2 Is it possible to determine the existence of age-effects regarding the level of icon recognition?

The notion of icon recognition was examined by assessing participants' pre-product-exposure levels of icon recognition, and their levels of post-product-exposure icon recognition. Analysis indicated no significant difference between the age groups at the pre-product-exposure stage, but significant differences between older age group and middle age group, and between the older age group and young age group in the post-product-exposure stage. Increases in age were also found to correlate to a significant decrease in icon recognition at the pre and post-product-exposure stages and correlated to decreases in iconic information acquisition during exposure. This provides further evidence for the generational effect – that as we age our ability to acquire new knowledge and learn from interaction decreases, and that the knowledge we bring to interaction also decreases as a factor of age.

9.1.3 Is it possible to determine the existence of age-effects regarding the level of product feature recognition?

The notion of feature recognition was examined by assessing participants' pre-product-exposure levels of feature recognition, and their levels of post-product-exposure feature recognition. Analysis indicated a significant difference between the 60-80 age group and the 26-59 age group at the pre-product-exposure stage. Significant differences were also indicated between the 60-80 and 26-59 age groups, and the 60-80 and 16-25 age groups in the post-product-exposure stage. In both stages age was a significant factor in feature identification and in the amount of product feature knowledge gained through exposure. The older age groups ability to acquire information and learn appeared to be adversely affected. Furthermore, increases in age correlated to significant decreases in feature recognition at the pre and post-product-exposure stage, and to decreases in the ability to acquire product feature knowledge. As individuals age their ability to acquire feature related information would appear to decrease as a correlational factor of age. These findings, again, are in accordance with literary expectation (Norman, 2002, Mescellany, 2002, Docampo-Rama, 2001 and Langdon et al., 2010).

9.1.4 Is it possible to determine the existence of age-effects regarding the numbers of products that participants are prompted of during interaction?

Prompted product recall was examined in both experiments, although primarily the latter. However, reappraisal of the findings of FSS1 in this context are warranted. Investigating the potential transference of product knowledge from familiar to unfamiliar products, the study examined the number of products participants referenced during experimentation. In the latter study this was expressly labelled ‘prompted product recall’. In the former study, examination focussed upon the most frequently referenced products during interaction and discussion. In this instance, it appeared that those in the 26-59 age group were most used to the multi-button-press interactional approach and the multi-button functionality model required. This feature of the product was most likened to alarm clocks, digital watches and DVD controllers by 14 out of 30 participants (Table 9). The 26-59 age group referenced the largest quantity of products possessing similar characteristics (16) followed by the 16-25 age group (10) and the 60-80 age group (6). In the latter study, comparison according to age group membership revealed that although there was no significant effect of age upon prompted product recall, a trend was evident that indicated recall differed uniformly with age. Younger individuals recalled higher numbers of products than older individuals, and although differences between groups were not significant, increases in age did correlate to a significant decrease in prompted product recall. This indicates the existence of a generational effect – our ability to recall products decreases with age. In terms of this research, this implies the older generation will be compromised in the extent to which they can draw on other frames of contemporary interactional reference, when interacting with a novel device. That the younger age groups indicated greater numbers of products, may be linked to their superior performance with the novel products, and provides further evidence for feature familiarity and the transference of product mental models facilitating novel product interaction.

9.1.5 Is it possible to determine the existence of age-effects regarding the extent of prior technological familiarity?

The administration of the Technological Familiarity Questionnaire (TFQ) provided the opportunity for experimentation to establish the extent to which participants' interacted with specified technology on a regular basis and the number of products with which they were familiar. In the former study, TFQ analysis showed a significant effect of age on frequency of contemporary product use, indicating that the older participants were less familiar and interacted with the products less frequently than the younger and mid-age groups. Analysis also indicated that there are significant differences between the older age group and the younger age group, and between the older age group and the mid age group, in terms of product feature familiarity. This result implies that older individuals are significantly less aware or use fewer features of the examples of the products presented than individuals belonging to the younger and mid-age groups. Increases in age significantly correlated to decreases in the frequency with which participants interacted with the technology identified in the TFQ and to a decrease in the use and awareness of product features. Overall, this indicates another strong generational effect – ageing equates to less feature awareness and contemporary product interaction.

In the latter study (FSS2), the expectation that older users would experience greater difficulty and be less familiar with current technology (Tarakanov-Plaz, 2005) was largely supported by the experimental data. Although there was no effect of age on TFQ Q1 score regarding the frequency with which participants interacted with the specified technology, there was a significant effect of age upon awareness and use of product features (Q2) between the older and younger generation, and this was replicated in terms of the overall TFQ Score. Similarly there was a significant correlation between age and overall TFQ score, indicating that increases in age correlated to decreases in the frequency with which participants interacted with the technology identified in the questionnaire, and to a decrease in the use and awareness of product features. Overall, this indicates another strong generational effect – ageing equates to less feature awareness and product interaction. Thus, it would appear that prior technological familiarity or experience is affected by age and that increases in age relate to decreases in breadth and depth of product knowledge and usage. This supports literary expectation that older individuals will experience difficulty interacting with non-familiar products or designs (Howard & Howard, 1997) and may provide some explanation as to why this might be the case.

9.1.6 Is it possible to determine the existence of age-effects upon conceptual understanding?

The concurrent protocol was assessed to examine how participants understanding of interaction differed between groups and changed over time. In the former study, all participants initially recognised that the product was electrical in nature and made reference to plug devices and measuring tools in the initial phase of questioning. The 26-59 age group provided the most accurate and elaborate descriptions at this stage. At the mid and the latter stages, again, the older generation provided the vaguest descriptions of the device and what it was designed for. The 16-25 and 26-59 age groups provided at this point, more concrete, thorough, and accurate descriptions of the purpose, function and interaction of the product. The scrolling menu feature of the product was learned and understood by all age groups, and the most cited product resemblance was to digital watches and alarm clocks, both featuring multi-button press requirements, scrolling menus, and up and down adjustment controls. The 26-59 age group cited the highest number of similar devices. Thus it was clear differences were apparent according to age group membership and the older generation again appeared most compromised in their ability to formulate accurate internal models of the product and its required interaction technique. This concurs with literary expectation that model development and interaction can be compromised with age (Burke & Mackay, 1997, Langdon et al., 2010, Pape et al., 2002, Dickinson et al., 2003 and Weiss, 2002).

Analysing the concurrent protocol of participants from the latter experimental study (FSS2) in combination with the experimental data (task performance times, icon recognition, product feature recognition, understanding of product function, functionality, and conceptual awareness), revealed increases in knowledge and understanding over the duration of product exposure. Design features appeared fundamental to the creation and development of product understanding and formation of an internalised mental model, and the mental model of the product was significantly developed in the latter stages of the experimentation from a basic initial concept to an accurate post-exposure conclusion. Feature familiarity was also a key factor. For example, the On/Off switches including the sliding switch to operate the laser function was felt to have been seen before by a number of participants in such devices as mobile phones, including the tactile requirement to hold specific buttons for a time period to activate a particular response or function. The transcribed reports indicate that the mental models developed were dependent upon observations of features, icon recognition, and the product design as a whole, as well as its designed interaction. Younger age groups recognised greater numbers of both icons and product features, possessed the greatest TFQ scores and highest numbers of prompted product recall. In combination, these elements contributed to the depth, accuracy and content of their mental models. This increased knowledge or awareness also appears to account for their superior performance with the laser detector.

9.1.7 Are there other generational or age-related differences in interactional approach observable?

Attitudes toward interaction also appeared to differ according to age as Dewsbury et al. (2007) has suggested. Of particular note, in FSS1, it appeared that participants belonging to the older age group were reticent and reluctant to try new things with the device, stating:

> "*I would have thought you should only have to press any of them (the buttons) once, not multiple times. You're afraid and think pressing the buttons quickly will break it*."

Accordingly, the average time per button press data revealed that those in the 60-80 age group took longer to make individual or combinations of moves, as opposed to the younger age groups who were noticeably quicker in their average times per button press. In conjunction with each groups level of technological familiarity, it is evident that the younger generations possessed a greater awareness and level of interaction with contemporary technology than the older generation. This greater level of familiarity may correspond to an increase in overall task performance, and perhaps a notable observation is that the younger generations were the most economical in their interaction – making the least number of errors in the shortest time. The older generation quickly became frustrated when the product would not respond in an intuitive fashion:

"*Young people would know about multi-button pressing and holding buttons, and have the patience to try different combinations, until they get the response they want. I just don't have the patience. I would try what I know, and if it didn't do what I wanted it to, I'd just go mad and give up with it*."

Conversely, the concurrent protocol indicated that the younger generations' interactional approach was more relaxed and that they were convinced that, given time, they would obtain the solution. These findings were considered further evidence for the fact that older participants are less prone to engage with modern products and interfaces. That a greater level of familiarity may consequently correspond to an increase in overall task performance is, again, in line with the research of Langdon et al. (2010) and Blackler (2006).

9.1.8 Is learning and interaction facilitated by ease of feature and icon recognition, and age dependent?

The awareness and recognition of product features and icons was examined in the solely in the latter study, and the number of product features identified increased cross-generationally over the course of exposure. The average number of increases in features identified over the course of exposure was 5.97 items. The extent to which a greater number of product features were recognised by the younger generations initially and subsequently is of interest both to this study and to the overall design of products. In both instances of learning and knowledge acquisition recorded by this approach that consisted of increases in warning icon and product feature awareness and understanding, it was evident that the younger age group exhibited greater rates of learning and knowledge acquisition. The 16-25 age groups' rate of learning was the most accelerated although the 26-59 age group exhibited the greatest amount of initial recognition and awareness of warning icons and product features. Of further interest is that the level of knowledge acquired by the older age group at the end of exposure, is roughly at the level at which the younger generations commence the study. Thus, it may be that these icons and features may themselves alienate older users. Greater levels of icon and feature recognition also correlate with greater levels of interaction performance in this study and are traits exhibited by the younger age groups. This provides further evidence that familiarity is age-related, and as such, is a key aspect in performance and user-centred design that aims to facilitate more intuitive interaction.

9.1.9 Subcomponent 1 Conclusion

The aim of subcomponent 1 was to determine the existence of age-effects regarding prior experience and any associated affects these have upon interaction with a number of household products. It is clear that the findings supported the notion that age-effects did exist in terms of physical approaches to interaction, the extent of icon and feature recognition and prompted product recall, and technological familiarity, and that these elements contributed to differences in terms of conceptual understanding and development. Furthermore, the ease of feature and icon recognition appears to facilitate successful and effective interaction. Through experimentation then, it has been possible to establish differences in performance according to age-group membership. Younger people appeared more adept at interacting with contemporary, novel products confirming literary expectation (Norman, 2002, Mescellany, 2002, Docampo-Rama, 2001, Langdon et al., 2010). It appeared that the specific features and warning icon designs and symbols used within this product may alienate older users, as fewer recognised and understood their meaning, and their overall performance suffered. This may provide further evidence and justification for feature familiarity being a key aspect in user-centred and inclusive design. The notion that older participants were hampered by being unable to transfer useful information from other products may be supported by the evidence that the number of products they were reminded of during interaction was significantly lower than the younger generations. The observation that the younger age groups were reminded of greater numbers of products may also be linked to their superior performance with the novel product. This supports the theory of feature familiarity and transference of product mental models facilitating novel product interactional performance. This notion is also supported by the results of the TFQ administration, which concluded older individuals possessed less prior experience with a range of contemporary technology products than the younger generation and may provide further support for a generational effect in that as we age our inclination to 'keep up to date' with the latest developments may decline (Wright, 2006).

Design elements were apparent in the studies causing users interactional difficulty. These ranged from poor display design – digits being too small and compromising readability, screen illumination being considered insufficient in the low-lighting conditions that the devices might reasonably be subject to, and the difficulty of button manipulation for older users. These factors are evidence of both poor user centred design and a lack of user consideration (Rogers et al., 1997). Amongst many other aspects, it is well reported that manual dexterity decreases with age and this impacts directly upon ease of product use for older people (Osman et al., 2003). Overall, the interaction and observational evidence presented throughout this work would suggest that simple alterations to the physical design and the method of interaction would enhance individuals' ability to learn and use these products, potentially having an immediate impact upon product usability. Indeed, more informed initial design conceptualisation might also have alleviated the problems experienced, regardless of age, in the products released to market.

9.2 Addressing the second subcomponent Research Aim

The second subcomponent research aim was: *'To verify if a correlation between product experience and age exists on a larger scale, outside of an experimental setting, and to investigate the extent to which individuals self-report using or avoiding instruction manuals when interacting with products and the associated implications for design and designers'*. This was addressed with a comparison of results from the Technological Familiarity Questionnaire administered as a factor of FSS2 and an online version of the questionnaire administered to a larger sample. Subdivided into 4 components, a key intention of conducting the online survey was to verify if the experimental trend of product experience decreasing as a factor of age was replicable on a larger scale outside of the experimental setting. The existence of age and gender effects were also examined in terms of the extent to which individuals self-reported using manuals when interacting with products, and finally, from a design perspective, if there are design implications posed by users' approaches to manual reading behaviour. Each of these subcomponent elements will be introduced and the findings discussed.

9.2.1 Is it possible to determine the existence of age-effects regarding the extent of prior technological familiarity in both an experimental and external setting?

The Technological Familiarity Questionnaire was developed into an online survey to investigate both if a correlation between age and product experience exists on a larger scale, and to examine the extent to which users read instruction manuals when confronted with novel products. Although there was a significant effect of age on TFQ score in the experimental setting, this was not replicated in the online survey results. However, the same trend was observed regarding overall TFQ scores in the online study as in the experimental setting – the 16-25 age group possessed a higher score than the 26-59 age group who possessed a higher score than the 60-80 age group. Thus, whilst it is not possible to confirm on a larger scale, that there is a significant effect of age upon TFQ score, the general trend observed indicates that although not statistically significant, the trend for younger individuals to possess greater amounts of contemporary product knowledge than older individuals is maintained.

9.2.2 Is it possible to determine the existence of age-effects regarding manual reading behaviour in both an experimental and external setting?

Analysis showed no significant effect of age on the avoidance of reading instruction manuals in the experimental condition or in the online survey condition. However, greater proportions of participants reported not reading manuals to interact with novel products in the online condition: 14% (n = 30) in the experimental condition and 34% (n = 74) of participants in the online survey condition. The results of the online survey condition, with the greatest reportage of instruction manual avoidance by the 26-59 age group, and with fewer older people reporting avoiding manuals than the younger age groups, suggests that the younger age groups are more prepared to 'learn-as-they-go' than the older generation, of whom greater proportions use manuals to interact with novel products.

9.2.3 Is gender a factor in self-reported manual reading behaviour?

In the experimental setting (n = 30), 7% of males and 7% of females reported intentionally avoiding instruction manuals when confronted with the products identified on the TFQ. In the online survey condition (n = 74), more females reported avoiding reading manuals (22%) than males (12%). Therefore, there does appear to be some evidence for gender to have an effect upon manual reading behaviour in the online survey condition. However, investigation of gender was only of peripheral interest to the study. The more relevant finding was that regarding the overall numbers of participants who admitted to avoiding reading manuals when interacting with products: 14% (n = 30) in the experimental condition and 34% (n = 74) in the online survey condition. This was felt to pose serious ramifications for designers, particularly of products or systems that possessed implications for user safety.

9.2.4 Are there design implications posed by users' approaches to manual reading?

As already mentioned, this study found that 14% of users in an experimental setting and 34% of users in an online survey admitted to ignoring or avoiding reading instruction manuals when confronted by new technology. Recalling that no participants in the experiment understood *all* the icons and warnings presented initially on the product in the study, and that 14% of these participants freely admitted their preference for avoiding manuals, it is a concern that the product itself does possess implications for user safety. There is a real potential for electrocution, gas or boiling water leakage, if the laser-level detector is incorrectly operated and a user inadvertently damages or drills through pipes or cables hidden behind walls or fascias. Although learning occurred in both scenarios due to product exposure, in both instances the level of knowledge developed by the older age groups peaked at a similar point to that at which the younger age groups awareness and recognition began. Clearly in these instances, product design can and should be improved to facilitate and encourage ease of learning, and to alleviate the generational effect that is evident. This effect either hampers the ability of the older generation to learn through exposure, or places them at an immediate disadvantage with regard to learning, operating and interacting with this product.

9.2.5 Subcomponent 2 Conclusion

The fact that older individuals were more inclined to read manuals may indicate the presence of a further generational effect in terms of their approach to technology and problem solving. Older users may have concerns about damaging products based on prior experience and thus 'follow the rules to the letter'. Or, as found in these studies, be less inclined to continue to achieve task completion or contemplate interacting with a novel product. Reasons for this were indicated by a number of older users who commented that when they were younger, products and technology were not as robust or reliable as today's products, therefore they were reluctant to misuse or abuse products through what they perceived to be inappropriate interaction. Similarly, some users stated that if the device didn't respond as they expected, they would be more inclined to "give up with it" than complete the task in hand. The study highlighted the importance of communicating effectively through design to compensate for the reluctance of users to peruse instruction manuals. Thus, there is greater impetus and need for design and designers to convey the correct message in a way it will be understood to ensure successful and safe interaction. The ability of users to accurately comprehend the message is also a factor within this research, as findings indicate that regarding icon and feature recognition, older users in particular may be placed at a disadvantage. This age group is thus being excluded, purely on the basis of age and insufficient consideration, awareness, or knowledge of the needs of a significant proportion of the potential product market.

9.3 Addressing the third subcomponent Research Aim

The third subcomponent research aim was: *'To investigate the efficacy of framing interaction in terms of Rasmussen's (1993) Skill, Rule and Knowledge-based model of behaviour and thereby determine how knowledge acquisition is facilitated and identify instances of interactional complexity'*. This was addressed with the application of the SRK framework at a granular level toward participant interaction and examined both interactional complexity and knowledge acquisition. The video-footage of each individual's user experience of interacting with the product within the latter experiment was observed, documented, and presented in transcript form. Each individual's actions were classified in terms of which category of Skill, Rule or Knowledge-based behaviour the behaviour was most indicative of. The procedure was applied to the 6 tasks completed by all 30 participants, providing 180 individual data sets, and the analysis examined the effects of age, gender, knowledge acquisition and interactional complexity. Each of the subcomponent elements will be introduced and the findings discussed.

9.3.1 Do users operate at different levels of Skill, Rule or Knowledge-based activity according to age?

It is evident from the analysis that the overall predominant behaviour type participants engaged in during interaction with the laser-level detector was skill-based in nature (Table 24). Rule-based behaviour was the next most commonly occurring type of activity with both knowledge-based and other activity showing comparatively minute differences in terms of overall percentages of behaviour participants were engaged in. Differences according to age group membership are also apparent: the 16-25 age group engage in greater amounts of skill-based interaction (54%) than either of the 26-59 age group (49%) or the 60-80 age group (39%).

	Behaviour Type			
Age Group	**Skill**	**Rule**	**Knowledge**	**Other**
16-25	54%	22%	11%	13%
26-59	49%	27%	11%	13%
60-80	39%	28%	15%	17%

Table 24: Behaviour Type according to age group membership

Thus, it is evident that users operate at different levels of skill, rule and knowledge-based behaviour according to age, and that interaction predominantly occurred at a skill-based level, followed by rule and knowledge-based activity respectively.

9.3.2 Do users operate at different levels of Skill, Rule or Knowledge-based activity according to gender?

The results indicate that the product has a marginal gender bias. Males spent 50% of the interaction operating at a skill-based level, whilst females spent only 45% of the interaction operating at a skill-based level (Table 25).

	Behaviour Type			
Gender	**Skill**	**Rule**	**Knowledge**	**Other**
Male	50%	23%	11%	15%
Female	45%	28%	14%	14%

Table 25: Behaviour Type according to gender

The results suggest that females exhibit marginally higher levels of rule and knowledge-based interaction than males as a percentage of overall interaction (28% to 23% and 14% to 11%

respectively). Thus the results indicate that there are mild gender differences with regard to level at which users operate.

9.3.3 How and what Knowledge is learned during interaction?

The analysis allowed examination of the type of knowledge sought by users when interacting with the product, and highlighted the issues that reduced interaction from a skill-based activity to a knowledge-based level of interaction. These were the key areas of design that compromised users' ability to interact intuitively with the device and caused interactional difficulty or increased the complexity of the interaction. Highlighted in the following diagram are all the instances where knowledge was either sought or gained during interaction with the product (Figure 52). The features causing the most challenge and greatest interruption to operation at skilled, or rule-based levels of interaction regardless of age or gender, revolve around determining battery polarity and the location of the battery compartment cover.

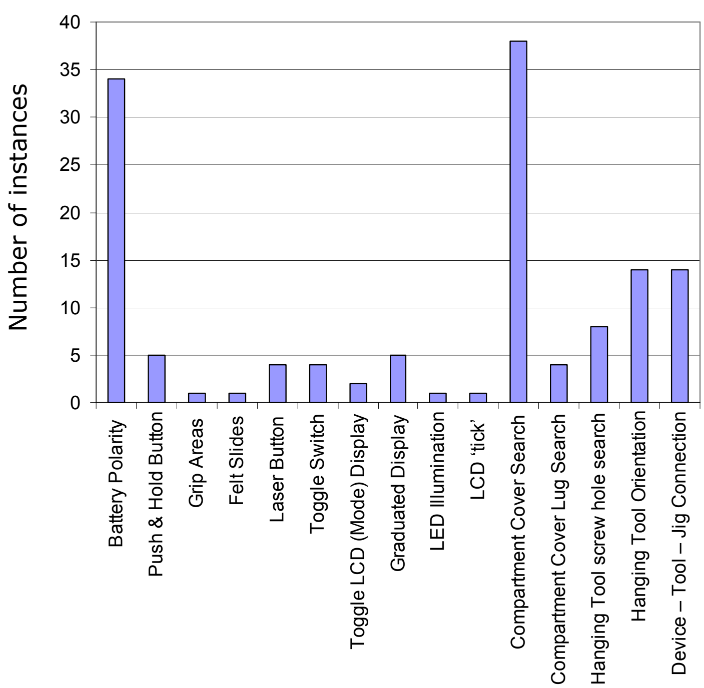

Figure 52: Instances of interactional complexity where interaction is reduced to a knowledge-based level, indicating the features of interaction involved (n = 30)

The next most frequently occurring design implications centre upon the use of the hanging tool that is attached when operating the laser-level function. This analysis defines the moments when the knowledge possessed by users was insufficient for them to operate at a skill-based level, and where users were required to search for more information in the environment and the product itself to be able to continue interaction. This approach has identified how and when learning occurs during interaction, revealing what information is learned, and required to be learned, and has indicated the elements that cause interactional complexity for users.

9.3.4 Is there a relationship between age, experience and level of interactional complexity?

From the results of FSS2 that are directly connected with the SRK classification, it is clear that the younger age groups showed a prevalence of operating at a skill-based level of interaction, indicating that their responses were more automated, immediate and quicker toward task completion than the older participants. To recall, Skill-based activity was defined as being automatic and fluid-like with minimal cognitive requirement due to the familiarity and experience. This finding is supported by the TFQ Data that also correlates technological familiarity with age, indicating the younger age groups had a higher level of technological familiarity with modern interfaces and products.

Interfaces ideally facilitate user-interaction at a skill-based level for successful operation. Although skill-based behaviour was certainly evident, inclusively, the design of the battery compartment cover and the battery recess was not as intuitively designed as it might have been. This was seen as a fundamental area where the design and intuitive interaction of the product could be significantly improved. Analysis revealed that 16 participants had difficulty solely coordinating their physical movement for successful interaction or had difficulty in visually recognising either the battery compartments location or internal battery polarity diagram (Figure 51).

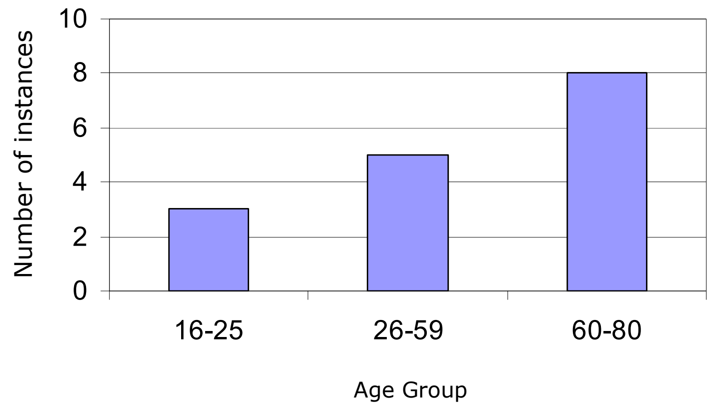

Figure 51: Instances of interactional difficulty in physical movement or visual recognition (n = 30)

9.3.5 Subcomponent 3 Conclusion

Developing the required skill–based behaviour should be straightforward and an underlying aim of designers. If a user continues to operate at a rule or knowledge based level, it may indicate that the user is experiencing difficulty deciphering interactional sequences or that the overall design of the product is not facilitatory toward intuitive interaction and understanding. Either specific elements of the task the user is trying to perform require alteration, or the product design requires evaluation and ultimately simplification, to maintain interaction at a skill-based level. To reiterate, if a user is still using the "slow, sequential, laborious and resource-limited conscious processing" (Reason, 1990, p. 57) of knowledge-based behaviour for basic operations, even after several times of trying to use it, at which point a user should normally have developed their own stored rules and procedures (Rasmussen, 1987, p. 293), it may be an indicator there is an issue with the way the product, or it's interaction, is designed or in the way information about the operation the user is trying to perform is being conveyed to the user. Users may engage in knowledge-based behaviour in order to comprehend the interaction initially and then follow through with planning, goal setting, and research, in order to formulate and consolidate rule-based behaviours. Finally, these may be developed into skill-based behaviours, capitalising upon an individual's automated, instinctual, behaviour and reduce the level of cognitive processing required. It was evident from framing interaction in terms of SRK activity, that subtle differences were observed according to age and gender in terms of knowledge acquisition, learning and skill-based interaction. In this respect the overall approach to determining both interactional design issues as well as analysing learning activity was achieved. In combination with the other results presented throughout this work, this has been successfully used to indicate how and when learning occurs during interaction, revealing what information is learned and indicating product elements that cause interactional complexity for users. These findings, then, can be used to inform the design process with the aim of ensuring products are more intuitive to use by a wider proportion of the population.

9.4 Addressing the Overarching Research Question

Is there further knowledge to be gained for the design community from the study of generational differences in terms of prior experience and contemporary product interaction?

The three main subcomponent research aims have each assisted toward understanding and answering the overarching research question. The over-riding observation from the experimental aspects of this work is the significance of prior experience and product knowledge on interaction. The following diagram depicts the effect experience has upon individuals' capability to recognise product iconography and product features, and subsequently upon product understanding and interaction (Figure 53).

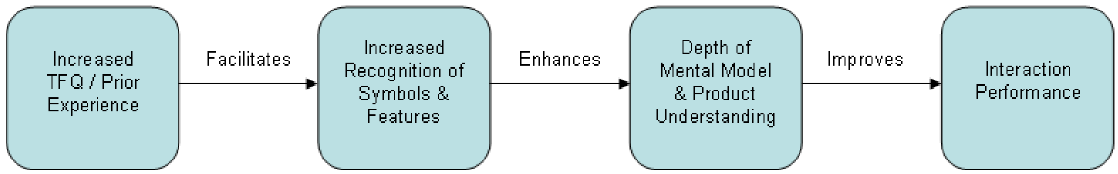

Figure 53: The effect of prior experience on interaction

Prior experience affects individuals' ability to make accurate inferences about a products function and purpose. This enhances the informational depth and content of the mental model of the device developed by the individual. In combination, these factors contribute to user's interactional performance. Figure 54 presents a holistic overview depicting in greater detail elements that were found to influence interaction that the design community should consider.

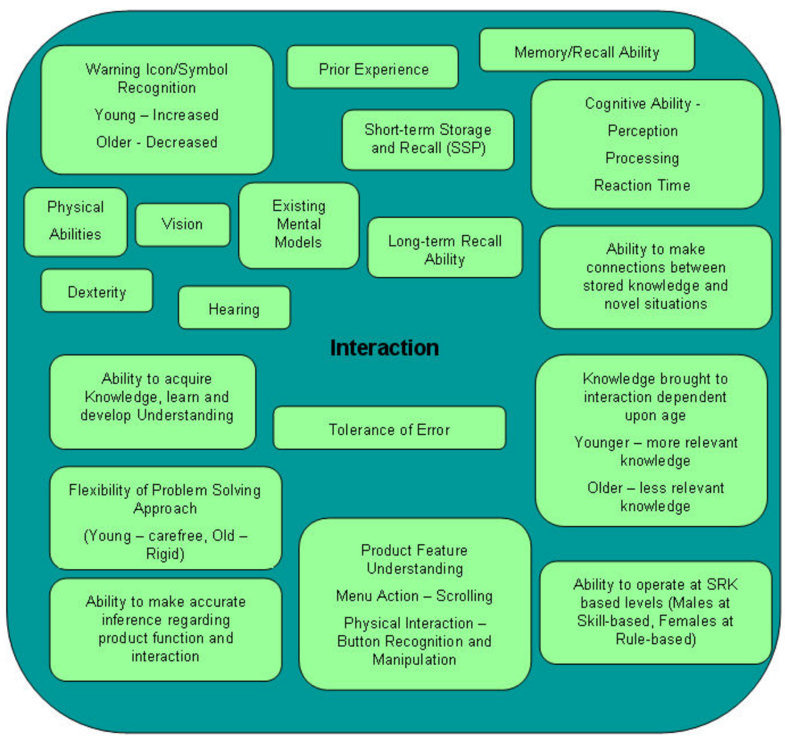

Figure 54: Holistic overview of factors found to influence interaction

This work has shown how prior product experience, and particularly age, influences the ease with which users are able to interact with products. Age and experience affect users' knowledge of interface icons and features, and this has a significant impact upon successful interaction. This research has successfully classified interaction at a granular level and in so doing has determined interactional complexity during the process of product interaction. By classifying human behaviour in terms of skill, rule and knowledge-based activity, it has been possible to observe where interaction was reduced to a knowledge-based level. It was evident when this occurred, that users were attempting to acquire or affirm knowledge and that they were being prevented from performing at a more desirable, skill-based level. The challenge remains then, for designers to facilitate or maintain interaction at a skill-based, automatic, and unconscious processing level, as it equates to usability, accessibility, and intuitive design and use. That older people were regularly reduced from operating at such a level, to either a knowledge or rule-based level of interaction, indicates they had to focus consciously on more aspects of the interface, or the product interaction, to achieve a successful outcome than other age groups. In this way, product design *did* compromise their ability to perform, and it would appear there is also a direct correlation between prior experience and their performance. Whilst with perseverance users were generally able to reach satisfactory outcomes with the devices, it is more desirable from a user and marketing perspective to be able to operate such products and devices intuitively and immediately. This remains a quest for Inclusive Designers.

9.4.1 Addressing Design for Older People

Differences in generational approach to problem solving with devices and gadgets were highlighted within this study. The older age groups appeared wary about interacting with the devices inappropriately. Whether this was due to their perception of contemporary technologies' inability to withstand abuse in today's materialistic and disposable society is not clear, but may explain why older participants in these studies frequently voiced concern that by pressing multiple buttons at the same time they might break the device, and may also explain their more restrained approach to discovering the correct sequences and problem solving in general. Ageing itself is a factor, as although people are often able to perform familiar tasks and skills up to a very advanced age, learning new skills and changing familiar routines becomes more difficult (Craik and Jacoby, 1996). Also with age, the ability to focus and divide attention tends to decrease (Greenwood & Parasuraman, 1997). Conversely, the younger generations are familiar with thousands of new technological developments that are robust, reliable, predictable, and safe. This is due to both internal and external components' improved design and use. Thus, modern devices can withstand what might be considered inappropriate input or abuse with comparative ease. The approach of younger individuals to interaction is also more flexible and uses more contemporary strategies and mechanisms (Docampo-Rama, 2001, Weiss, 2002).

If the output of this study is viewed in terms of the age affects found, it is clear that older users face greater difficulty interacting with products and require greater consideration:

- Physical approaches to interaction were a function of age – younger individuals exhibited quicker task completion times than older individuals
- The ability to acquire iconic information was found to decrease as a function of age
- Age was found to be a significant factor in feature recognition and in the amount of product feature knowledge gained through exposure
- Younger individuals recalled greater numbers of similar products than older individuals
- There was a significant effect of age upon awareness and use of product features and in terms of the overall TFQ Score – younger individuals possessing the higher TFQ scores

- Conceptual understanding of the product and it's interaction was heightened for participants in the younger age group, and the above factors appeared to have contributed to both the increased depth, accuracy, and content of their mental models as well as their performance with the product

9.4.2 How can this work impact and benefit the Design Community?

This research provides a wealth of information from experimental investigation and participants' interactional experiences that could be applied to the initial design and, if necessary, the potential redesign of products and their interaction. Such improvements would increase both the market and marketability of the product, whilst improving the user experience and interaction for all individuals regardless of age.

These findings go some way to revealing why older participants ability to learn from product interaction and exposure in the study and on a larger scale, may be adversely affected. Older users recognised fewer features and iconic warning symbols than younger users. This appears to place them at a disadvantage in terms of then learning from interaction, and affects their ability to draw accurate inference from products. It also appears to impair their ability to create accurate mental models, reinforcing the previously mentioned implication for design and designers. This research provides the opportunity for designers to understand the age-related issues involved, and identify the physical and cognitive issues causing interactional complexity. The following diagram encapsulates the areas of study involved in this research and identifies the knowledge gained from the study of generational differences in terms of prior experience and interaction with contemporary technology products (Figure 55). The design community can use this information to create better, more informed, and inclusive, design methods.

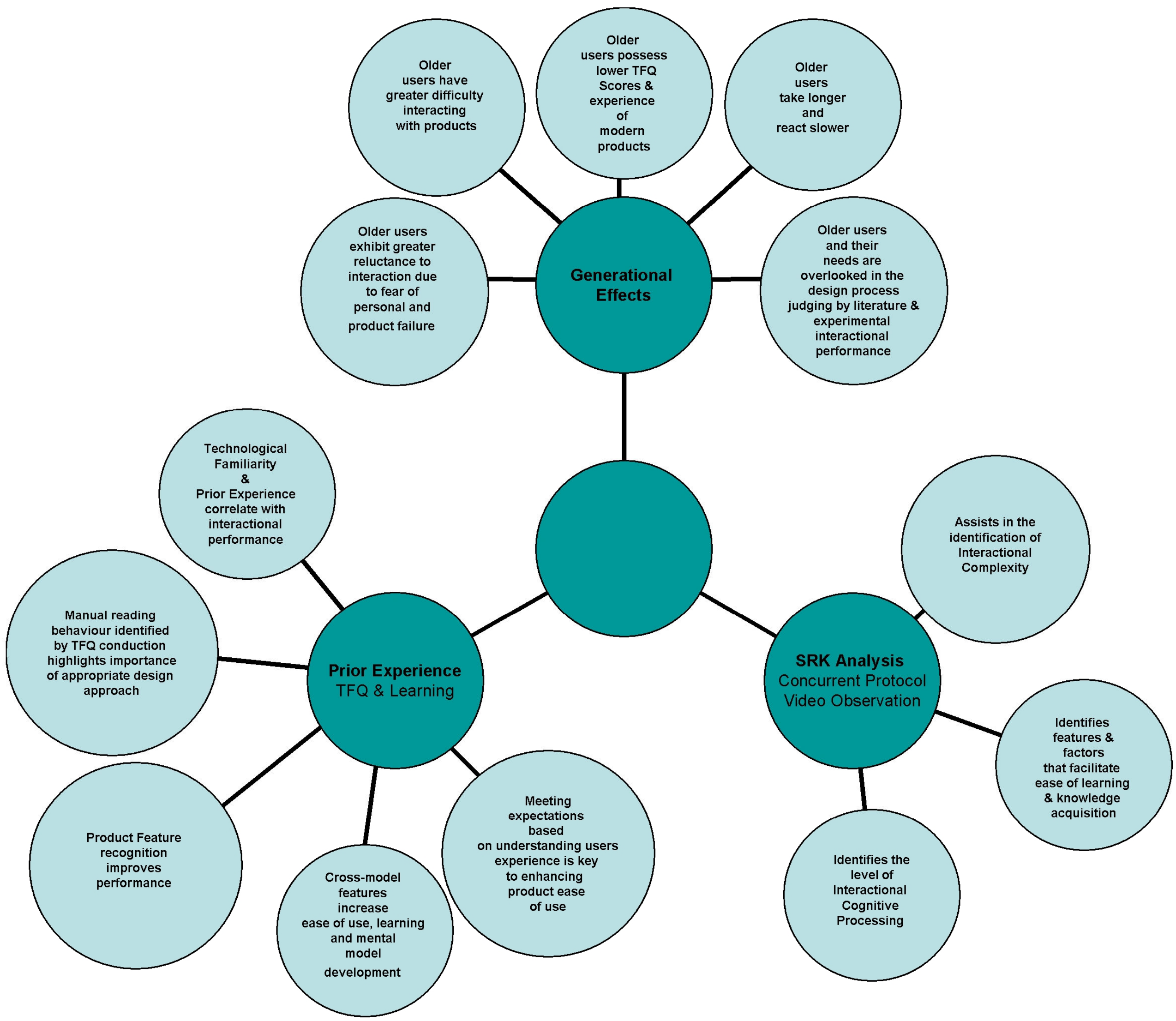

Figure 55: Nodes of knowledge gained from the study of generational differences in terms of prior experience and interaction with contemporary technology products

9.4.3 In conclusion

The overall intention of the thesis is to generate knowledge to inform designers and thereby the design process. The research has also successfully highlighted where insufficient designer consideration has negatively affected usability and product interaction for all users – young and old alike. This has cost implications on product and brand loyalty. Adopting the inclusive design approach forming the basis of this thesis has the potential to increase usability regardless of age, reduce subsequent manufacturing retooling and operational costs, and widen the market for existing or potential products, designs and artefacts. As a whole, the thesis contains knowledge that will help designers formulate better design methods. It aids and increases design knowledge and understanding, can help designers to produce informed designs that will be applicable to a wider proportion of the population and designs that work more effectively and optimally first time and 'out-of-the-box', and can thereby increase product adoption and product or brand loyalty.

9.5 Critique of Works and Avenues for Future Research

This section sets out to acknowledge the areas of research that were unforeseen or unanticipated, and attempts to modestly acknowledge where good research practice was manifest. Ideas and suggestions for future research are then presented.

9.5.1 Critique of Works

9.5.1.1 Sampling Methodology

Although the intention of sourcing a representative sample from which to generalise was present throughout the study, one shortfall was that verification wasn't conducted. For example, although the procedure adopted attempted to utilise participants from a broad spectrum of educational backgrounds, participants were not required to divulge their actual level of educational or academic achievement. Retrospectively, this was an oversight on behalf of the experimenter who attempted to minimise the extent of personal intrusion in the interests of encouraging participation.

Equally, issues regarding computer literacy were not acknowledged. Although multiple sample participant acquisition streams were utilised including local publications and advertisements in local shops, the remaining stream relied upon web-related media and therefore required internet access and a degree of computer literacy. This may have caused bias or introduced an extraneous variable within the participant recruitment process that may have affected individual performance. This should have been verified and needs to be acknowledged.

Furthermore, the online investigation into technological familiarity naturally relied upon an adequate level of computer literacy and internet access. Although an efficient questionnaire administration strategy, this undoubtedly introduces an unwelcome element of bias when attempting to generalise from the sample population, as it cannot be concluded that all members of a population will have similar levels of competency or internet connectivity. Computer literacy, web access and the ability to respond electronically, may be seen in themselves, as additional indicators of increased technological familiarity that could potentially distort the results. However, the technological familiarity questionnaires in particular were designed to target specific contemporary technology products in order to minimise this possibility.

9.5.1.2 Allocation of Participants to Age Group Ranges

Although the rationale for the age groups utilised in the study has been well justified, if time and resources presented no obstacle to research, it would be rewarding to re-administer the two main investigations using a more granular age separation; perhaps separating the sample from

16-80 in approximately 10 year segments. This may elucidate more specific findings and a specific age range within which interactional ability is optimum.

9.5.1.3 Pilot Study

Regarding the pilot study, the Cantabeclipse MOT reaction-time results were as expected, showing that the younger age group performed the quickest, followed in turn by the 26-59 age group, and the older age group taking the longest time to complete the test. However, the difference between the groups did not appear particularly significant. The trend exhibited in the SSP results was not as expected, with marginal differences between the youngest and oldest groups, and the middle 26-59 age group possessing the greatest amount of short-term memory retrieval. Equally, the number of button presses was highest for 26-59 group, as was the rate of error, and mean interactional task completion times, and in this instance task completion times were lowest for older age group. Time per button press was also lowest for older group, who possessed the highest TFQ scores. Arguably the results exhibit little consistency, and don't conform to the literary expectation that the younger generation will perform the most effectively and efficiently, and have greatest knowledge of contemporary technology. In defence, conducting research and particularly hypothesis testing with premeditated results in mind, is not good practice, and as much is learned from mistakes as from success. Regardless, the methodology appeared fruitful and appropriate.

A factor that undoubtedly contributed to the effects observed was the use of only 3 participants. This was perhaps not ideal ecologically, neither was it ideal that all participants possessed a similar educational background. Both factors clearly compromised the opportunity to draw significant conclusions from the pilot study results, but useful output was forthcoming that assisted the development of the later studies.

9.5.1.4 Full Scale Study 1

In Full Scale Study 1, again, the Cantabeclipse MOT and SSP results were not as expected, with the 26-59 age group performing poorly in terms of task completion time, and slightly more effectively than the younger age group regarding memory capability. The larger sample should have prevented the experimentation from being susceptible to the problems experienced in the pilot study. However, the product interaction results are generally more consistent and reveal the expected trend of the youngest participants performing the most effectively and the older participants taking longer and performing less well. The TFQ results were not entirely consistent with expectation, indicating that the 26-59 age group used, and were familiar with, more of features of the products listed than either of the other age groups. Perhaps the products listed were more generationally orientated than expected – even though contemporary, it may be that the middle age group were more attuned to the actual products listed.

9.5.1.5 Full Scale Study 2

The results of Full Scale Study 2 were largely as literature might have predicted. The younger age group consistently performed the best regarding the MOT and SSP tests, the product interaction task completion time assessment, and in terms of product recall comparison. Similarly the older age group consistently performed the least well, particularly in terms of icon and feature recognition and learning. Indeed, the researcher's continued accumulation of knowledge and the application of this knowledge in terms of performing research, may have contributed to the consistency of the results observed in this study.

9.5.1.6 Non-validation of the SRK Classification Scheme

Inter-coder (or interrater) reliability or agreement is the extent to which independent coders evaluate a characteristic of a message or artefact and reach the same conclusion (Tinsley & Weiss, 2000). The coding analysis and interpretation were conducted solely by the researcher. Although not entirely an oversight, it is clearly deemed best-practice to perform such activities by independent coders and to investigate the consistency of the results to minimise any subjective effects. There was a concern regarding how much of the work would constitute being the candidates' sole research alone – a key requirement of thesis submission – if another individual was tasked with coding the transcriptions of observed activity. This regulation may have been taken too literally, and retrospectively, a compromise might have been to acknowledge an additional coders contribution and obtain coding consistency on a small subset of transcriptional data.

Chi (1997) states: "If there is a great deal of discrepancy between two raters in the first pass (interrater reliability of less than 80%, for instance, then this should caution the researchers to redefine the categories, rather than to concentrate their efforts only on resolving the interrater discrepancies" (p.23). This was a key reason much time and effort was consumed ensuring the definitions of Skill, Rule, and Knowledge-based activity were thorough, clear, and unequivocal – to make it transparent and clear how the approach was applied, and thus make it easily repeatable. This objective, it is felt, was successful.

Transaction and coding are also often labour-intensive: "Typically, verbal data tend to be voluminous: 1 hr of tape may take up to 10 hr to transcribe, which can result in 15 to 50 pages of text (to code)" (Chi, 1997, p8). This study's data collection consisted of 30 x 1 hour records that were transcribed and coded in their entirety. This fact compounded the researcher's concerns about requesting additional coders to contribute to the coding and analysis. However, as Chi also states: "Oftentimes, a researcher's (unique) contribution is the evidence that she or he can ferret out of the verbal data" (p13).

Although no formal verification of the coding procedure occurred, the researcher would request the reader to observe that the potentially subjective interpretation was validated by other qualitative and quantitative data presented in the study:

- *Qualitative in terms of participants discussions of their conceptualised understanding during the study*
- *Quantitative in terms of icon and feature recognition data, task completion time data, and technological familiarity questionnaire data*

These factors support and validate the interpretation and classification by indicating often strong correlations between age and performance. Indeed, "quantitative data can serve as confirmation of the qualitative analysis and vice-versa" (Chi, 1997, p7). The fact that older users recognised fewer features and icons and performed less well correlates with them operating at a knowledge-based level. This empirical data alone goes some way to validate the potentially subjective interpretation and results thereof. The sole remaining counter-argument would therefore be that the researcher has made the findings of the SRK classification 'fit' the non-subjective and empirical quantitative and qualitative results, and with the utmost integrity and honesty, the researcher states this is not the case.

9.5.1.7 The Development of Mental Model Understanding

Although this work focuses heavily upon the concept of mental models and product interaction, and routinely determined what users described as the contents of their mental models, this research did not determine the exact form that mental models may assume. A contribution to understanding users conceptual development through experience and interaction was achieved, but future research may try to specify more clearly the form that mental models actually take.

9.5.1.8 Inclusive Design Exclusion

With an increasing ageing population, in time, if not now, there will be reason to ensure those from 80-100 at least are included in such studies, and it is arguable that the inclusive design approach presented has, in fact, excluded a proportion of the population on whose behalf it is trying to change design-thinking. There is some justification for the approach used however, in that it was attempting to obtain more generic baseline data of a large proportion of users with the minimum ethical constraint and maximum ecological validity.

9.5.1.9 Critique Conclusion

It is felt that both a useful method and methodology have been developed for the design and research community, and that this represents a commercially valuable and viable approach to product redesign that will provide an output of value to manufacturers as well as product users. In an Industrial context, manufacturers could adopt this methodology and evaluate existing products, novel designs, or prototypes, to assess how varying age groups may respond, and utilise it to determine where intuitive interaction and usability gains may be made for increased commercial advantage. Overall, this project has provided a unique and great opportunity to further develop, enhance and hone research skills, and has been a hugely enjoyable and informative experience.

9.5.2 Avenues for Future Research

9.5.2.1 Method Validation

Further research would seek to validate the methodology in terms of identifying interactional complexity and the types of redesign suggested. Indeed, if time and both physical and financial resources permitted, an intention would be to seek the permission of the manufacturers of the products used within the study to redesign the features that were found to cause interactional complexity, and retest them under similar circumstances to assist designers to create more user friendly and inclusive products. However, the approach addressed the issues under investigation, and the output, both quantitative and qualitative, can still be seen as commercially valuable and valid.

9.5.2.2 Other Investigation 1

One suggestion would be to investigate products and product generations more closely. The main finding from this research was that older people perform less well with modern products. Bearing in mind the generational effect, it would be of significant interest to observe if older users would perform better with products from their youth and, in turn, would younger users exposed to the same products perform less well. This may reveal if there is there a connection between product performance ability and time-in-life exposure to the product itself. If there is some connection it would be interesting to determine why, and also what effect the design of the features of the products used have upon this phenomenon. The qualitative results of the pilot study support this, as an older participant observed the design of the product appeared “dated like a ‘70’s calculator”. It may be this very factor that permitted his superior performance in that experiment.

9.5.2.3 Other Investigation 2

The significance of icon and feature awareness was also highlighted in Full Scale Study 2. The 26-59 age group were initially able to identify more features and icons than any other age group, and continued to develop their understanding to the greatest extent. Although this didn’t directly contribute to an overall performance advantage for this age group, it is another example of the significance of icon and feature design within interaction, well supported in literature (Langdon et al., 2010, Okeye, 1998, Henson et al., 2006) and is an area worthy of continued study.

9.5.2.4 Future Research Conclusion

With an ageing population, developments within the realm of technology use for older people can only be seen as worthwhile both commercially, and from a product interaction perspective. Inclusive Design will thus play a very real role toward this, in the usability of the future.

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Appendix 1: Risk Assessment and Hazard Analysis Form

UNIVERSITY OF CAMBRIDGE
Department of Engineering

Engineering Design Centre

Experimental Risk Assessment: August 2010
An assessment of risk and hazard analysis has been conducted involving:

Christopher Wilkinson (the Researcher) Engineering Design Centre Department of Engineering The University of Cambridge	Ian Slack Heath and Safety Officer Department of Engineering The University of Cambridge	Richard J. Collet-Fenson Secretary of Department (F) & Chairman of Health and Safety Committee Department of Engineering University of Cambridge

The following considerations were identified and have been addressed:

Factor identified	**Resolution**
Requested out-of-hours-access and isolated risk	Due to the small numbers of participants involved and after discussion with both the Health and Safety Officer and Chairman of the Health and Safety Committee, it has been agreed the Researcher will assume full responsibility for participants and their welfare whilst they are inside the building, and will escort them on and off the premises as a matter of course. It is also noted out-of-hours-access will only be required as a last resort and Security (including the **watchman@eng.cam.ac.uk**) have been informed.
Conveyance of knowledge regarding Fire Exits and Escape Routes in the event of Emergency	This responsibility is assumed by the Researcher as detailed above.
Apparatus, Security and Safety	Experimentation will be conducted in a lab within the old EDC loft. During non-experimentation periods all equipment will be removed to safeguard the experimental apparatus. Earth-testing has been performed on all relevant equipment involved in the experimentation – namely an electrical lamp. Although the product under examination (a laser-level) contains a laser that complies to EN 608251:1994+A1+A2 it is deemed completely safe at distances over 1 meter, and eyelid reflexes are deemed to provide sufficient protection. Furthermore, the design of the device ensures that the laser itself doesn't operate unless positioned on a flat surface and operating at less than 10 degrees to horizontal and all interaction will be overseen by the experimenter.
Data Protection	The consent form which must be signed by all participants clearly identifies that a recording will be made of the experimentation, that only members of the research team will have access to the recordings and collected data, and that participants may discontinue participation at any time without comment. It also states that participant confidentiality will be protected at all times, that their name will not be used in any document or published paper, and that the collected data will be stored in a secure location.

Appendix 2: Consent Form

UNIVERSITY OF CAMBRIDGE
Department of Engineering

Engineering Design Centre

Statement of Informed Consent

Contact Information:

Christopher R Wilkinson
Engineering Design Centre
The University of Cambridge
Department of Engineering
Trumpington Street
Cambridge
CB2 1PZ
UNITED KINGDOM

Phone: 01223 766962
Mobile: 07772 750405

Project Title:
Investigating Prior experience and Product Learning through novel interface interaction

This project is being conducted as part of my PhD studies within the Engineering Design Centre, University of Cambridge. This study is designed to investigate whether existing products and designs can be enhanced for those with cognitive or physical impairment of any age. Indeed, the department concentrates upon improving everyday products such as microwaves and toasters for example, and in order to enhance them for the ageing and/or impaired we require baseline data on product interaction with non-impaired individuals.

Research involves investigating how individuals transfer knowledge of one interface to another and the extent to which their prior experience may affect this knowledge transfer and their subsequent interactional ability.

Project Objectives:

- What effect does the level of previous experience with the same or similar products have upon users' ability to interact with products?
- Is there an effect upon interactional ability caused by age of the user and their membership of a corresponding technology generation?
- Is there evidence of an ageing effect – a declination of learning or cognitive ability due to increasing age – that affects product understanding and interaction?

What you are being asked to do:
You are asked to complete a computer controlled assessment followed by undertaking a number of tasks with an everyday product available on the high street. You are asked to explain your understanding of the product during this process. You will be filmed undertaking the tasks and afterwards asked about how you interacted with it. A short questionnaire is also administered.
It is not possible to participate in the project without being recorded, but only members of the research team will have access to the recordings.

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Department of Engineering

Engineering Design Centre

Participant Selection:
Participants are recruited to ensure that a balanced and representative number of people undertake the assessment. This is to allow for useful comparison between the groups in the study.

Expected outcomes of research:
I hope to contribute toward the development of a theoretical or conceptual model that can predict how people learn to interact and transfer knowledge of one interface to another and the extent to which their prior experience may affect this knowledge transfer and their subsequent interactional ability.

This would be supported by relevant examples and results are expected to be published in scholarly journals. If you would like to have copies of published papers or feedback about the results of the research when data has been acquired and analysed, please contact Christopher Wilkinson (contact details provided).

Benefits of the research:
Products are often difficult to use correctly and are frequently misused for a variety of reasons by able bodied and non-impaired individuals. While there may be no immediate benefit for you as an individual participating in this research, the overall intention is that this research will benefit both the research community and wider community of consumers by providing guidance to designers about how they can make their products and designs more accessible to a wider proportion of the population, including those with impairment or age-related difficulties.

Confidentiality:
Your confidentiality will be protected at all times. Your name will not be used to identify you in any document or published paper, and only the research team will have access to the collected data, which will be stored in a secure location.

Voluntary Participation:
Your participation in the project is entirely voluntary. If you decide to withdraw from the study, you will not be penalised or judged in any way. You may discontinue participation at any time without comment.

Please contact Christopher Wilkinson (details provided) for any further details about this project or if you have any questions, now or in the future.

UNIVERSITY OF CAMBRIDGE
Department of Engineering

Engineering Design Centre

PARTICIPANT NO # _____

TASK ORDER_____ _____

Contact Information:

Christopher Wilkinson
Engineering Design Centre
The University of Cambridge
Department of Engineering
Trumpington Street
Cambridge
CB2 1PZ
UNITED KINGDOM

Phone: 01223 766962
Mobile: 07772 750405

Project Title:
Investigating Prior experience and Product Learning through novel interface interaction

Statement of consent:
I have read and understood the information provided, and have had any queries answered to my satisfaction.

I understand that I can contact the researcher if I have any additional questions.

I understand that I can withdraw from the study at any time, without comment or penalty.

I understand that participation in the project involves being recorded, and that it is not possible to take part in the research without being recorded. I understand that only members of the research team will have access to the recordings and they will be stored in a secure location.

I agree to participate in this research project.

Name ________________________________

Signature ________________________________

Date ____________

Age_____
(To facilitate placement of results within corresponding age-group)

Appendix 3: Experimental Protocols

Experimental Protocol

Reset product price to 00.00 £/kWh

1. Administer Consent Form
2. Administer Cantab Assessment
3. Press Record on video
4. **"What do you understand about the product I've just handed to you?"**
5. Provide TASK 1, 2, and 3 in randomised order.
6. **"What do you understand about the device and its interaction at this point?"**
7. Provide TASK 4, 5, and 6 in randomised order.
8. **"What do you understand about the product now that you've had chance to interact with it?"**
9. **"Ok, some brief questions about the product":**

   "Did you find any features of the product (design) familiar?"

   "If so, what was the original device that you found that particular element similar to?"

   "Did you feel it was easy to understand and complete the tasks with the product?"

   "At what stage were you able to guess how to interact with the product to access the function you desired (if at all)?"

   "At what stage did you feel you'd learned the functions of the product?"

   "Any other observations?"
10. Questionnaire Administration
11. Debrief – Any Questions?
12. Email confirmation for voucher

Experimental Protocol

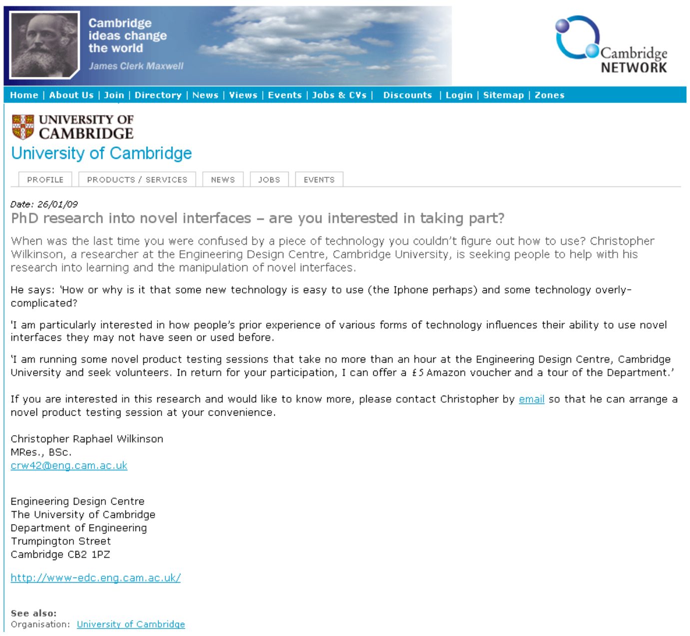
1. Administer Consent Form
2. Administer Cantab Assessment
3. Press Record on video
4. **"Please look at these images and write down (whilst verbalising to help you get used to it) what you feel they represent or mean."**
5. **"We're obviously interested in design, so I wondered what the design of this product says to you and what you understated about this product, from its design."**

Inform participant (hopefully after they have observed the product contains a laser) about precautions of using the product.

6. **"Here's the battery – can you insert it, and then tell me what you observe or understand about the product?"**
7. Provide jigs in random order, asking them to locate the position of electric cables, wooden studs, or copper pipe
8. **"Here's the hanging tool – could you fit that to the device for me please?"**
9. **"Could you hang the device on the jig and operate the laser level function?"**
10. **"So could you tell me what you understand about this product now, and give a summary of its design and function?"**
11. **"And, looking again at the images, what do you think they may mean now – same as before or something different?"**
12. **"Can you identify all the design features present on the product?"**
13. Questionnaire Administration
14. Debrief – Any Questions?
15. Email confirmation for voucher

Appendix 4: Recruitment Advertising

Selections of the advertising used to recruit participants for the study are reproduced below.



Cambridge ideas change the world
James Clerk Maxwell

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UNIVERSITY OF CAMBRIDGE

University of Cambridge

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Date: 26/01/09

PhD research into novel interfaces – are you interested in taking part?

When was the last time you were confused by a piece of technology you couldn't figure out how to use? Christopher Wilkinson, a researcher at the Engineering Design Centre, Cambridge University, is seeking people to help with his research into learning and the manipulation of novel interfaces.

He says: 'How or why is it that some new technology is easy to use (the Iphone perhaps) and some technology overly-complicated?

'I am particularly interested in how people's prior experience of various forms of technology influences their ability to use novel interfaces they may not have seen or used before.

'I am running some novel product testing sessions that take no more than an hour at the Engineering Design Centre, Cambridge University and seek volunteers. In return for your participation, I can offer a £5 Amazon voucher and a tour of the Department.'

If you are interested in this research and would like to know more, please contact Christopher by email so that he can arrange a novel product testing session at your convenience.

Christopher Raphael Wilkinson
MRes., BSc.
crw42@eng.cam.ac.uk

Engineering Design Centre
The University of Cambridge
Department of Engineering
Trumpington Street
Cambridge CB2 1PZ

http://www-edc.eng.cam.ac.uk/

See also:
Organisation: University of Cambridge

Engineering Design Centre
Cambridge University

Are you aged between 16 – 80?

The **Inclusive Design Group** is investigating how technology can be enhanced for the older generation and need your help!

Participate in research and receive a £5 Amazon Gift Voucher and a free tour of the Engineering Design Centre!

Sessions last no more than 35 minutes and you will be contributing toward ground-breaking research!

For more information please contact:
Christopher Wilkinson

01223 766962

07772 750405

crw42@eng.cam.ac.uk

CamCreative Newsletter - October 2009

In This Issue

News and Events
Get Involved
Creative Picks
Member Spotlight
Spotlight on New Member
Just for Fun
About Us

Join Our Mailing List

Welcome to CamCreative

Get Involved

Take part in PhD research

When was the last time you were confused by a piece of technology you couldn't figure out how to use, or annoyed with a house-hold device that was unnecessarily complicated?

CamCreative member Chris Wilkinson is a researcher at the Engineering Design Centre, Cambridge University, and is seeking people of all ages who might be interested in participating into research that involves the learning and manipulation of interfaces, products and devices.
The test sessions generally take no more than an hour and you'll get an Amazon voucher for your trouble.

Contact Chris to find out more

Appendix 5: Raw Data: Pilot Study

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
16-25	1	F	66	7	1	72	9	4	8	28	41	69
					2	29	16	9	1.81			
					3	578	107	102	5.4			
					4	18	5	0	3.6			
					5	12	4	3	4			
					6	21	7	0	3			
					Total	730	148	118	25.81			
					Mean	121.67	24.67	19.67	4.30			
26-59	2	M	69	9	1	204	26	21	7.84	16	20	36
					2	7	7	0	1			
					3	980	215	210	4.55			
					4	9	8	3	1.12			
					5	5	4	3	1.25			
					6	15	7	0	2.14			
					Total	1220	267	237	17.9			
					Mean	203.3	44.5	39.5	2.98			
60-80	3	M	57	6	1	52	14	9	3.71	28	16	44
					2	7	7	0	1			
					3	523	206	201	2.53			
					4	6	5	0	1.2			
					5	8	4	3	2			
					6	23	7	0	3.2			
					Total	619	243	213	13.64			
					Mean	103.17	40.50	35.50	2.27			

Appendix 5: Raw Data: Full Scale Study 1 Part 1

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
16-25	1	F	133	5	1	7	6	0	1.16	44	36	80
					2	10	8	0	1.25			
					3	451	98	92	4.6			
					4	50	4	0	12.5			
					5	5	3	2	1.67			
					6	19	3	0	6.33			
					Total	542	122	94	27.51			
					Mean	90.33	20.33	15.67	4.59			
16-25	2	M	54	4	1	48	1	4	48	40	51	91
					2	10	5	0	2			
					3	191	103	98	1.85			
					4	8	5	0	1.6			
					5	5	3	2	1.67			
					6	19	8	0	2.38			
					Total	281	125	104	57.5			
					Mean	46.83	20.83	17.33	9.58			
16-25	3	M	52	6	1	3	2	4	1.5	57	46	103
					2	8	4	0	2			
					3	267	112	107	2.38			
					4	6	8	0	0.75			
					5	6	4	3	1.5			
					6	9	7	0	1.28			
					Total	299	137	114	9.41			
					Mean	49.83	22.83	19.00	1.57			
16-25	5	M	63	6	1	32	5	0	6.4	68	40	108
					2	8	4	0	2			
					3	46	22	18	2.09			
					4	7	5	0	1.4			
					5	4	1	0	4			
					6	10	3	0	3.33			
					Total	107	40	18	19.22			
					Mean	17.83	6.67	3.00	3.20			

Appendix 5: Raw Data: Full Scale Study 1 Part 2

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
16-25	29	F	57	5	1	7	2	0	3.5	43	28	71
					2	31	8	5	3.87			
					3	210	54	49	3.88			
					4	8	5	0	1.6			
					5	5	2	1	2.5			
					6	3	2	0	1.5			
					Total	264	148	55	16.85			
					Mean	44.00	12.17	9.17	2.81			
16-25	21	M	97	6	1	7	2	0	3.5	38	24	62
					2	9	2	0	4.5			
					3	404	73	68	5.53			
					4	3	5	0	0.6			
					5	4	2	0	2			
					6	8	7	0	1.14			
					Total	435	91	68	17.27			
					Mean	72.50	15.17	11.33	2.88			
16-25	22	F	53	8	1	165	43	38	3.83	69	46	115
					2	2	4	0	0.5			
					3	132	51	46	2.58			
					4	6	5	0	1.2			
					5	2	1	0	2			
					6	4	2	0	2			
					Total	311	106	84	12.11			
					Mean	51.83	17.67	14.00	2.02			
16-25	23	F	127	7	1	23	1	4	23	31	20	51
					2	18	9	7	2			
					3	275	69	64	3.98			
					4	15	11	6	1.36			
					5	14	4	3	3.5			
					6	6	2	5	3			
					Total	351	96	89	36.84			
					Mean	58.50	16.00	14.83	6.14			

Appendix 5: Raw Data: Full Scale Study 1 Part 3

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
16-25	24	M	163	8	1	3	2	0	1.5	33	28	61
					2	6	4	0	1.5			
					3	24	26	21	0.92			
					4	4	5	0	0.8			
					5	4	1	0	4			
					6	7	2	0	3.5			
					Total	48	40	21	12.22			
					Mean	8.00	6.67	3.50	2.04			
16-25	25	M	51	9	1	5	6	0	0.83	28	32	60
					2	11	3	0	3.66			
					3	414	106	101	4.25			
					4	9	8	0	1.13			
					5	8	2	1	2			
					6	4	2	0	2			
					Total	451	127	102	13.87			
					Mean	75.17	21.17	17.00	2.31			
26-59	4	M	60	6	1	43	1	4	43	54	36	90
					2	48	2	1	6			
					3	193	3	31	5.36			
					4	16	4	0	3.2			
					5	52	5	7	6.5			
					6	23	6	6	23			
					Total	375	21	49	87.06			
					Mean	62.50	3.50	8.17	14.51			
26-59	6	M	58	7	1	18	10	8	6.4	61	48	109
					2	11	3	0	2			
					3	285	168	163	2.09			
					4	10	5	0	1.4			
					5	18	2	1	4			
					6	13	7	0	3.33			
					Total	355	195	172	19.22			
					Mean	59.17	32.50	28.67	3.20			

Appendix 5: Raw Data: Full Scale Study 1 Part 4

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
26-59	7	F	49	9	1	51	14	9	3.64	41	37	78
					2	11	7	0	1.57			
					3	793	136	131	5.83			
					4	9	2	3	4.5			
					5	11	4	3	2.75			
					6	9	7	0	1.28			
					Total	884	170	146	19.57			
					Mean	147.33	28.33	24.33	3.26			
26-59	8	M	53	6	1	26	12	6	2.16	56	49	105
					2	64	3	0	21.3			
					3	236	67	62	3.52			
					4	6	7	0	0.85			
					5	0	0	0	0			
					6	14	7	0	2			
					Total	346	96	68	29.83			
					Mean	57.67	16.00	11.33	4.97			
26-59	9	M	62	9	1	62	14	9	4.42	45	40	85
					2	10	7	0	1.42			
					3	212	75	70	2.82			
					4	7	5	0	1.4			
					5	8	4	3	2			
					6	8	7	0	1.14			
					Total	307	112	82	13.2			
					Mean	51.17	18.67	13.67	2.20			
26-59	10	M	61	7	1	4	2	0	2	42	46	88
					2	17	6	3	2.83			
					3	168	70	65	2.4			
					4	5	5	0	1			
					5	6	1	0	6			
					6	9	7	0	1.28			
					Total	209	91	68	15.51			
					Mean	34.83	15.17	11.33	2.59			

Appendix 5: Raw Data: Full Scale Study 1 Part 5

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
26-59	11	M	61	6	1	37	8	3	4.62	51	45	96
					2	7	8	1	0.87			
					3	99	18	13	5.5			
					4	4	5	0	0.8			
					5	6	1	0	6			
					6	5	7	0	0.71			
					Total	158	47	17	18.5			
					Mean	26.33	7.83	2.83	3.08			
26-59	12	M	49	7	1	47	5	0	9.4	58	48	106
					2	15	3	0	5			
					3	174	25	20	6.96			
					4	10	5	0	0.2			
					5	11	1	0	11			
					6	20	16	10	0.13			
					Total	277	55	30	32.69			
					Mean	46.17	9.17	5.00	5.45			
26-59	14	F	74	5	1	26	3	3	8.66	64	41	105
					2	63	18	15	3.5			
					3	70	26	21	2.69			
					4	15	4	0	3.75			
					5	5	1	0	5			
					6	27	8	1	3.37			
					Total	206	60	40	26.97			
					Mean	34.33	10.00	6.67	4.50			
26-59	27	M	70	8	1	31	5	3	6.2	43	33	76
					2	39	3	0	13			
					3	594	296	294	2			
					4	8	6	1	1.33			
					5	3	2	1	1.5			
					6	4	2	0	2			
					Total	679	314	299	26.03			
					Mean	113.17	52.33	49.83	4.34			

Appendix 5: Raw Data: Full Scale Study 1 Part 6

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
60-80	13	M	64	6	1	13	2	0	6.5	53	37	90
					2	16	3	0	5.33			
					3	295	52	47	5.6			
					4	10	5	0	0.2			
					5	22	2	1	11			
					6	7	2	0	3.5			
					Total	363	66	48	32.13			
					Mean	60.50	11.00	8.00	5.36			
60-80	15	F	41	5	1	233	10	5	23.3	20	8	28
					2	84	7	5	12			
					3	268	97	92	2.76			
					4	12	3	0	4			
					5	3	1	0	3			
					6	34	2	5	17			
					Total	634	120	107	62.06			
					Mean	105.67	20.00	17.83	10.34			
60-80	16	M	52	5	1	89	13	8	6.84	28	16	44
					2	63	17	0	9			
					3	72	38	33	1.89			
					4	6	5	0	1.2			
					5	50	13	12	3.84			
					6	18	16	9	1.12			
					Total	298	102	62	23.89			
					Mean	49.67	17.00	10.33	3.98			
60-80	18	M	57	6	1	52	14	9	3.71	28	18	46
					2	7	7	0	1			
					3	523	206	201	2.53			
					4	6	5	0	1.2			
					5	8	4	3	2			
					6	23	7	0	3.2			
					Total	619	243	213	13.64			
					Mean	103.17	40.50	35.50	2.27			

Appendix 5: Raw Data: Full Scale Study 1 Part 7

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
60-80	19	F	59	3	1	10	8	6	1.25	36	22	58
					2	50	11	8	4.54			
					3	218	135	130	1.61			
					4	15	6	1	2.5			
					5	7	3	2	2.33			
					6	4	2	0	2			
					Total	304	165	147	14.23			
					Mean	50.67	27.50	24.50	2.37			
60-80	20	F	52	5	1	19	7	0	2.71	33	22	55
					2	7	3	2	2.33			
					3	164	59	54	2.77			
					4	8	5	0	1.6			
					5	8	1	0	8			
					6	64	28	25	2			
					Total	270	103	81	19.41			
					Mean	45.00	17.17	13.50	3.24			
60-80	28	F	57	5	1	291	111	105	2.62	14	7	21
					2	86	4	1	21.5			
					3	673	231	226	2.91			
					4	46	8	0	5.75			
					5	25	8	7	3.13			
					6	51	7	0	7.28			
					Total	1172	369	339	43.19			
					Mean	195.33	61.50	56.50	7.20			
60-80	30	M	240	3	1	16	5	1	3.2	32	23	55
					2	24	9	2	2.66			
					3	323	21	16	15.35			
					4	3	1	0	3			
					5	23	8	7	2.87			
					6	28	2	0	14			
					Total	417	46	26	41.08			
					Mean	69.50	7.67	4.33	6.85			

Appendix 5: Raw Data: Full Scale Study 1 Part 8

Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Task	Task Completion Time (s)	Number of Button Presses	Error Rate	Mean time per button press (s/bp)	TFQ1	TFQ2	TFQ Total
60-80	31	F	57	7	1	35	19	13	1.84	36	31	67
					2	7	4	3	7.75			
					3	124	75	70	1.65			
					4	8	8	7	1			
					5	19	8	7	2.37			
					6	4	8	1	0.5			
					Total	197	122	101	15.11			
					Mean	32.83	20.33	16.83	2.52			
60-80	32	F	55	5	1	20	6	0	3.33	15	7	22
					2	34	4	1	8.5			
					3	459	147	142	3.12			
					4	13	7	0	1.85			
					5	42	4	3	10.5			
					6	2	1	0	2			
					Total	570	169	146	29.3			
					Mean	95.00	28.17	24.33	4.88			

Appendix 5: Raw Data: Full Scale Study 2

Age	Age Group	Participant Number	Gender	MOT Reaction Time (s)	SSP Memory Capacity Score	Pre-exp Warning Icon ID	Post-exp Warning Icon ID	Pre/Post Warning Icon ID Diff.	Pre-exp Feature ID	Post-exp Feature ID	Pre/Post Feature ID Diff.	Task1(b) Time (s)	Task2(w) Time (s)	Task3(m) Time (s)	Task4(e) Time (s)	Task5(t) Time (s)	Task6(l) Time (s)	Task2(w) Response Correct	Task3(m) Response Correct	Task4(e) Response Correct	TFQ 1	TFQ 2	TFQ Total	Product Recall
24	1	8	1	54	4	6	9	3	11	17	6	38	65	141	83	9	17	Y	N	Y	36	73	109	0
22	1	12	2	56	9	5	9	4	11	16	5	18	49	55	45	6	18	Y	N	Y	44	38	82	5
23	1	13	2	49	8	6	9	3	5	19	14	16	65	149	70	6	23	Y	Y	Y	41	32	73	1
21	1	14	2	43	7	4	8	4	11	15	4	23	79	43	27	5	39	Y	Y	Y	49	48	97	0
24	1	15	2	47	8	3	7	4	7	12	5	17	25	111	63	9	30	Y	N	N	48	26	74	3
25	1	16	2	48	6	5	9	4	5	14	9	35	58	108	51	14	88	N	Y	N	64	36	100	2
22	1	20	2	53	6	4	9	5	11	18	7	15	20	30	18	13	31	Y	Y	N	47	51	98	6
24	1	22	2	45	6	2	7	5	12	21	9	31	82	16	8	5	46	Y	Y	Y	43	67	110	6
23	1	24	2	49	7	3	8	5	4	13	9	45	20	18	5	6	14	N	Y	Y	51	57	108	4
23	1	34	1	48	8	8	9	1	10	19	9	12	9	6	2	8	8	Y	Y	Y	49	73	122	3
46	2	1	1	57	8	5	7	2	3	5	2	10	67	35	50	18	38	Y	Y	Y	23	42	65	4
55	2	2	1	48	5	2	3	1	3	4	1	27	30	20	34	17	63	N	Y	Y	16	11	27	0
26	2	5	2	56	8	7	9	2	11	21	10	13	142	16	83	76	7	Y	Y	Y	34	27	61	4
56	2	6	2	59	3	3	9	6	7	19	12	23	266	62	62	24	50	N	Y	Y	40	24	64	4
47	2	9	1	61	7	8	9	1	12	18	6	21	33	184	24	11	22	Y	Y	Y	73	78	151	5
46	2	11	1	64	5	4	9	5	19	19	0	33	20	46	132	11	22	Y	Y	N	58	62	120	3
31	2	19	1	58	7	7	9	2	16	20	4	9	252	216	109	9	14	N	N	N	56	79	135	1
27	2	21	1	38	6	7	9	2	13	17	4	37	76	27	66	20	7	N	Y	N	56	47	103	3
27	2	23	1	38	7	6	9	3	11	17	6	10	38	42	27	9	4	N	N	Y	37	38	75	2
31	2	33	1	42	8	6	9	3	13	17	4	15	102	85	76	7	12	Y	Y	N	33	22	55	1
75	3	3	2	47	3	4	5	1	4	11	7	208	253	164	126	19	115	N	N	Y	27	22	49	1
66	3	4	2	42	5	4	7	3	2	7	5	28	115	112	85	11	55	Y	Y	Y	37	18	55	0
71	3	7	1	64	6	5	9	4	6	11	5	86	89	82	86	14	34	N	Y	Y	61	45	106	3
66	3	17	2	41	5	4	8	4	8	16	8	32	282	96	169	35	31	Y	Y	Y	26	10	36	0
66	3	18	1	52	5	5	8	3	7	10	3	20	33	65	73	26	25	N	Y	N	30	19	49	5
59	3	27	2	57	7	4	7	3	10	17	7	72	72	67	34	16	18	N	N	Y	42	27	69	1
83	3	28	2	57	3	1	1	0	9	12	3	141	61	15	68	48	97	N	Y	Y	27	26	53	0
66	3	29	1	46	5	5	6	1	12	14	2	31	127	57	182	6	8	N	Y	Y	55	44	99	1
68	3	30	2	58	5	7	7	0	1	8	7	33	65	33	42	8	39	Y	N	Y	46	25	71	0
74	3	32	2	64	5	2	4	2	5	11	6	37	478	141	128	14	34	N	Y	Y	43	18	61	0

Appendix 5: Raw Data: Online TFQ Survey

Age Group	Participant Number	Gender	6	5	4	3	2	1	0	4	3	2	1	0
16-25	2	2	2	3	0	0	0	0	19	1	3	0	0	20
16-25	5	2	2	0	1	2	6	10	3	**0**	8	10	3	3
16-25	6	2	2	0	2	5	3	7	5	1	7	6	6	4
16-25	19	2	3	3	0	0	8	10	0	**0**	0	24	0	0
16-25	24	2	4	0	1	0	10	4	5	1	16	0	1	6
16-25	18	1	2	2	2	3	9	5	1	18	0	3	3	0
16-25	37	1	0	1	7	5	1	4	6	**0**	17	0	0	7
16-25	40	2	3	2	1	2	2	3	11	1	12	0	0	11
16-25	41	2	2	3	0	1	0	0	18	**0**	5	1	0	18
16-25	42	1	5	1	1	7	2	3	5	1	18	0	0	5
16-25	44	1	10	0	0	0	2	1	11	7	3	4	0	10
16-25	45	2	7	3	1	0	0	3	10	2	14	0	1	7
16-25	46	2	4	1	0	0	1	0	18	**0**	5	1	0	18
16-25	47	1	4	2	1	1	1	3	12	3	8	0	0	13
16-25	48	1	3	0	5	1	1	3	11	1	5	6	0	12
16-25	49	1	5	0	0	0	3	8	8	6	2	7	0	9
16-25	50	1	4	3	0	2	3	5	7	6	5	3	2	8
16-25	51	2	4	0	0	3	5	3	9	**0**	14	0	0	10
16-25	52	2	4	1	0	0	2	9	8	**0**	8	5	3	8
16-25	53	1	2	1	2	0	0	0	19	**0**	0	0	0	24
16-25	62	2	4	0	0	6	3	4	7	**0**	10	6	0	8
26-59	1	1	3	4	2	3	2	2	8	2	1	1	3	4
26-59	3	1	2	0	1	2	5	9	5	2	3	1	2	0
26-59	7	2	3	2	1	4	1	3	10	2	7	2	3	2
26-59	8	2	3	1	1	1	0	0	18	2	8	2	3	1
26-59	9	2	3	2	1	3	3	7	5	2	9	2	3	2
26-59	10	1	1	1	0	0	4	10	8	2	10	1	1	1
26-59	11	1	2	1	0	0	2	6	13	2	11	1	2	1
26-59	12	2	2	1	0	1	4	6	10	2	12	2	2	1
26-59	13	1	1	0	5	1	7	3	7	2	13	1	1	0
26-59	14	1	2	1	0	2	6	4	9	2	14	1	2	1
26-59	15	2	5	3	1	1	4	3	6	2	15	2	5	3
26-59	16	2	2	0	0	0	7	10	5	2	16	2	2	0
26-59	17	1	3	4	1	0	5	6	5	2	17	1	3	4
26-59	20	2	2	1	3	1	0	1	16	2	20	2	2	1
26-59	21	2	2	2	0	1	1	6	12	2	21	2	2	2
26-59	22	1	6	1	1	5	2	7	2	2	22	1	6	1
26-59	23	1	4	0	0	2	9	8	1	2	23	1	4	0
26-59	25	1	2	0	1	0	8	5	8	2	25	1	2	0
26-59	26	2	3	0	0	0	4	6	11	2	26	2	3	0
26-59	27	2	2	1	1	1	2	4	13	2	27	2	2	1
26-59	28	1	2	0	1	1	9	6	5	2	28	1	2	0
26-59	29	1	1	4	0	4	3	1	11	2	29	1	1	4
26-59	30	1	5	0	0	3	2	3	11	2	30	1	5	0
26-59	31	2	1	1	2	1	2	10	7	2	31	2	1	1
26-59	32	1	1	2	6	3	4	1	7	2	32	1	1	2
26-59	33	1	2	3	0	0	4	3	12	2	33	1	2	3
26-59	34	2	4	1	0	5	2	0	12	2	34	2	4	1
26-59	35	1	4	0	0	0	4	0	16	2	35	1	4	0
26-59	36	2	2	1	2	2	4	9	4	2	36	2	2	1
26-59	43	2	2	1	0	4	3	4	10	2	43	2	2	1
26-59	56	2	6	0	3	2	1	1	11	2	56	2	6	0
26-59	71	1	2	0	3	2	2	7	8	2	71	1	2	0
26-59	73	1	5	0	0	0	5	0	14	2	73	1	5	0
60-80	4	1	6	1	0	2	2	3	10	3	4	1	6	1
60-80	38	2	1	4	1	1	1	0	16	3	38	2	1	4
60-80	39	1	1	0	0	4	0	0	19	3	39	1	1	0
60-80	54	1	3	2	3	4	0	0	12	3	54	1	3	2
60-80	55	2	4	1	0	2	0	9	8	3	55	2	4	1
60-80	57	2	2	5	0	1	1	1	14	3	57	2	2	5
60-80	58	2	4	3	2	2	2	6	5	3	58	2	4	3
60-80	59	2	5	0	1	0	1	3	14	3	59	2	5	0
60-80	60	2	2	1	0	1	4	0	16	3	60	2	2	1
60-80	61	1	1	5	0	1	5	0	12	3	61	1	1	5
60-80	63	1	0	2	4	4	2	2	10	3	63	1	0	2
60-80	64	1	0	2	4	2	3	1	12	3	64	1	0	2
60-80	65	2	2	1	0	3	0	1	17	3	65	2	2	1
60-80	66	2	7	1	0	2	1	3	10	3	66	2	7	1
60-80	67	2	4	3	3	0	0	3	11	3	67	2	4	3
60-80	68	2	1	0	1	5	0	0	18	3	68	2	1	0
60-80	69	2	0	4	3	0	2	0	15	3	69	2	0	4
60-80	70	1	6	0	2	0	3	3	10	3	70	1	6	0
60-80	72	2	0	1	3	2	0	3	15	3	72	2	0	1
60-80	74	2	5	1	1	3	0	3	11	3	74	2	5	1

Appendix 5: Raw Data: Transformed Online TFQ Survey

Age Group	Participant Number	Gender	6	5	4	3	2	1	0	4	3	2	1	0
16-25	2	2	2	3	0	0	0	0	19	1	3	0	0	20
16-25	5	2	2	0	1	2	6	10	3	**0**	8	10	3	3
16-25	6	2	2	0	2	5	3	7	5	1	7	6	6	4
16-25	19	2	3	3	0	0	8	10	0	**0**	0	24	0	0
16-25	24	2	4	0	1	0	10	4	5	1	16	0	1	6
16-25	18	1	2	2	2	3	9	5	1	18	0	3	3	0
16-25	37	1	0	1	7	5	1	4	6	**0**	17	0	0	7
16-25	40	2	3	2	1	2	2	3	11	1	12	0	0	11
16-25	41	2	2	3	0	1	0	0	18	**0**	5	1	0	18
16-25	42	1	5	1	1	7	2	3	5	1	18	0	0	5
16-25	44	1	10	0	0	0	2	1	11	7	3	4	0	10
16-25	45	2	7	3	1	0	0	3	10	2	14	0	1	7
16-25	46	2	4	1	0	0	1	0	18	**0**	5	1	0	18
16-25	47	1	4	2	1	1	1	3	12	3	8	0	0	13
16-25	48	1	3	0	5	1	1	3	11	1	5	6	0	12
16-25	49	1	5	0	0	0	3	8	8	6	2	7	0	9
16-25	50	1	4	3	0	2	3	5	7	6	5	3	2	8
16-25	51	2	4	0	0	3	5	3	9	**0**	14	0	0	10
16-25	52	2	4	1	0	0	2	9	8	**0**	8	5	3	8
16-25	53	1	2	1	2	0	0	0	19	**0**	0	0	0	24
16-25	62	2	4	0	0	6	3	4	7	**0**	10	6	0	8
26-59	1	1	3	4	2	3	2	2	8	2	1	1	3	4
26-59	3	1	2	0	1	2	5	9	5	2	3	1	2	0
26-59	7	2	3	2	1	4	1	3	10	2	7	2	3	2
26-59	8	2	3	1	1	1	0	0	18	2	8	2	3	1
26-59	9	2	3	2	1	3	3	7	5	2	9	2	3	2
26-59	10	1	1	1	0	0	4	10	8	2	10	1	1	1
26-59	11	1	2	1	0	0	2	6	13	2	11	1	2	1
26-59	12	2	2	1	0	1	4	6	10	2	12	2	2	1
26-59	13	1	1	0	5	1	7	3	7	2	13	1	1	0
26-59	14	1	2	1	0	2	6	4	9	2	14	1	2	1
26-59	15	2	5	3	1	1	4	3	6	2	15	2	5	3
26-59	16	2	2	0	0	0	7	10	5	2	16	2	2	0
26-59	17	1	3	4	1	0	5	6	5	2	17	1	3	4
26-59	20	2	2	1	3	1	0	1	16	2	20	2	2	1
26-59	21	2	2	2	0	1	1	6	12	2	21	2	2	2
26-59	22	1	6	1	1	5	2	7	2	2	22	1	6	1
26-59	23	1	4	0	0	2	9	8	1	2	23	1	4	0
26-59	25	1	2	0	1	0	8	5	8	2	25	1	2	0
26-59	26	2	3	0	0	0	4	6	11	2	26	2	3	0
26-59	27	2	2	1	1	1	2	4	13	2	27	2	2	1
26-59	28	1	2	0	1	1	9	6	5	2	28	1	2	0
26-59	29	1	1	4	0	4	3	1	11	2	29	1	1	4
26-59	30	1	5	0	0	3	2	3	11	2	30	1	5	0
26-59	31	2	1	1	2	1	2	10	7	2	31	2	1	1
26-59	32	1	1	2	6	3	4	1	7	2	32	1	1	2
26-59	33	1	2	3	0	0	4	3	12	2	33	1	2	3
26-59	34	2	4	1	0	5	2	0	12	2	34	2	4	1
26-59	35	1	4	0	0	0	4	0	16	2	35	1	4	0
26-59	36	2	2	1	2	2	4	9	4	2	36	2	2	1
26-59	43	2	2	1	0	4	3	4	10	2	43	2	2	1
26-59	56	2	6	0	3	2	1	1	11	2	56	2	6	0
26-59	71	1	2	0	3	2	2	7	8	2	71	1	2	0
26-59	73	1	5	0	0	0	5	0	14	2	73	1	5	0
60-80	4	1	6	1	0	2	2	3	10	3	4	1	6	1
60-80	38	2	1	4	1	1	1	0	16	3	38	2	1	4
60-80	39	1	1	0	0	4	0	0	19	3	39	1	1	0
60-80	54	1	3	2	3	4	0	0	12	3	54	1	3	2
60-80	55	2	4	1	0	2	0	9	8	3	55	2	4	1
60-80	57	2	2	5	0	1	1	1	14	3	57	2	2	5
60-80	58	2	4	3	2	2	2	6	5	3	58	2	4	3
60-80	59	2	5	0	1	0	1	3	14	3	59	2	5	0
60-80	60	2	2	1	0	1	4	0	16	3	60	2	2	1
60-80	61	1	1	5	0	1	5	0	12	3	61	1	1	5
60-80	63	1	0	2	4	4	2	2	10	3	63	1	0	2
60-80	64	1	0	2	4	2	3	1	12	3	64	1	0	2
60-80	65	2	2	1	0	3	0	1	17	3	65	2	2	1
60-80	66	2	7	1	0	2	1	3	10	3	66	2	7	1
60-80	67	2	4	3	3	0	0	3	11	3	67	2	4	3
60-80	68	2	1	0	1	5	0	0	18	3	68	2	1	0
60-80	69	2	0	4	3	0	2	0	15	3	69	2	0	4
60-80	70	1	6	0	2	0	3	3	10	3	70	1	6	0
60-80	72	2	0	1	3	2	0	3	15	3	72	2	0	1
60-80	74	2	5	1	1	3	0	3	11	3	74	2	5	1

Appendix 6: SPSS Output: FSS1

FSS1 MOT – 1-way ANOVA (Section 5.6.1.1)

Oneway

Descriptives

MOTScore

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	84.7000	42.07678	13.30585	54.6001	114.7999	51.00	163.00
2.00	10	60.0000	8.20569	2.59487	54.1300	65.8700	49.00	74.00
3.00	10	73.4000	58.84292	18.60776	31.3063	115.4937	41.00	240.00
Total	30	72.7000	41.83725	7.63840	57.0777	88.3223	41.00	240.00

ANOVA

MOTScore

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3057.800	2	1528.900	.865	.432
Within Groups	47702.500	27	1766.759		
Total	50760.300	29			

FSS1 MOT – Pearson product moment correlation coefficient (Section 5.6.1.1)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
MOTScore	72.7000	41.83725	30

Correlations

		Age	MOTScore
Age	Pearson Correlation	1	.022
	Sig. (2-tailed)		.908
	N	30	30
MOTScore	Pearson Correlation	.022	1
	Sig. (2-tailed)	.908	
	N	30	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
MOTScore	72.7000	41.83725	30

Correlations

		Age	MOTScore
Age	Pearson Correlation	1	.022
	Sig. (1-tailed)		.454
	N	30	30
MOTScore	Pearson Correlation	.022	1
	Sig. (1-tailed)	.454	
	N	30	30

FSS1 SSP – 1-way ANOVA (Section 5.6.1.2)

Oneway

Descriptives

SSPScore

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	6.4000	1.57762	.49889	5.2714	7.5286	4.00	9.00
2.00	10	7.0000	1.33333	.42164	6.0462	7.9538	5.00	9.00
3.00	10	5.0000	1.24722	.39441	4.1078	5.8922	3.00	7.00
Total	30	6.1333	1.59164	.29059	5.5390	6.7277	3.00	9.00

ANOVA

SSPScore

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21.067	2	10.533	5.427	.010
Within Groups	52.400	27	1.941		
Total	73.467	29			

Post Hoc Tests

Multiple Comparisons

SSPScore
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.60000	.62302	.606	-2.1447	.9447
	3.00	1.40000	.62302	.081	-.1447	2.9447
2.00	1.00	.60000	.62302	.606	-.9447	2.1447
	3.00	2.00000*	.62302	.009	.4553	3.5447
3.00	1.00	-1.40000	.62302	.081	-2.9447	.1447
	2.00	-2.00000*	.62302	.009	-3.5447	-.4553

*. The mean difference is significant at the 0.05 level.

FSS1 SSP – Pearson product moment correlation coefficient (Section 5.6.1.2)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
SSPScore	6.1333	1.59164	30

Correlations

		Age	SSPScore
Age	Pearson Correlation	1	-.450*
	Sig. (2-tailed)		.013
	N	30	30
SSPScore	Pearson Correlation	-.450*	1
	Sig. (2-tailed)	.013	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
SSPScore	6.1333	1.59164	30

Correlations

		Age	SSPScore
Age	Pearson Correlation	1	-.450**
	Sig. (1-tailed)		.006
	N	30	30
SSPScore	Pearson Correlation	-.450**	1
	Sig. (1-tailed)	.006	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

FSS1 Task Completion Times (TCT) – Multivariate ANOVA (Section 5.6.2.1)

General Linear Model

Within-Subjects Factors

Measure:MEASURE_1

TCT	Dependent Variable
1	LOGTCT1
2	LOGTCT2
3	LOGTCT3
4	LOGTCT4
5	LOGTCT5
6	LOGTCT6

Between-Subjects Factors

		N
AgeGroup	1.00	10
	2.00	10
	3.00	10

	Mean	Std. Deviation
1	1.1326	.3553
2	1.3408	.3047
3	1.4538	.4135

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
LOGTCT1	1.00	1.0954	.57259	10
	2.00	1.4552	.34015	10
	3.00	1.5939	.51844	10
	Total	1.3815	.51645	30
LOGTCT2	1.00	.9628	.30788	10
	2.00	1.3212	.36240	10
	3.00	1.4008	.44587	10
	Total	1.2283	.41162	30
LOGTCT3	1.00	2.2510	.42379	10
	2.00	2.3419	.31709	10
	3.00	2.4120	.29738	10
	Total	2.3350	.34478	30
LOGTCT4	1.00	.9116	.33607	10
	2.00	.9162	.19324	10
	3.00	.9872	.31242	10
	Total	.9383	.27959	30
LOGTCT5	1.00	.7031	.21966	10
	2.00	.9640	.34036	10
	3.00	1.1831	.38614	10
	Total	.9501	.37016	30
LOGTCT6	1.00	.8719	.27207	10
	2.00	1.0467	.27541	10
	3.00	1.1460	.52124	10
	Total	1.0215	.37961	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	308.479	1	308.479	1385.396	.000
AgeGroup	3.185	2	1.593	7.153	.003
Error	6.012	27	.223		

Post Hoc Tests

AgeGroup

Multiple Comparisons

MEASURE_1
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1.00	2.00	-.2082	.08615	.057	-.4218	.0054
	3.00	-.3212*	.08615	.003	-.5348	-.1076
2.00	1.00	.2082	.08615	.057	-.0054	.4218
	3.00	-.1129	.08615	.401	-.3266	.1007
3.00	1.00	.3212*	.08615	.003	.1076	.5348
	2.00	.1129	.08615	.401	-.1007	.3266

Based on observed means.
The error term is Mean Square(Error) = .037.

*. The mean difference is significant at the .05 level.

FSS1 TCT/Age – Pearson product moment correlation coefficient (Section 5.6.2.1)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTCT1	1.3815	.51645	30

Correlations

		Age	LogTCT1
Age	Pearson Correlation	1	.364*
	Sig. (2-tailed)		.048
	N	30	30
LogTCT1	Pearson Correlation	.364*	1
	Sig. (2-tailed)	.048	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTCT2	1.2283	.41162	30

Correlations

		Age	LogTCT2
Age	Pearson Correlation	1	.401*
	Sig. (2-tailed)		.028
	N	30	30
LogTCT2	Pearson Correlation	.401*	1
	Sig. (2-tailed)	.028	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTCT5	.9501	.37016	30

Correlations

		Age	LogTCT5
Age	Pearson Correlation	1	.400*
	Sig. (2-tailed)		.028
	N	30	30
LogTCT5	Pearson Correlation	.400*	1
	Sig. (2-tailed)	.028	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTCT6	1.0215	.37961	30

Correlations

		Age	LogTCT6
Age	Pearson Correlation	1	.339*
	Sig. (1-tailed)		.034
	N	30	30
LogTCT6	Pearson Correlation	.339*	1
	Sig. (1-tailed)	.034	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
MeanTCT	1.3091	.22991	30

Correlations

		Age	MeanTCT
Age	Pearson Correlation	1	.482**
	Sig. (2-tailed)		.007
	N	30	30
MeanTCT	Pearson Correlation	.482**	1
	Sig. (2-tailed)	.007	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

FSS1 Number of Button Clicks – Multivariate ANOVA (Section 5.6.2.2)

General Linear Model

Within-Subjects Factors

Measure:MEASURE_1

factor1	Dependent Variable
1	LOGNBC1
2	LOGNBC2
3	LOGBNC3
4	LOGBNC4
5	LOGBNC5
6	LOGBNC6

Between-Subjects Factors

		N
AgeGroup	1.00	10
	2.00	10
	3.00	10

	Mean	Std. Deviation
1	0.7579	.2631
2	0.5666	.3085
3	0.9328	.3616

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
LOGNBC1	1.00	.5093	.48723	10
	2.00	.7451	.38753	10
	3.00	1.0110	.45525	10
	Total	.7551	.47756	30
LOGNBC2	1.00	.6646	.20597	10
	2.00	.7438	.26215	10
	3.00	.7677	.25539	10
	Total	.7254	.23821	30
LOGBNC3	1.00	1.7978	.25187	10
	2.00	1.8001	.39681	10
	3.00	1.9226	.33345	10
	Total	1.8402	.32646	30
LOGBNC4	1.00	.7643	.13631	10
	2.00	.6720	.14457	10
	3.00	.6702	.26677	10
	Total	.7022	.19062	30
LOGBNC5	1.00	.3061	.23918	10
	2.00	.3108	.31883	10
	3.00	.5805	.38879	10
	Total	.3992	.33650	30
LOGBNC6	1.00	.5053	.25807	10
	2.00	.7479	.34123	10
	3.00	.6449	.47047	10
	Total	.6327	.36840	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	127.750	1	127.750	947.879	.000
AgeGroup	.921	2	.460	3.417	.048
Error	3.639	27	.135		

Post Hoc Tests

AgeGroup

Multiple Comparisons

MEASURE_1
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.0787	.06703	.478	-.2449	.0875
	3.00	-.1749*	.06703	.038	-.3411	-.0087
2.00	1.00	.0787	.06703	.478	-.0875	.2449
	3.00	-.0962	.06703	.337	-.2624	.0700
3.00	1.00	.1749*	.06703	.038	.0087	.3411
	2.00	.0962	.06703	.337	-.0700	.2624

Based on observed means.
The error term is Mean Square(Error) = .022.

*. The mean difference is significant at the .05 level.

FSS1 Number of Button Clicks /Age – Pearson product moment correlation coefficient (Section 5.6.2.2)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogNoBP1	.7551	.47756	30

Correlations

		Age	LogNoBP1
Age	Pearson Correlation	1	.398*
	Sig. (2-tailed)		.029
	N	30	30
LogNoBP1	Pearson Correlation	.398*	1
	Sig. (2-tailed)	.029	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogNoBPMean	.8425	.16188	30

Correlations

		Age	LogNo BPMean
Age	Pearson Correlation	1	.323*
	Sig. (1-tailed)		.041
	N	30	30
LogNoBPMean	Pearson Correlation	.323*	1
	Sig. (1-tailed)	.041	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

FSS1 Error Rate Data Analysis – Multivariate ANOVA (Section 5.6.2.3)

General Linear Model

Within-Subjects Factors

Measure:MEASURE_1

factor1	Dependent Variable
1	LOGError1
2	LOGError2
3	LOGError3
4	LOGError4
5	LOGError5
6	LOGError6

Between-Subjects Factors

		N
AgeGroup	1.00	10
	2.00	10
	3.00	10

	Mean	Std. Deviation
1	0.4088	.3266
2	0.4801	.3356
3	0.6128	.4252

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
LOGError1	1.00	.3386	.52033	10
	2.00	.5623	.35366	10
	3.00	.6470	.66339	10
	Total	.5160	.52623	30
LOGError2	1.00	.1544	.32734	10
	2.00	.1653	.38550	10
	3.00	.2681	.33235	10
	Total	.1960	.34113	30
LOGError3	1.00	1.6567	.43583	10
	2.00	1.7477	.43910	10
	3.00	1.8860	.36410	10
	Total	1.7634	.41124	30
LOGError4	1.00	.0778	.24607	10
	2.00	.0477	.15088	10
	3.00	.0845	.26724	10
	Total	.0700	.21974	30
LOGError5	1.00	.1556	.20932	10
	2.00	.1799	.30654	10
	3.00	.4870	.40575	10
	Total	.2742	.34260	30
LOGError6	1.00	.0699	.22103	10
	2.00	.1778	.37850	10
	3.00	.3051	.51880	10
	Total	.1843	.39079	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	45.114	1	45.114	241.087	.000
AgeGroup	1.288	2	.644	3.440	.047
Error	5.052	27	.187		

Post Hoc Tests

AgeGroup

Multiple Comparisons

MEASURE_1
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.0713	.07898	.643	-.2671	.1245
	3.00	-.2041*	.07898	.040	-.3999	-.0083
2.00	1.00	.0713	.07898	.643	-.1245	.2671
	3.00	-.1328	.07898	.230	-.3286	.0630
3.00	1.00	.2041*	.07898	.040	.0083	.3999
	2.00	.1328	.07898	.230	-.0630	.3286

Based on observed means.
The error term is Mean Square(Error) = .031.

*. The mean difference is significant at the .05 level.

FSS1 Error/Age – Pearson product moment correlation coefficient (Section 5.6.2.3)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogErrorRate5	.2742	.34260	30

Correlations

		Age	LogError Rate5
Age	Pearson Correlation	1	.316*
	Sig. (1-tailed)		.044
	N	30	30
LogErrorRate5	Pearson Correlation	.316*	1
	Sig. (1-tailed)	.044	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogErrorMean	.5006	.19089	30

Correlations

		Age	LogErrorMean
Age	Pearson Correlation	1	.315*
	Sig. (1-tailed)		.045
	N	30	30
LogErrorMean	Pearson Correlation	.315*	1
	Sig. (1-tailed)	.045	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

FSS1 Mean Time per Button Press Data Analysis – Multivariate ANOVA (Section 5.6.2.4)

General Linear Model

Within-Subjects Factors

Measure:MEASURE_1

factor1	Dependent Variable
1	LOGTpBP1
2	LOGTpBP2
3	LOGTpBP3
4	LOGTpBP4
5	LOGTpBP5
6	LOGTpBP6

Between-Subjects Factors

		N
AgeGroup	1.00	10
	2.00	10
	3.00	10

	Mean	Std. Deviation
1	0.3701	.3055
2	0.4636	.3849
3	0.5199	.3658

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
LOGTpBP1	1.00	.5856	.56825	10
	2.00	.7649	.37952	10
	3.00	.5825	.35413	10
	Total	.6444	.43744	30
LOGTpBP2	1.00	.2980	.27784	10
	2.00	.5504	.43793	10
	3.00	.7361	.38912	10
	Total	.5282	.40473	30
LOGTpBP3	1.00	.4562	.23516	10
	2.00	.5506	.20236	10
	3.00	.4880	.29139	10
	Total	.4982	.24044	30
LOGTpBP4	1.00	.1473	.36392	10
	2.00	.1282	.39553	10
	3.00	.2167	.40413	10
	Total	.1641	.37661	30
LOGTpBP5	1.00	.3671	.16123	10
	2.00	.5628	.32566	10
	3.00	.6024	.27983	10
	Total	.5108	.27610	30
LOGTpBP6	1.00	.3664	.22736	10
	2.00	.2250	.56901	10
	3.00	.4939	.47696	10
	Total	.3618	.44676	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	36.650	1	36.650	182.775	.000
AgeGroup	.687	2	.344	1.714	.199
Error	5.414	27	.201		

FSS1 Mean Time per Button Press /Age – Pearson product moment correlation coefficient (Section 5.6.2.4)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTpBP2	.5282	.40473	30

Correlations

		Age	LogTpBP2
Age	Pearson Correlation	1	.445*
	Sig. (2-tailed)		.014
	N	30	30
LogTpBP2	Pearson Correlation	.445*	1
	Sig. (2-tailed)	.014	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTpBP5	.5108	.27610	30

Correlations

		Age	LogTpBP5
Age	Pearson Correlation	1	.343*
	Sig. (1-tailed)		.032
	N	30	30
LogTpBP5	Pearson Correlation	.343*	1
	Sig. (1-tailed)	.032	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
LogTMean	.4512	.18726	30

Correlations

		Age	LogTMean
Age	Pearson Correlation	1	.346*
	Sig. (1-tailed)		.031
	N	30	30
LogTMean	Pearson Correlation	.346*	1
	Sig. (1-tailed)	.031	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

FSS1 Technological Familiarity Questionnaire: Q1 Analysis – 1-Way ANOVA (Section 5.6.2.5)

Oneway

Descriptives

TFQQ1

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	1.6343	.13698	.04332	1.5363	1.7323	1.45	1.84
2.00	10	1.7066	.07125	.02253	1.6556	1.7575	1.61	1.81
3.00	10	1.4378	.18063	.05712	1.3086	1.5670	1.15	1.72
Total	30	1.5929	.17569	.03208	1.5273	1.6585	1.15	1.84

ANOVA

TFQQ1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.387	2	.193	10.278	.000
Within Groups	.508	27	.019		
Total	.895	29			

Post Hoc Tests

Multiple Comparisons

TFQQ1
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.07228	.06136	.476	-.2244	.0798
	3.00	.19649*	.06136	.009	.0444	.3486
2.00	1.00	.07228	.06136	.476	-.0798	.2244
	3.00	.26877*	.06136	.000	.1166	.4209
3.00	1.00	-.19649*	.06136	.009	-.3486	-.0444
	2.00	-.26877*	.06136	.000	-.4209	-.1166

*. The mean difference is significant at the 0.05 level.

FSS1 Technological Familiarity Questionnaire: Q2 Analysis – 1-Way ANOVA (Section 5.6.2.5)

Oneway

Descriptives

TFQQ2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	1.5272	.13408	.04240	1.4313	1.6231	1.30	1.71
2.00	10	1.6227	.06028	.01906	1.5795	1.6658	1.52	1.69
3.00	10	1.2159	.26411	.08352	1.0269	1.4048	.85	1.57
Total	30	1.4552	.24405	.04456	1.3641	1.5464	.85	1.71

ANOVA

TFQQ2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.905	2	.452	14.858	.000
Within Groups	.822	27	.030		
Total	1.727	29			

Post Hoc Tests

Multiple Comparisons

TFQQ2
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.09544	.07805	.450	-.2889	.0981
	3.00	.31133*	.07805	.001	.1178	.5048
2.00	1.00	.09544	.07805	.450	-.0981	.2889
	3.00	.40677*	.07805	.000	.2133	.6003
3.00	1.00	-.31133*	.07805	.001	-.5048	-.1178
	2.00	-.40677*	.07805	.000	-.6003	-.2133

*. The mean difference is significant at the 0.05 level.

FSS1 Technological Familiarity Questionnaire: Total Analysis – 1-Way ANOVA (Section 5.6.2.5)

Oneway

Descriptives

TFQTotal

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	1.8884	.12360	.03908	1.8000	1.9768	1.71	2.06
2.00	10	1.9688	.05730	.01812	1.9279	2.0098	1.88	2.04
3.00	10	1.6442	.20972	.06632	1.4942	1.7943	1.32	1.95
Total	30	1.8338	.19777	.03611	1.7600	1.9077	1.32	2.06

ANOVA

TFQTotal

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.571	2	.286	13.706	.000
Within Groups	.563	27	.021		
Total	1.134	29			

Post Hoc Tests

Multiple Comparisons

TFQTotal
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-.08046	.06457	.437	-.2406	.0796
	3.00	.24413*	.06457	.002	.0840	.4042
2.00	1.00	.08046	.06457	.437	-.0796	.2406
	3.00	.32460*	.06457	.000	.1645	.4847
3.00	1.00	-.24413*	.06457	.002	-.4042	-.0840
	2.00	-.32460*	.06457	.000	-.4847	-.1645

*. The mean difference is significant at the 0.05 level.

FSS1 Technological Familiarity Questionnaire: Q1/Age – Pearson product moment correlation coefficient (Section 5.6.2.5)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
TFQQ1	42.0333	14.79628	30

Correlations

		Age	TFQQ1
Age	Pearson Correlation	1	-.424*
	Sig. (2-tailed)		.020
	N	30	30
TFQQ1	Pearson Correlation	-.424*	1
	Sig. (2-tailed)	.020	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

FSS1 Technological Familiarity Questionnaire: Q2/Age – Pearson product moment correlation coefficient (Section 5.6.2.5)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
TFQQ2	32.1667	13.14399	30

Correlations

		Age	TFQQ2
Age	Pearson Correlation	1	-.563**
	Sig. (2-tailed)		.001
	N	30	30
TFQQ2	Pearson Correlation	-.563**	1
	Sig. (2-tailed)	.001	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

FSS1 Technological Familiarity Questionnaire: TFQ Total/Age – Pearson product moment correlation coefficient (Section 5.6.2.5)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	42.4667	19.59545	30
TFQTotal	74.2000	26.84104	30

Correlations

		Age	TFQTotal
Age	Pearson Correlation	1	-.509**
	Sig. (2-tailed)		.004
	N	30	30
TFQTotal	Pearson Correlation	-.509**	1
	Sig. (2-tailed)	.004	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix 6: SPSS Output: FSS2

FSS2 MOT – 1-way ANOVA (Section 6.5.1.1)

Oneway

Descriptives

MOTRT

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	49.2000	4.04969	1.28062	46.3030	52.0970	43.00	56.00
2.00	10	52.1000	9.76900	3.08923	45.1117	59.0883	38.00	64.00
3.00	10	52.8000	8.49575	2.68659	46.7225	58.8775	41.00	64.00
Total	30	51.3667	7.72137	1.40972	48.4835	54.2499	38.00	64.00

ANOVA

MOTRT

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	72.867	2	36.433	.594	.559
Within Groups	1656.100	27	61.337		
Total	1728.967	29			

FSS2 MOT – Pearson product moment correlation coefficient (Section 6.5.1.1)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.9000	20.96853	30
MOTRT	51.3667	7.72137	30

Correlations

		Age	MOTRT
Age	Pearson Correlation	1	.317*
	Sig. (1-tailed)		.044
	N	30	30
MOTRT	Pearson Correlation	.317*	1
	Sig. (1-tailed)	.044	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

FSS2 SSP – 1-way ANOVA (Section 6.5.1.2)

Oneway

Descriptives

SSPScore

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	6.9000	1.44914	.45826	5.8633	7.9367	4.00	9.00
2.00	10	6.4000	1.64655	.52068	5.2221	7.5779	3.00	8.00
3.00	10	4.9000	1.19722	.37859	4.0436	5.7564	3.00	7.00
Total	30	6.0667	1.63861	.29917	5.4548	6.6785	3.00	9.00

ANOVA

SSPScore

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	21.667	2	10.833	5.205	.012
Within Groups	56.200	27	2.081		
Total	77.867	29			

Post Hoc Tests

Multiple Comparisons

SSPScore
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.50000	.64521	.721	-1.0997	2.0997
	3.00	2.00000*	.64521	.012	.4003	3.5997
2.00	1.00	-.50000	.64521	.721	-2.0997	1.0997
	3.00	1.50000	.64521	.069	-.0997	3.0997
3.00	1.00	-2.00000*	.64521	.012	-3.5997	-.4003
	2.00	-1.50000	.64521	.069	-3.0997	.0997

*. The mean difference is significant at the 0.05 level.

FSS2 SSP – Pearson product moment correlation coefficient (Section 6.5.1.2)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
SSPScore	6.0667	1.63861	30

Correlations

		Age	SSPScore
Age	Pearson Correlation	1	-.664**
	Sig. (2-tailed)		.000
	N	30	30
SSPScore	Pearson Correlation	-.664**	1
	Sig. (2-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

FSS2 Task Completion Times (TCT) – Multivariate ANOVA (Section 6.5.2.1)

General Linear Model

Within-Subjects Factors

Measure:MEASURE_1

TCTimes	Dependent Variable
1	LogT1biPerf Time
2	LogT2wPerf Time
3	LogT3mPerf Time
4	LogT4ePerf Time
5	LogT5tPerf Time
6	LogT6lPerf Time

Between-Subjects Factors

		N
AgeGroup	1	10
	2	10
	3	10

	Mean	Std. Deviation
1	1.3715	.3327
2	1.4979	.3233
3	1.7190	.3095

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
LogT1biPerfTime	1	1.35752676	.197227638	10
	2	1.24463037	.226102656	10
	3	1.70905288	.336259517	10
	Total	1.43707000	.321696622	30
LogT2wPerfTime	1	1.58451342	.324340017	10
	2	1.85705079	.390924119	10
	3	2.06207787	.355684693	10
	Total	1.83454736	.398648687	30
LogT3mPerfTime	1	1.64896483	.468957675	10
	2	1.70876711	.378708814	10
	3	1.83988343	.308710354	10
	Total	1.73253845	.385894369	30
LogT4ePerfTime	1	1.35140256	.550772539	10
	2	1.76118517	.249365698	10
	3	1.94100160	.241244167	10
	Total	1.68452978	.440996807	30
LogT5tPerfTime	1	.88040402	.161166671	10
	2	1.18841447	.299238235	10
	3	1.21380462	.278403284	10
	Total	1.09420770	.289240563	30
LogT6lPerfTime	1	1.40634553	.294095533	10
	2	1.22805049	.396100197	10
	3	1.54895189	.336996326	10
	Total	1.39444930	.358617942	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Intercept	421.118	1	421.118	1847.059	.000	.986
AgeGroup	3.714	2	1.857	8.146	.002	.376
Error	6.156	27	.228			

Post Hoc Tests

AgeGroup

Multiple Comparisons

Measure:MEASURE_1

	(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Tukey HSD	1	2	-.12649021	.087176791	.330	-.34263789	.08965747
		3	-.34760253*	.087176791	.001	-.56375021	-.13145485
	2	1	.12649021	.087176791	.330	-.08965747	.34263789
		3	-.22111232*	.087176791	.044	-.43725999	-.00496464
	3	1	.34760253*	.087176791	.001	.13145485	.56375021
		2	.22111232*	.087176791	.044	.00496464	.43725999
Bonferroni	1	2	-.12649021	.087176791	.475	-.34900538	.09602496
		3	-.34760253*	.087176791	.001	-.57011770	-.12508736
	2	1	.12649021	.087176791	.475	-.09602496	.34900538
		3	-.22111232	.087176791	.052	-.44362748	.00140285
	3	1	.34760253*	.087176791	.001	.12508736	.57011770
		2	.22111232	.087176791	.052	-.00140285	.44362748

Based on observed means.
The error term is Mean Square(Error) = .038.

*. The mean difference is significant at the .05 level.

FSS2 TCT / Age – Pearson product moment correlation coefficient (Section 6.5.2.1)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT1	37.8667	41.76679	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT1	37.8667	41.76679	30

Correlations

		Age	TCT1
Age	Pearson Correlation	1	.544**
	Sig. (2-tailed)		.002
	N	30	30
TCT1	Pearson Correlation	.544**	1
	Sig. (2-tailed)	.002	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		Age	TCT1
Age	Pearson Correlation	1	.544**
	Sig. (1-tailed)		.001
	N	30	30
TCT1	Pearson Correlation	.544**	1
	Sig. (1-tailed)	.001	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT2	102.4333	104.44358	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT2	102.4333	104.44358	30

Correlations

		Age	TCT2
Age	Pearson Correlation	1	.431*
	Sig. (2-tailed)		.017
	N	30	30
TCT2	Pearson Correlation	.431*	1
	Sig. (2-tailed)	.017	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		Age	TCT2
Age	Pearson Correlation	1	.431**
	Sig. (1-tailed)		.009
	N	30	30
TCT2	Pearson Correlation	.431**	1
	Sig. (1-tailed)	.009	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT4	67.6000	45.86607	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT4	67.6000	45.86607	30

Correlations

		Age	TCT4
Age	Pearson Correlation	1	.508**
	Sig. (2-tailed)		.004
	N	30	30
TCT4	Pearson Correlation	.508**	1
	Sig. (2-tailed)	.004	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		Age	TCT4
Age	Pearson Correlation	1	.508**
	Sig. (1-tailed)		.002
	N	30	30
TCT4	Pearson Correlation	.508**	1
	Sig. (1-tailed)	.002	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT6	33.6333	27.23396	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCT6	33.6333	27.23396	30

Correlations

		Age	TCT6
Age	Pearson Correlation	1	.451*
	Sig. (2-tailed)		.012
	N	30	30
TCT6	Pearson Correlation	.451*	1
	Sig. (2-tailed)	.012	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Correlations

		Age	TCT6
Age	Pearson Correlation	1	.451**
	Sig. (1-tailed)		.006
	N	30	30
TCT6	Pearson Correlation	.451**	1
	Sig. (1-tailed)	.006	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCTMean	55.5333	32.98457	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TCTMean	55.5333	32.98457	30

Correlations

		Age	TCTMean
Age	Pearson Correlation	1	.575**
	Sig. (2-tailed)		.001
	N	30	30
TCTMean	Pearson Correlation	.575**	1
	Sig. (2-tailed)	.001	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations

		Age	TCTMean
Age	Pearson Correlation	1	.575**
	Sig. (1-tailed)		.000
	N	30	30
TCTMean	Pearson Correlation	.575**	1
	Sig. (1-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

FSS2 Warning Icon Recognition – Multivariate ANOVA (Section 6.5.2.2)

General Linear Model

Within-Subjects Factors

Measure:MEASURE_1

WarningID	Dependent Variable
1	WarningPre
2	WarningPost

Between-Subjects Factors

		N
AgeGroup	1.00	10
	2.00	10
	3.00	10

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
WarningPre	1.00	4.6000	1.77639	10
	2.00	5.5000	1.95789	10
	3.00	4.1000	1.66333	10
	Total	4.7333	1.83704	30
WarningPost	1.00	8.4000	.84327	10
	2.00	8.2000	1.93218	10
	3.00	6.2000	2.34758	10
	Total	7.6000	2.02740	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	2281.667	1	2281.667	415.969	.000
AgeGroup	32.233	2	16.117	2.938	.070
Error	148.100	27	5.485		

Pairwise Comparisons

Measure:MEASURE_1

WarningID	(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a] Lower Bound	Upper Bound
1	1.00	2.00	-.900	.806	.274	-2.555	.755
		3.00	.500	.806	.540	-1.155	2.155
	2.00	1.00	.900	.806	.274	-.755	2.555
		3.00	1.400	.806	.094	-.255	3.055
	3.00	1.00	-.500	.806	.540	-2.155	1.155
		2.00	-1.400	.806	.094	-3.055	.255
2	1.00	2.00	.200	.815	.808	-1.472	1.872
		3.00	2.200*	.815	.012	.528	3.872
	2.00	1.00	-.200	.815	.808	-1.872	1.472
		3.00	2.000*	.815	.021	.328	3.672
	3.00	1.00	-2.200*	.815	.012	-3.872	-.528
		2.00	-2.000*	.815	.021	-3.672	-.328

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

FSS2 Warning Icon Recognition – Pearson product moment correlation coefficient (Section 6.5.2.2)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
IconRecogPre	4.7333	1.83704	30

Correlations

		Age	IconRecogPre
Age	Pearson Correlation	1	-.335
	Sig. (2-tailed)		.071
	N	30	30
IconRecogPre	Pearson Correlation	-.335	1
	Sig. (2-tailed)	.071	
	N	30	30

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
IconRecogPre	4.7333	1.83704	30

Correlations

		Age	IconRecogPre
Age	Pearson Correlation	1	-.335*
	Sig. (1-tailed)		.035
	N	30	30
IconRecogPre	Pearson Correlation	-.335*	1
	Sig. (1-tailed)	.035	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
IconRecogPost	7.6000	2.02740	30

Correlations

		Age	IconRecog Post
Age	Pearson Correlation	1	-.613**
	Sig. (2-tailed)		.000
	N	30	30
IconRecogPost	Pearson Correlation	-.613**	1
	Sig. (2-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
IconRecogPost	7.6000	2.02740	30

Correlations

		Age	IconRecog Post
Age	Pearson Correlation	1	-.613**
	Sig. (1-tailed)		.000
	N	30	30
IconRecogPost	Pearson Correlation	-.613**	1
	Sig. (1-tailed)	.000	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
IconRecogDiffAcqui	2.8667	1.59164	30

Correlations

		Age	IconRecogDiff Acqui
Age	Pearson Correlation	1	-.394*
	Sig. (2-tailed)		.031
	N	30	30
IconRecogDiffAcqui	Pearson Correlation	-.394*	1
	Sig. (2-tailed)	.031	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
IconRecogDiffAcqui	2.8667	1.59164	30

Correlations

		Age	IconRecogDiff Acqui
Age	Pearson Correlation	1	-.394*
	Sig. (1-tailed)		.016
	N	30	30
IconRecogDiffAcqui	Pearson Correlation	-.394*	1
	Sig. (1-tailed)	.016	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

FSS2 Feature Recognition – Multivariate ANOVA (Section 6.5.2.3)

Within-Subjects Factors

Measure:MEASURE_1

FeatureID	Dependent Variable
1	FeatureID_Pre
2	FeatureID_Post

Between-Subjects Factors

		N
AgeGroup	1.00	10
	2.00	10
	3.00	10

Descriptive Statistics

	AgeGroup	Mean	Std. Deviation	N
FeatureID_Pre	1.00	8.7000	3.09300	10
	2.00	10.8000	5.18116	10
	3.00	6.4000	3.50238	10
	Total	8.6333	4.29501	30
FeatureID_Post	1.00	16.4000	2.91357	10
	2.00	15.7000	6.05622	10
	3.00	11.7000	3.19896	10
	Total	14.6000	4.65055	30

Tests of Between-Subjects Effects

Measure:MEASURE_1
Transformed Variable:Average

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	8096.817	1	8096.817	268.518	.000
AgeGroup	202.533	2	101.267	3.358	.050
Error	814.150	27	30.154		

Pairwise Comparisons

Measure:MEASURE_1

						95% Confidence Interval for Difference[a]	
FeatureID	(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.[a]	Lower Bound	Upper Bound
1	1.00	2.00	-2.100	1.801	.254	-5.796	1.596
		3.00	2.300	1.801	.213	-1.396	5.996
	2.00	1.00	2.100	1.801	.254	-1.596	5.796
		3.00	4.400*	1.801	.021	.704	8.096
	3.00	1.00	-2.300	1.801	.213	-5.996	1.396
		2.00	-4.400*	1.801	.021	-8.096	-.704
2	1.00	2.00	.700	1.922	.719	-3.243	4.643
		3.00	4.700*	1.922	.021	.757	8.643
	2.00	1.00	-.700	1.922	.719	-4.643	3.243
		3.00	4.000*	1.922	.047	.057	7.943
	3.00	1.00	-4.700*	1.922	.021	-8.643	-.757
		2.00	-4.000*	1.922	.047	-7.943	-.057

Based on estimated marginal means

*. The mean difference is significant at the .05 level

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

FSS2 Feature Recognition – Pearson product moment correlation coefficient (Section 6.5.2.3)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
ProdFeatRecogPre	8.6333	4.29501	30

Correlations

		Age	ProdFeat RecogPre
Age	Pearson Correlation	1	-.384*
	Sig. (2-tailed)		.036
	N	30	30
ProdFeatRecogPre	Pearson Correlation	-.384*	1
	Sig. (2-tailed)	.036	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
ProdFeatRecogPre	8.6333	4.29501	30

Correlations

		Age	ProdFeat RecogPre
Age	Pearson Correlation	1	-.384*
	Sig. (1-tailed)		.018
	N	30	30
ProdFeatRecogPre	Pearson Correlation	-.384*	1
	Sig. (1-tailed)	.018	
	N	30	30

*. Correlation is significant at the 0.05 level (1-tailed).

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
ProdFeatRecogPost	14.6000	4.65055	30

Correlations

		Age	ProdFeat RecogPost
Age	Pearson Correlation	1	-.544**
	Sig. (2-tailed)		.002
	N	30	30
ProdFeatRecogPost	Pearson Correlation	-.544**	1
	Sig. (2-tailed)	.002	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
ProdFeatRecogPost	14.6000	4.65055	30

Correlations

		Age	ProdFeat RecogPost
Age	Pearson Correlation	1	-.544**
	Sig. (1-tailed)		.001
	N	30	30
ProdFeatRecogPost	Pearson Correlation	-.544**	1
	Sig. (1-tailed)	.001	
	N	30	30

**. Correlation is significant at the 0.01 level (1-tailed).

FSS2 Prompted Product Recall – 1-way ANOVA (Section 6.5.2.4)

Oneway

ANOVA

PromtProdRec

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.867	2	10.433	2.965	.069
Within Groups	95.000	27	3.519		
Total	115.867	29			

Post Hoc Tests

Multiple Comparisons

PromtProdRec
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	.30000	.83887	.932	-1.7799	2.3799
	3.00	1.90000	.83887	.078	-.1799	3.9799
2.00	1.00	-.30000	.83887	.932	-2.3799	1.7799
	3.00	1.60000	.83887	.156	-.4799	3.6799
3.00	1.00	-1.90000	.83887	.078	-3.9799	.1799
	2.00	-1.60000	.83887	.156	-3.6799	.4799

FSS2 Prompted Product Recall – Pearson product moment correlation coefficient (Section 6.5.2.4)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
PromtProdRecall	2.2667	1.99885	30

Correlations

		Age	PromtProd Recall
Age	Pearson Correlation	1	-.383*
	Sig. (2-tailed)		.037
	N	30	30
PromtProdRecall	Pearson Correlation	-.383*	1
	Sig. (2-tailed)	.037	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

FSS2 TFQ: Q1 Analysis – 1-way ANOVA (Section 6.5.2.5)

Oneway

Descriptives

TFQQ1

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	47.2000	7.42069	2.34663	41.8916	52.5084	36.00	64.00
2.00	10	42.6000	17.68992	5.59404	29.9454	55.2546	16.00	73.00
3.00	10	39.4000	12.26739	3.87929	30.6244	48.1756	26.00	61.00
Total	30	43.0667	13.09628	2.39104	38.1764	47.9569	16.00	73.00

ANOVA

TFQQ1

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	307.467	2	153.733	.890	.423
Within Groups	4666.400	27	172.830		
Total	4973.867	29			

FSS2 TFQ: Q2 Analysis – 1-way ANOVA (Section 6.5.2.5)

Oneway

Descriptives

TFQQ2

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	50.1000	17.12990	5.41695	37.8460	62.3540	26.00	73.00
2.00	10	43.0000	23.58436	7.45803	26.1288	59.8712	11.00	79.00
3.00	10	25.4000	11.21705	3.54714	17.3758	33.4242	10.00	45.00
Total	30	39.5000	20.35334	3.71600	31.8999	47.1001	10.00	79.00

ANOVA

TFQQ2

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3234.200	2	1617.100	4.973	.014
Within Groups	8779.300	27	325.159		
Total	12013.500	29			

Post Hoc Tests

Multiple Comparisons

TFQQ2
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	7.10000	8.06423	.657	-12.8946	27.0946
	3.00	24.70000*	8.06423	.013	4.7054	44.6946
2.00	1.00	-7.10000	8.06423	.657	-27.0946	12.8946
	3.00	17.60000	8.06423	.092	-2.3946	37.5946
3.00	1.00	-24.70000*	8.06423	.013	-44.6946	-4.7054
	2.00	-17.60000	8.06423	.092	-37.5946	2.3946

*. The mean difference is significant at the 0.05 level.

FSS2 TFQ: TFQ Total Analysis – 1-way ANOVA (Section 6.5.2.5)

Oneway

Descriptives

TFQ

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	97.3000	16.32347	5.16193	85.6229	108.9771	73.00	122.00
2.00	10	85.6000	39.69663	12.55318	57.2027	113.9973	27.00	151.00
3.00	10	64.8000	22.36465	7.07232	48.8013	80.7987	36.00	106.00
Total	30	82.5667	30.22979	5.51918	71.2787	93.8547	27.00	151.00

ANOVA

TFQ

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5419.267	2	2709.633	3.470	.046
Within Groups	21082.100	27	780.819		
Total	26501.367	29			

Post Hoc Tests

Multiple Comparisons

TFQ
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	11.70000	12.49655	.623	-19.2842	42.6842
	3.00	32.50000*	12.49655	.038	1.5158	63.4842
2.00	1.00	-11.70000	12.49655	.623	-42.6842	19.2842
	3.00	20.80000	12.49655	.237	-10.1842	51.7842
3.00	1.00	-32.50000*	12.49655	.038	-63.4842	-1.5158
	2.00	-20.80000	12.49655	.237	-51.7842	10.1842

*. The mean difference is significant at the 0.05 level.

FSS2 TFQ Q2 Analysis – Pearson product moment correlation coefficient (Section 6.5.2.5)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TFQQ2	39.5000	20.35334	30

Correlations

		Age	TFQQ2
Age	Pearson Correlation	1	-.509**
	Sig. (2-tailed)		.004
	N	30	30
TFQQ2	Pearson Correlation	-.509**	1
	Sig. (2-tailed)	.004	
	N	30	30

**. Correlation is significant at the 0.01 level (2-tailed).

FSS2 TFQ: TFQ Total Analysis – Pearson product moment correlation coefficient (Section 6.5.2.5)

Correlations

Descriptive Statistics

	Mean	Std. Deviation	N
Age	43.8000	20.78196	30
TFQScore	82.5667	30.22979	30

Correlations

		Age	TFQScore
Age	Pearson Correlation	1	-.462*
	Sig. (2-tailed)		.010
	N	30	30
TFQScore	Pearson Correlation	-.462*	1
	Sig. (2-tailed)	.010	
	N	30	30

*. Correlation is significant at the 0.05 level (2-tailed).

Appendix 6: SPSS Output: TFQ Survey

Effect of Age on Technological Familiarity – Experimental Condition (Section 7.7.1)

Oneway

ANOVA

TFQScoreExp

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	5419.267	2	2709.633	3.470	.046
Within Groups	21082.100	27	780.819		
Total	26501.367	29			

Post Hoc Tests

Multiple Comparisons

TFQScoreExp
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	11.70000	12.49655	.623	-19.2842	42.6842
	3.00	32.50000*	12.49655	.038	1.5158	63.4842
2.00	1.00	-11.70000	12.49655	.623	-42.6842	19.2842
	3.00	20.80000	12.49655	.237	-10.1842	51.7842
3.00	1.00	-32.50000*	12.49655	.038	-63.4842	-1.5158
	2.00	-20.80000	12.49655	.237	-51.7842	10.1842

*. The mean difference is significant at the 0.05 level.

Effect of Age on Technological Familiarity – Online Condition (Section 7.7.1)

Oneway

ANOVA

TFQScoreOnline

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3377.509	2	1688.755	2.552	.085
Within Groups	46976.829	71	661.645		
Total	50354.338	73			

Post Hoc Tests

Multiple Comparisons

TFQScoreOnline
Tukey HSD

(I) AgeGroup	(J) AgeGroup	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
1.00	2.00	3.39394	7.18031	.884	-13.7945	20.5824
	3.00	16.95000	8.03674	.095	-2.2886	36.1886
2.00	1.00	-3.39394	7.18031	.884	-20.5824	13.7945
	3.00	13.55606	7.28918	.158	-3.8930	31.0051
3.00	1.00	-16.95000	8.03674	.095	-36.1886	2.2886
	2.00	-13.55606	7.28918	.158	-31.0051	3.8930

Appendix 6: SPSS Output: Manual Reading Behaviour

Effect of Age on Manual Reading Behaviour – Experimental Condition (Section 7.7.2)

Oneway

Descriptives

NonManReadBehaviour

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	10	.1000	.31623	.10000	-.1262	.3262	.00	1.00
2.00	10	.1000	.31623	.10000	-.1262	.3262	.00	1.00
3.00	10	.2000	.42164	.13333	-.1016	.5016	.00	1.00
Total	30	.1333	.34575	.06312	.0042	.2624	.00	1.00

ANOVA

NonManReadBehaviour

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.067	2	.033	.265	.769
Within Groups	3.400	27	.126		
Total	3.467	29			

Effect of Age on Manual Reading Behaviour – Online Condition (Section 7.7.2)

Oneway

Descriptives

NonManReadBehaviour

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	21	.4286	.50709	.11066	.1977	.6594	.00	1.00
2.00	33	.3636	.48850	.08504	.1904	.5369	.00	1.00
3.00	20	.2000	.41039	.09177	.0079	.3921	.00	1.00
Total	74	.3378	.47620	.05536	.2275	.4482	.00	1.00

ANOVA

NonManReadBehaviour

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.575	2	.287	1.277	.285
Within Groups	15.979	71	.225		
Total	16.554	73			

Appendix 7: Technological Familiarity Questionnaires

Participant Number ______________________________

Age Group (please circle) 16-25 26-59 60-80

Gender (please circle) Male Female

How often do you use the following products?
(if you have never used a product of the type indicated, please tick never)

Product	Every day	Several times a week	Once or twice a week	Every few weeks	Every few months	Only ever used it once or twice	never
Television with remote control							
Video Recorder							
Satellite Television							
Camcorder							
DVD Recorder capable of recording television programs							
Mobile Telephone							
Home Hi-fi or Stereo							
Personal Stereo – eg: Sony Walkman							
Car Stereo							
Personal Electronic Organiser							
Laptop							
Satellite Navigation System (Sat Nav)							
Ipod							
Plug in electricity and cost calculator							
Other Products							

When using the products below, how many features on the product are you familiar with and do you use?

Product	All of the features (you read the manual to check them)	As many as you can figure out without the manual	Just enough to get by with	Your limited knowledge of the features limits your use of the product	None of the features – you do not use this product
Television with remote control					
Video Recorder					
Satellite Television					
Camcorder					
DVD Recorder capable of recording television programs					
Mobile Telephone					
Home Hi-fi or Stereo					
Personal Stereo – eg: Sony Walkman					
Car Stereo					
Personal Electronic Organiser					
Laptop					
Satellite Navigation System (Sat Nav)					
Ipod					
Plug in electricity and cost calculator					
Other Products					

Participant Number

How often do you use the following products?
(if you have never used a product of the type indicated, please tick never)

Product	Every day	Several times a week	Once or twice a week	Every few weeks	Every few months	Only used once or twice	Never	
Television with remote control								
Video Recorder								
Satellite Television								
Camcorder								
(TV) DVD Recorder								
Mobile Telephone								
Home Hi-fi or Stereo								
Personal Stereo – eg: Sony Walkman								
Car Stereo								
Personal Electronic Organiser								
Laptop								
Satellite Navigation System								
MP3/Music player (eg: Ipod)								
Laser Pointer/Pen								
Plug-in electricity monitor								
Spirit level								
Cable/Stud/Utility Detector								
Power Tools – Sanders, Grinders								
Laser tape measure								
Digital Central Heating Controls								
Burglar Alarm Control Panels								
Humidity Sensors								
Hand-held tools								
Walkie-Talkie's								
Now use the remaining column to identify any of the above devices you thought about whilst interacting with the laser level detector, and please verbalise your thoughts whilst doing so								↑

When using the products below, how many features on the product are you familiar with and do you use on a regular basis?

Product	All of the features (you read the manual to check them)	As many as you can figure out without the manual	Just enough to get by with	Your limited knowledge of the features limits your use of the product	None of the features – you do not use this product
Television with remote control					
Video Recorder					
Satellite Television					
Camcorder					
(TV) DVD Recorder					
Mobile Telephone					
Home Hi-fi or Stereo					
Personal Stereo – eg: Sony Walkman					
Car Stereo					
Personal Electronic Organiser					
Laptop					
Satellite Navigation System					
MP3/Music player (eg: Ipod)					
Laser Pointer/Pen					
Plug-in electricity monitor					
Spirit level					
Utility Detector					
Power Tools – Sanders, Grinders					
Laser tape measure					
Digital Central Heating Controls					
Burglar Alarm Control Panels					
Humidity Sensors					
Hand-held tools					
Walkie-Talkie's					

Appendix 8: TFQ Rating Protocol

The scoring system used to calculate individual and overall TFQ Scores according to the Blacker (2006) approach (p. 278-281). Product list is reduced for brevity.

How often do you use the following products?

Product	**Every day**	**Several times a week**	**Once or twice a week**	**Every few weeks**	**Every few months**	**Only used once or twice**	**Never**	
Television			•					
Video Recorder					•			
Satellite Television						•		
Camcorder				•				
(TV) DVD Recorder				•				
Mobile Telephone				•				
Each Column assigned a number	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
Number of responses multiplied by the column number	**0**	**0**	**4**	**9**	**2**	**1**	**0**	
TFQ 1 Score								**16**

How many features on the product are you familiar with and do you use on a regular basis?

Product	**All of the features (you read the manual to check them)**	**As many as you can figure out without the manual**	**Just enough to get by with**	**Your limited knowledge of the features limits your use of the product**	**None of the features – you do not use this product**	
Television				•		
Video Recorder		•				
Satellite Television		•	•			
Camcorder						
(TV) DVD Recorder		•				
Mobile Telephone				•		
Each Column assigned a number	**4**	**3**	**2**	**1**	**0**	
Number of responses multiplied by the column number	**0**	**9**	**2**	**2**	**0**	
TFQ 2 Score						**13**

TFQ 1 + TFQ 2						**16 + 13**
Overall TFQ Score						**29**

Appendix 9: Investigation 1 and 2 Tasks

Task 1:

Find the lowest wattage reading (W) for the lamp attached to this product:

Write down the wattage displayed.

___ ___ ■ ___ W

Lo

Task 2:

Find the current reading (A) for the lamp attached to this product:

Write down the current displayed.

___ ■ ___ ___ ___ A

Task 3:

Set Unit Cost Price to 99.50 £/kWh

___ ___ ■ ___ ___ £/kWh

Task 4:

Find the frequency reading (Hz) for the lamp attached to this product:

Write down the frequency displayed.

___ ___ Hz

Task 5:

Find out how much the lamp attached to this product has consumed since the start:

Write down the amounts displayed.

___ ■ ___ ___ ___ kWh

___ ■ ___ ___ £

Task 6:

Find the highest wattage (w) reading for the lamp attached to this product:

Write down the wattage displayed.

___ ___ ■ ___ W

Hi

Appendix 10: FSS2 Technological Familiarity Questionnaire

Participant Number

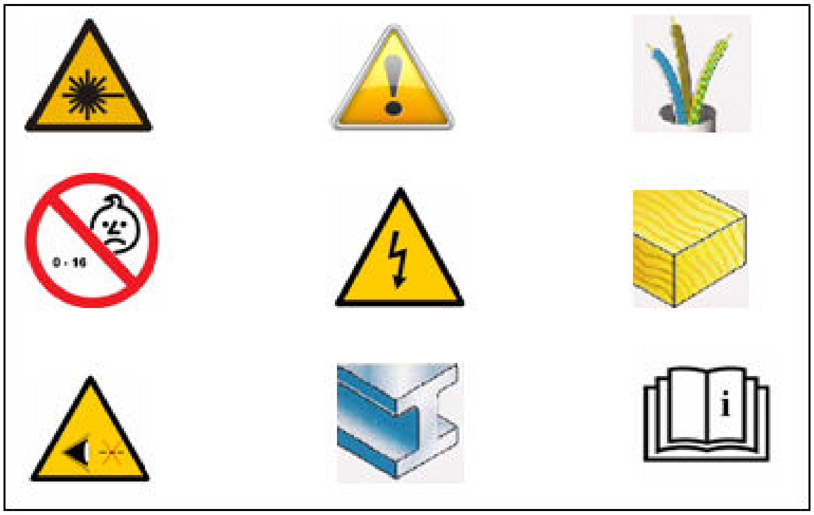
How often do you use the following products?
(if you have never used a product of the type indicated, please tick never)

Product	**Every day**	**Several times a week**	**Once or twice a week**	**Every few weeks**	**Every few months**	**Only used once or twice**	**Never**	
Television with remote control								
Video Recorder								
Satellite Television								
Camcorder								
(TV) DVD Recorder								
Mobile Telephone								
Home Hi-fi or Stereo								
Personal Stereo – eg: Sony Walkman								
Car Stereo								
Personal Electronic Organiser								
Laptop								
Satellite Navigation System								
MP3/Music player (eg: Ipod)								
Laser Pointer/Pen								
Plug-in electricity monitor								
Spirit level								
Cable/Stud/Utility Detector								
Power Tools – Sanders, Grinders								
Laser tape measure								
Digital Central Heating Controls								
Burglar Alarm Control Panels								
Humidity Sensors								
Hand-held tools								
Walkie-Talkie's								
Now use the remaining column to identify any of the above devices you thought about whilst interacting with the laser level detector, and please verbalise your thoughts whilst doing so								↑

When using the products below, how many features on the product are you familiar with and do you use on a regular basis?

	All of the features (you read the manual to check them)	**As many as you can figure out without the manual**	**Just enough to get by with**	**Your limited knowledge of features limits your use of the product**	**None of the features – you do not use this product**
Television with remote control					
Video Recorder					
Satellite Television					
Camcorder					
(TV) DVD Recorder					
Mobile Telephone					
Home Hi-fi or Stereo					
Personal Stereo – eg: Sony Walkman					
Car Stereo					
Personal Electronic Organiser					
Laptop					
Satellite Navigation System					
MP3/Music player eg: Ipod					
Laser Pointer/Pen					
Plug-in electricity monitor					
Spirit level					
Utility Detector					
Power Tools – Sanders, Grinders					
Laser tape measure					
Digital Central Heating Controls					
Burglar Alarm Control Panels					
Humidity Sensors					
Hand-held tools					
Walkie-Talkie's					

Appendix 11: Warning Icon and Product Feature Analysis



Warning Icon Assessment Sheet

As mentioned in text, the above Warning Icon Assessment Sheet was presented to each participant at the commencement of the product interaction phase. Participants were asked to label and write down what they thought the icons meant or implied. Post-interaction, the assessment sheets were revisited and the opportunity provided for participants to alter their descriptions if desired. One point was awarded for each correctly identified icon out of a maximum of nine. In this way, it was possible to determine pre and post recognition scores, changes in conceptualisations over time, and infer elements of information that had thus been acquired due to product exposure and interaction.

The actual warning icon meanings are represented below:

Laser	Hazard/Warning	Electrical Cables
Not for use by under 16's	Electrical Shock Hazard	Wood
Do not look directly into Laser	Metal	Information

Product Feature Assessment Sheet

The Product Feature Analysis consisted of comparing pre and post interaction observations of product features. By observing the video-captured and verbal report data during the initial phase, it was possible to identify the features referenced by participants prior to interaction. After interaction participants indicated the features they were aware of on the product feature assessment sheet. A point was awarded for each identified feature which contributed to the pre and post interaction scores. This then indicated the additional features observed, understood, or learnt in conjunction with developments in warning icon understanding that were affects of interaction, and contributed to product overall understanding.

The total product features are listed below:

FRONT/SIDE FEATURES:	**REAR FEATURES:**
SIDE GRIPS, FAKE ALAN KEY BOLTS, BLACK & DECKER LOGO, LASERPLUS LOGO, 'VIEWFINDER AREA', SHOCK ICON, LED LIGHTS – DURING CALIBRATION & WHEN ELECTRICITY DETECTED, WEB ADDRESS, TOGGLE BUTTON, BLOCK/BEAM ICONS, DETECTION ZONE, DETECTOR BUTTON (PUSH & HOLD), LASER ON/OFF SLIDER CONTROL, LASER EMITTING ORIFICE S, LINES/BEAMS, BATTERY ICON, 'CALIBRATING' SQUARES, CALIBRATION 'TICK' (TOP), CALIBRATION 'TICK' (MID), WOOD BLOCK ICON (LCD), METAL BEAM ICON (LCD), ICON SELECTED INDICATOR, AUTO LEVELLING	DATE STAMP, FELT 'GLIDES' (3), BLACK & DECKER STICKER, HEX NUT HEADS, BATTERY COMPARTMENT COVER, LASER RADIATION STICKER, WARNING DON'T LOOK INTO BEAM, LASER, INFORMATION BOOK, NO UNDER 16's, PUSH-TOGETHER CATCHES **OTHER**: AUDIBLE NOISE (BEEP)

Appendix 12: SRK Classification Data

Age Group	Participant Number	Gender	% Skill-based Interaction	% Rule–based Interaction	% Knowledge-based Interaction	% Other Interaction	Instances of difficulty in physical movement or visual recognition	Features of Interaction	Instances of Knowledge-based Activity
16-25	8	1	45	26	14	15	3	Battery Polarity	34
	12	2	60	24	2	14		Push & Hold Button	5
	13	2	77	16	4	3		Grip Areas	1
	14	2	61	24	4	11		Felt Slides	1
	15	2	48	29	21	1		Laser Button	4
	16	2	26	24	30	20		Toggle Switch	4
	20	2	44	23	11	23		Toggle LCD Mode Display	2
	22	2	48	20	15	18		Graduated Display	5
	24	2	60	19	6	15		LED Illumination	1
	34	1	71	16	8	5		LCD 'tick'	1
								Compartment Cover Search	38
26-59	1	1	40	37	18	6	5	C'tment Cover Lug Search	4
	2	1	27	59	15	0		Hanging Tool Hole Search	8
	5	2	33	46	9	11		Hanging Tool Orientation	14
	6	2	37	28	18	17		Device–Tool-Jig Connection	14
	9	1	51	7	21	21			
	11	1	67	11	13	10			
	19	1	43	34	0	24			
	21	1	41	29	4	26			
	23	1	81	5	2	11			
	33	1	69	12	9	9			
60-80	3	2	8	76	4	12	11		
	4	2	32	30	28	9			
	7	1	28	22	19	31			
	17	2	37	13	21	29			
	18	1	47	14	13	26			
	27	2	50	21	25	4			
	28	2	41	26	12	21			
	29	1	45	25	12	19			
	30	2	60	26	9	5			
	32	2	45	25	11	19			