CAD Models as a Co-Design Tool For Older Users: A Pilot Study

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ABSTRACT
The UK population is ageing, and currently, the design needs of older adults are not being met. Increased older user participation is required in design. It is proposed that CAD (Computer Aided Design) and Rapid Prototyping (RP) models can be used as a tool to facilitate user involvement early in the design process. This paper explores the potential for a computer-aided participatory-design process for older adults. It questions older users' understanding of CAD models of products in terms of 'physical product properties' such as perceived size, weight, colour, surface properties and 'subjective attributes' such as perceived quality. It aims to establish how far older adults are able to understand CAD models shown on a computer screen. This work-in-progress paper discusses the current literature in relation to ageing and CAD, and goes on to describe the methodology for a pilot study, which forms part of the first stage of PhD research.

Keywords
Ageing, Computer Aided Design (CAD), Ergonomics, Design, Rapid Prototyping

INTRODUCTION
By 2020 half the UK adult population will be aged 50 or over [2] and this trend is shared by other EU countries. Globally, the number of people aged 60 years or over is expected to triple by 2050, increasing from 606 million currently to 2 billion [15].

With governmental policies encouraging a large proportion of the population to live independently for a longer period of time, it therefore makes commercial sense for manufacturers to produce products that are suitable for these users, as part of the mainstream design process.

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Design for a 'grey market' constitutes many of the opportunities for new product development, and coupled with advances in manufacturing technology, the potential market is continuously growing. The market can be extended further by taking an inclusive approach to the design of new products, whereby no part of the user population is excluded by inappropriate design. Adopting a 'design for all' approach ensures that the least able can use a product, thus maximizing the number of potential users. This approach also creates products which more able users may prefer to use.

Older users of modern products experience changing physical, psychomotor, sensory and cognitive capacities related to the ageing process. As such, they often require solutions, which are sensitive to their changing needs and extend their period of independence and social participation. To achieve this, it is desirable that older users play a role in the design of products they wish to use, thus informing designers of the problems associated with ageing. New product designs should be inspired by their intended users' habits, needs, environment and capacities relevant to the use of products [18]. UK designers already involve end users in design but this information is often provided too late in the design process when it is dfficult to solve problems [10].

The UK Foresight Manufacturing 2020 Panel final report recommended that manufacturers should focus on high value-added products and support research into more highly customised products [7]. Manufacturing products that are tailored to a specific user-group such as older adults fits both of these strategies. The technologies required to achieve these aims are becoming available in the form of more representative CAD models and rapid prototyping systems. There is therefore, a convergence of needs from the directions of the user, the designer and the manufacturer.

The focus of the research project is to evaluate the potential of designers collaborating with older adult users. This provides a mechanism for giving users a voice in the design process and an opportunity for the stakeholders in product development to meet, work with, and understand their users. The use of Computer-Aided Design (CAD) and three-dimensional physical modelling to produce appearance and functional models is proposed as a way to facilitate this.

This paper reports on a work in progress pilot study forming part of the first stage of PhD research. It builds upon previous work by the Loughborough team in the area of inclusive design [1].

LITERATURE

Who are 'Older People'?

The term 'elderly people' is no longer relevant, as this has the effect of setting apart a significant proportion of the population on the basis of age, even though that proportion can include two generations. As life expectancy extends and birth rates diminish, active life well into retirement is now the norm. The term 'elderly people' is therefore inappropriate when discussing people aged 50 to 100. The terms 'older people' and 'older adults' are the preferred vocabulary to use when referring to people who experience developmental changes after the age of 50.

Computer-Aided Participatory Design

The principle of participatory design is that the end user has an important contributing role in the development of products they will eventually use [11, 5]. In the literature there are a number of studies involving older users in design [4, 6], but these mainly involve group activities focusing on product evaluation rather than on design. Much of the current literature on participatory design deals with information systems, as opposed to the design of physical products [for example 9]. There is therefore an opening for research into the role that CAD, RP and customisation can play in the participatory design process of physical products. One study of users proposed that more systematic studies are needed into the variables specific to human perception. That is, how humans perceive images on a computer screen [20].

Few other studies have been found to address the issues of using 3D CAD modeling as a co-design tool with individual users. It has however, been claimed by Mitchell [14] that CAD has few advantages over 2D drawings on paper. An approach whereby designers generate designs as 2-dimensional drawings and have potential users comment on them was criticised as offering little scope for laypeople to understand them, thus having no meaningful input in the design process. The authors disagree with this viewpoint as representational CAD technologies have become increasingly advanced over recent years and offer considerable scope for involving users early in the design process. This is not to say that CAD models are going to replace drawings, cardboard mockups and other modeling media, but it is simply another representational tool available to the designer.

Mass Customisation

The participation of users in the design process is leading to an increasing customisation of products. Manufacturing industries are seeing manufacturing processes going back in time to a pre-Fordist paradigm where products were created individually by collaboration between the producer and the customer. Users are now able to participate in the design process by customising their products; internet technologies are advancing this phenomenon. Products may be customised by the user after production; for example, clip on mobile phone covers, or products may adapt to the user; such as intelligent systems in cars. Crayton [3] refers to these as 'soft customisation'. It is also possible for end-users to interact with the design and manufacturing process to alter the core design of the product, perhaps choosing from pre-defined, configured choices.

Computer Aided Design (CAD)

CAD and computer-aided-manufacture (CAM) are transforming design processes as well as the aesthetic nature of the products that can be created [16]. The design software used by designers has moved from being a tool to being an intelligent environment that can guide and inform the design process. If a 3D CAD-CAM system is used, then the modelling stage of the design process can be performed on the screen. Crayton [3] recognises that with suitable refinements, technologies available to designers can be put in the hands of non-designers such as end-users. This would allow users to configure, or co-design products by interacting with highly flexible manufacturing systems. CAD models would be the obvious interface.

Formats of CAD Models

CAD solid models evolve through various formats in a design process. For example, 3D CAD allows the designer to model the product in three dimensions rendered as either a solid form or a 'wire-frame' construction. These wire-frame models can be shaded grey to give them depth and form. Later in the process, the models can be rendered to represent actual colours and materials, shadows and reflections. The pilot study discussed in this report aims to test how far these display formats can be understood by older users.

Rapid Prototyping

Rapid Prototyping is the collective name given to a range of processes used to create actual size components using 3D

CAD data. RP is opening up new design opportunities due to reduced build times and product customization, and can be compared to 'printing out' an object in three dimensions, providing inexpensive tactile feedback to designers and users. Stereolithography is an example of such a process where lasers are used to build models from fine skeins of liquid resin, and can be ready in a matter of hours [16]. It is argued that the potential of RP is not how realistic the output is, but the speed in which the virtual computer world can be replicated in a physical model [21].

Sensory, Cognitive and Emotional Variables

In the context of this research, it is necessary to know how much older users can understand from a CAD model. By this, it is meant whether they can identify physical properties such as a product's size, weight, colour and surface properties and subjective attributes, such as perceived quality and product personality. To identify products, the sensory variables of vision and touch are used along with the subjective elements of user experience.

Physical information about products is perceived by one, or a combination of the five senses; the senses of vision and touch being the most commonly used. In the literature, there are many descriptions dealing with the changes that take place in the eye and the neural mechanisms as people grow older [8, 17]. The lens becomes thicker, more yellow and opaque, visual acuity and pupil size diminish, and there is a heightened sensitivity to glare. Spatial vision and motion perception also change, as the individual grows older.

In human-product interaction, touch is important for the ability to locate, manipulate and identify products manually. Touch supplies information about products that is not available to other senses, such as softness and temperature. Diminished tactile sensibility has been reported with increasing age [19]. The number of receptors in the fingertips decreases and their morphology changes, resulting in a loss of tactile sensitivity.

In addition to identifying physical properties, users also experience emotional attachments with products [12]. Properties such as enhancement of quality of life, status and cultural significance are assessed through user experience, aspirations, memory and familiarity.

METHODOLOGY

The methodology describes work in progress addressing how far older users can understand physical and subjective product properties from different formats of 3D models (CAD models and physical models). The broad objectives of the study are:

- To determine how far older users are able to identify a product and its physical and subjective properties from viewing a 3D CAD model of it on a computer screen.
- To establish which format of model older users most relate to, in terms of their physical and subjective product properties.
- To determine how older users perceive the realism of the CAD and rapid prototyped models when compared to the actual products they represent.
- To begin to establish the potential of involving older users as part of the designing process.
- To gain experience in conducting studies using older users, including the development of a common design vocabulary.
- To gain experience in producing models through the use of CAD and rapid prototyping technologies.

Sampling

Twelve participants, all over the age of 50 will be used in the study (6 males and 6 females). 6 of the participants will have had some previous experience of viewing computer graphics. Participants will be asked to wear the glasses or contact lenses that they would normally wear when viewing a computer screen. The participants will be recruited through contacts (staff and students) from Loughborough University.

Products and Modelling

Small hand tools for gardening (a garden fork and a pruning saw) have been selected for the pilot study because:

- There is an above-average participation in gardening in later life, which increases in importance as people grow older and have more free time [13].
- Gardening is an activity which people can continue to enjoy into old age and many of the products available are suitable for use by older or disabled users.
- Most people are familiar with the types of products used for gardening, even if they have never used them themselves.
- The products are relatively easy to model on a CAD system due to the small size and small number of moving parts.

3D solid modelling software called Pro Engineer is to be used to model the products. The CAD models will then be produced as physical models using rapid prototyping techniques (the particular technique will depend upon machine availability). This will allow participants to also evaluate 3D physical models; in contrast to viewing 3D models on a computer screen. Two versions of the rapid prototyped models will be used in the trials – one will be considered 'unfinished', as it will not be painted or polished. The other will be considered as 'finished' as it will be made to look as much like the actual product as possible; for example, painted, and filled inside to represent the correct weight.

Product Properties

The product properties, which will be the focus of the pilot study discussed in this report, are summarised in Figure 1. For each format of model, these properties will be used as the basis for data collection.

Physical Properties	Subjective Attributes
Function - What the product does	Quality
Size - The perceived size of the actual product	Cost
Weight - The perceived weight of the actual product	Personality
Surface Properties - Materials, texture, roughness, thermal qualities	Desirability, Status
Colour - The perceived colours of the actual product	Aesthetic appeal
Design Features - Specific features identifiable from the model on the screen	Previous use, familiarity and need

Figure 1. A summary of the product properties.

Data Collection

Semi-structured interviews (lasting a maximum of 2 hours) will be the main method of data collection. To maintain the richness of participants' responses, open-ended questioning will be used, guided by a set of core questions and issues to be explored. Prompts will be used to elicit more specific information. Figure 2 shows the different formats of CAD models to be tested. The participants are divided into two groups. Presentation of the products to Group A and B will be balanced to minimize any learning effect.

Model Formats	**Group A**	**Group B**
	Participants 1, 3, 5, 7, 9, 11	Participants 2, 4, 6, 8, 10, 12
2D orthographic line drawing	Fork Pruning saw	Pruning saw Fork
3D grey-shaded model	Fork Pruning saw	Pruning saw Fork
3D photo-realistic model	Fork Pruning saw	Pruning saw Fork
3D physical model (unfinished)	Fork Pruning saw	Pruning saw Fork
3D physical model (finished)	Fork Pruning saw	Pruning saw Fork

Figure 2. Presentation of model formats.

Trials Procedure

The trials are divided into 3 main parts:

1. Introduction interview to establish the participant's user profile, their previous computer experience and that they have suitable eyesight.

2. Identification of physical and subjective product properties from different formats of CAD and rapid prototyped models.

3. Ranking the realism of the product properties shown by the model formats against the actual products they represent.

Part 1

Questions are asked which build a socio-economic profile of the participant and they are asked about their previous computer experience. Two simple visual screening tests are performed to establish that the participant has suitable visual acuity and no colour deficiencies, which would affect what they see on a screen.

Part 2

Participants are shown the line drawing of the product (fork or pruning saw) on the computer screen. They are asked to describe what they can see. Prompts can be used to elicit more information, until as much information about the physical and subjective product properties has been collected. Reference props such as rulers, weights and material samples are available to be handled to assist the participants in describing size, weight and surface properties. Once as much detail as possible has been collected, the next format of CAD model (grey shaded) is shown on the computer screen and participants are prompted using the product properties (Figure 1). The process is then repeated for the fully rendered CAD model and the unfinished and finished 3D physical models. When all the questions for the first product are completed, the same questions are then asked of the second product (pruning saw or fork). To capture participants' subjective views on the products, they are asked to describe the product by imagining it is a real person. The investigator will use appropriate prompts to elicit this information. The trials will be video recorded in order to capture the participants' responses and body language.

Part 3
Participants are shown the 5 representations of each of the products as paper printouts. They are asked to consider each of the properties of Function, Weight, Materials, Size, Usability (ease-of-use) and Quality in turn and rank the images in order of which one gives them most information about that particular property. The product representations will be ranked accordingly.

Closure
The trial will close with a brief structured interview to confirm how the participants felt about the trial and if they experienced any difficulty viewing or handling the models.

CONCLUDING REMARKS

The need to involve older users in the design process has been discussed. 3D CAD and rapid prototyped models have been identified as possible tools to achieve this, but first, it must be established how far older users are able to understand CAD models. The study discussed in this paper aims to determine if older users are able to identify a product and its physical and subjective properties from viewing a 3D CAD model of it on a computer screen and to ascertain which format of model allows older users to identify the most product properties.

The authors expect to find that fully rendered CAD models and finished rapid prototyped models will allow older users to report the most product properties. It is thought that 2D line drawings will provide the least amount of information about product properties. It will be interesting to see how older users perceive grey-shaded CAD and unfinished rapid-prototyped models. The trials will take place in May-June 2002, and preliminary results will be reported at the conference.

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