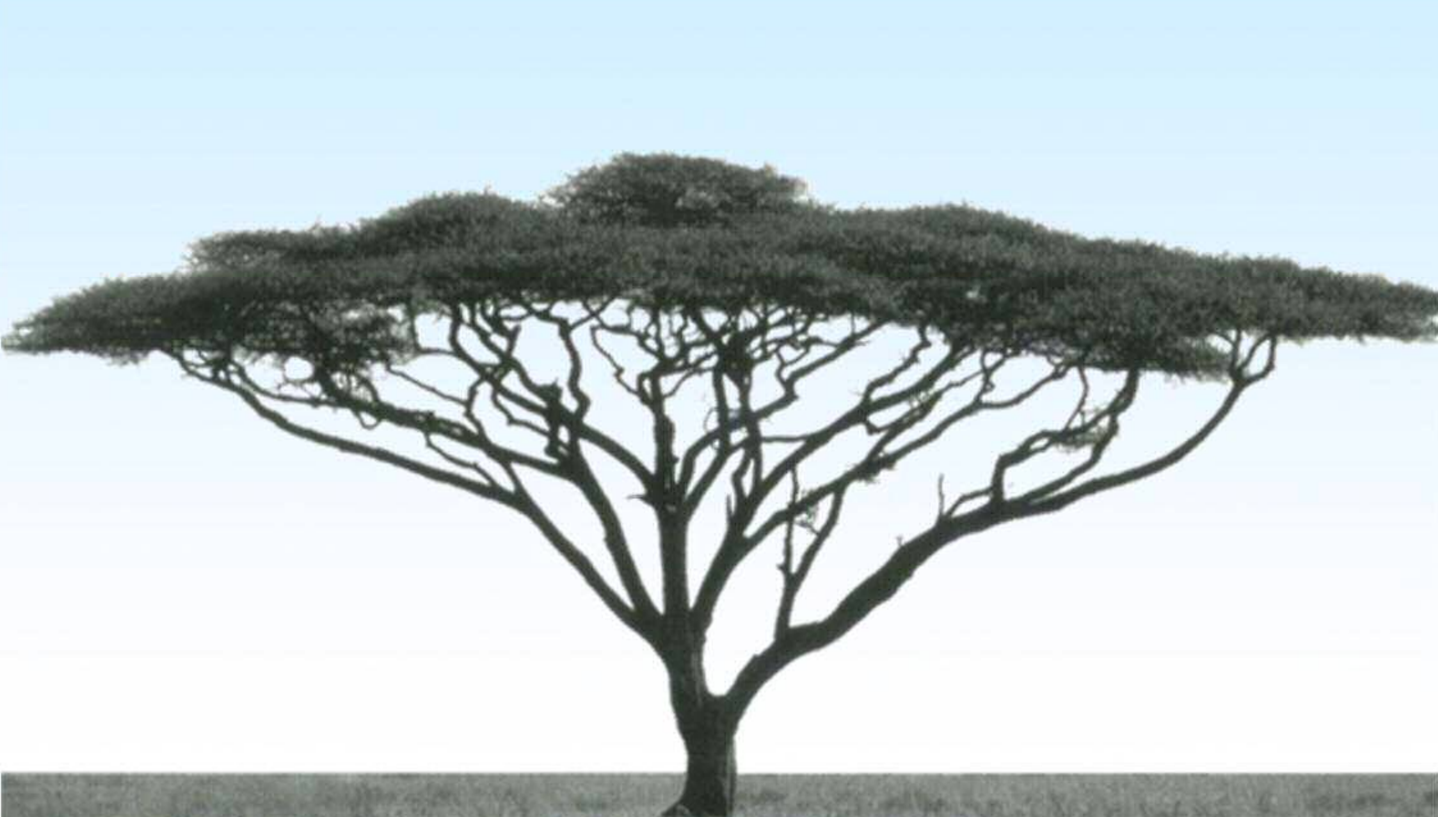

International Journal of Design Sciences & Technology

Volume 20 Number 1

Blackler A, Popovic V and Mahar D (2014) Applying and testing design for intuitive interaction, *International Journal of Design Sciences and Technology*, 20:1, pp 7-26

ISSN 1630 - 7267

europia

ISSN 1630 - 7267

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International Journal of
Design Sciences and Technology

Volume 20 Number 1

ISSN 1630 - 7267

International Journal of **Design Sciences and Technology**

Applying and testing design for intuitive interaction

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Various tools have been developed to assist designers in making interfaces easier to use although none yet offer a complete solution. Through previous work we have established that intuitive interaction is based on past experience. From this we have developed theory around intuitive interaction, a continuum and a conceptual tool for intuitive use. We then trialled our tool. Firstly, one designer used the tool to design a camera. Secondly, seven groups of postgraduate students re-designed various products using our tool. We then chose one of these - a microwave – and prototyped the new and original microwave interfaces on a touchscreen. We tested them on three different age groups. We found that the new design was more intuitive and rated by participants as more familiar. Therefore, design interventions based on our intuitive interaction theory can work. Work is ongoing to develop the tool further.

Keywords: *design tools, human factors, interface design, intuitive interaction*

1 Introduction

We have spent the past 12 years investigating the role of intuitive interaction in the way that people operate devices, and how intuitive interaction can be applied in the design process to allow for more intuitive interfaces. Intuition is a type of cognitive processing that is often non-conscious and is based on prior knowledge. Intuitive interaction involves the use of knowledge gained from other products and/or experiences [11]. Therefore, products that people use intuitively are those with features, functions and/or processes that they have encountered before.

This definition has been supported by several experimental studies, in which we found that prior experience with products employing similar features helped participants to complete set tasks with novel interfaces more quickly, accurately and intuitively, and that familiar features were intuitively used more often than unfamiliar ones [5, 11]. We applied Technology Familiarity (TF) as a measure of prior experience. It was measured through a questionnaire, in which participants provided details of their experience with relevant products that have similar features to those they would encounter during the experiment. More frequent and more extensive use of the products in the questionnaire produced a higher TF score, which correlated with more intuitive uses, faster times to complete set tasks, more correct uses and less errors. We also found that older people were significantly slower at completing the tasks and had significantly fewer intuitive uses [5, 11]. From our empirical research, we developed three principles of intuitive interaction to guide designers in designing for intuitive interaction [5]:

1 Use familiar features from the same domain. Make function, appearance and location familiar for features that are already known. Use familiar symbols and/or words, put them in a familiar or expected position and make the function comparable with similar functions users have seen before.

2 Transfer familiar things from other domains. Make it obvious what less well-known functions will do by using familiar things to demonstrate their function. Again use familiar function, appearance and location.
3 Apply redundancy and internal consistency. Providing as many options as possible will enable more people to use the interface intuitively. Increase the consistency within the interface so that function, appearance and location of features are consistent between different parts of the design and on every page, screen, part and/or mode.

We developed a continuum based on the principles and related theories (Figure 1). The lower or left side of the continuum relates to Principle 1 while the higher or right side relates to Principle 2. The continuum starts at the lower (left) end with the simplest form of intuitive interaction; body reflectors [13], which are based on embodied knowledge learned so early that it seems almost innate. Bush [13] described body reflectors as products or parts that resemble or mirror the body because they come into close contact with it, e.g. headsets, glasses, shoes, gloves or handles. Bush claimed that it is not necessary to be familiar with a body reflector in order to ascertain its relation to a person; these forms are self-evident. Any person would be able to make the association whether familiar with similar things or not.

Figure 1 Continuum of Intuitive Interaction [5]

At a slightly more complex level, intuitive interaction employs population stereotypes which are engrained from an early age. Humans have assimilated a large number of arbitrary, unnatural mappings from the world around them which they apply easily because they have used them from a young age [31, 32]. For example, clockwise movement for progression or increase, and colour codes such as red for stop and green for go. These stereotypes are conventions that are well known by whole populations and so can be widely applied.

At the next level again intuitive interaction can be applied through similar features from the same or differing domains. Our three initial experiments were based on the differentiation of familiar and unfamiliar features, applied from both similar and differing domains. All these experiments showed that familiarity with a feature will allow a person to use it more quickly and intuitively [5].

At its most complex, intuitive interaction requires the application of metaphor, used to explain a completely new concept or function. Metaphors are grounded in experience and allow people to transfer knowledge between domains. The desktop metaphor is a good example [34, 39].

Affordances [19] have been much popularised [e.g. 31] and have been used to describe both physical and virtual interface objects [35], which became confusing for designers and researchers alike. Therefore, Norman [33] tried to clarify the situation by talking about perceived and real affordances. Physical objects have real affordances, like grasping, that are perceptually obvious and do not have to be learned. We therefore see the physical affordance as being equivalent to and have placed it on the continuum below the body reflector [13]: a very basic and easy to perceive fit with a part of the body, which people know and understand because of their lifelong experience of embodiment. Perceived affordances are essentially learned conventions. Perceived affordance has therefore been placed on the continuum as being equivalent to both population stereotypes and familiar features. Further discussion of the continuum and how it compares to another intuitive interaction continuum can be found in Blackler and Hurtienne [6].

1.1 Conceptual Tool for Designing for Intuitive Interaction

Based on the principles and the continuum, we developed a conceptual tool to assist in designing for intuitive interaction (Figure 2), which applies our continuum to the design process. The continuum (in a vertical orientation) is juxtaposed with an iterative spiral, which represents a design process with a variety of entry and exit points.

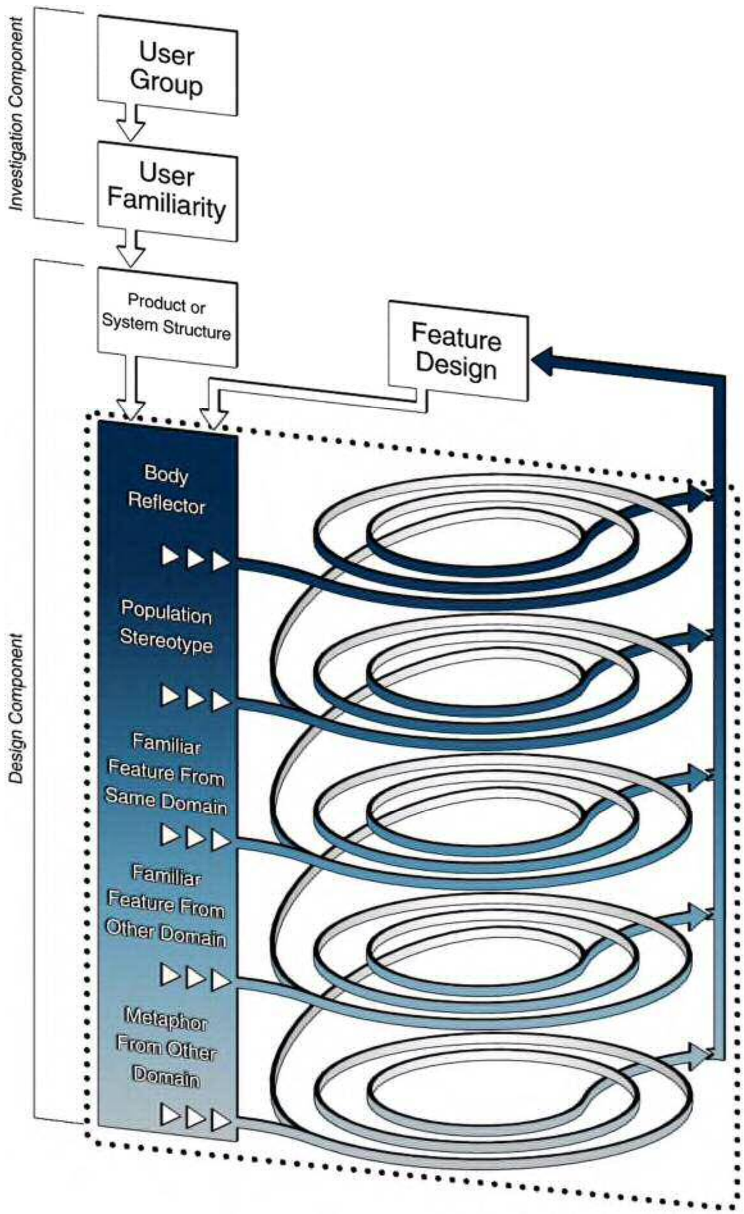

Figure 2 Conceptual tool for applying intuitive interaction during the design process [5]

Each loop of the spiral has three layers (Figure 3). These layers represent three factors which form the design of each feature (*i*) function, (*ii*) appearance and (*iii*) location. They are placed like this so that function is tackled first, then appearance and finally location. This order of priority was established through our previous research, which suggested that appearance of a feature was more influential in supporting accurate and intuitive use than location [5]. However, function was placed first as it is difficult to design appearance or location for a feature which has no assigned function.

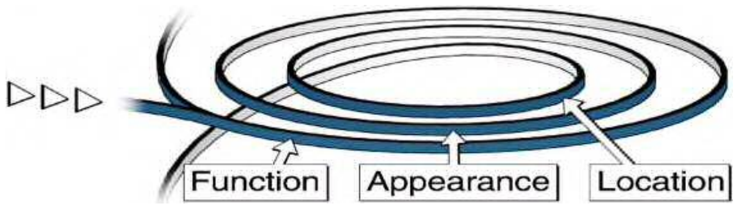

Figure 3 Order of addressing factors of feature design

Since Principles 1 and 2 are incorporated into the continuum, consistency and redundancy (Principle 3) are represented as a dotted line surrounding the spiral, as they should be considered at all times during the design process. This could mean, for example, that if the function of the feature requires a metaphor, that metaphor is also applied to the appearance and location of that feature, so that the metaphor remains consistent.

As indicated at the top of the diagram, before starting design, designers need to establish who the users are and what they are already familiar with so that they know what stereotypes, features or metaphors would be suitable to apply. We called this part the investigation component. Designers then need to go through the spiral twice. Firstly the structure or form of the system or product needs to be established. Then the spiral is entered a second time for the detailed design of each feature. We called this part the design component. Having described our own conceptual tool, we now offer a brief review of other design methods and tools which relate to intuitive interaction or to parts of our continuum.

1.2 Design Methods and Tools for Intuitive Interaction

Lim and Sato [24] provided a method which they call the “design information framework” (DIF) for applying scenarios to the design process. DIF was developed to enable designers to organise and manipulate information during the design process. DIF encourages designers to focus on various “aspects” of the situation, for example spatial, operational, different actors. This is laudable but the framework itself is complex and does not appear easy to use. It relies on reducing the situation and its aspects and actors to parts of a formula, which is then used to create flowcharts and spatial maps. Lim and Sato [24] suggest that the DIF can be used to create spatial layouts, Hierarchical Task Analyses, and other models, which should be used to create scenarios that designers can use in the design process. This tool unfortunately does not give designers the first steps (e.g. help in conducting observations and investigating the context or situation), or the last steps (applying the scenario to a new design). It forms only a middle step.

Hsiao, et al. [21] created an online affordance evaluation model to be used to evaluate products and/or prototypes for inclusion of clear affordances. The authors aimed to improve intuitiveness of products, so their tool has a similar aim to ours, especially as they used an affordance approach, which ties in with our continuum. Closely based on theory of affordances [e.g. 19, 33], their tool allows designers to get feedback on the appearance, responsiveness and clarity of affordances included in products. Hsiao, et al. [21] described how the tool has been tested with users and used to evaluate and redesign an iron. The tool appears to work, but the example used (steam iron) is unfortunate as it would seem that online evaluation of such a product will never provide enough information about physical affordances. This tool could work much more reliably in the evaluation of software interfaces and smart touch screen devices (containing perceived affordances).

Mudd and Karsh [26] developed a population stereotype approach for US and Allied armies to standardise some vehicle symbols and alleviate misunderstanding in international arenas (e.g. NATO postings). Their methods involved first identifying and categorising possible existing candidates for stereotype symbols, then showing them to potential users and asking for a "free-response" in order to find stereotyped meanings. Then, users from various armies were asked to sketch 34 possible control symbols based on their names and functions. The data from the free response and the sketching exercise were then analysed using categorisation and ranking to obtain possible population stereotypes. Mudd and Karsh claimed that in most cases the existence of stereotypes was revealed. However, they stressed that is it essential to use a truly representative sample population for this sort of exercise, and that developed symbols should then be subjected to testing on a different set of participants.

Chong, et al. [14] used a similar population-stereotype production technique to gather drivers' suggestions for symbols for both familiar and new vehicle functions. Participants were asked to sketch ideas for 14 function symbols. They found that the symbol production task identified useful and interesting ideas for symbols, which designers alone may not have generated, although these were obviously in need of refinement and testing. Ng, et al. [27] discussed a similar stereotype production method applied to public symbols. They found that symbols could be sketched by participants of all ages and levels of education and experience for both familiar and unfamiliar referents without too much difficulty. They claimed that the involvement of users at an early stage of symbol design increases chances of resulting symbols being understood.

Mieczakowski, et al. [25] developed the GABO (Goals, Actions, Beliefs, Objects) approach, which aims to discover the mental models of designers and users with the intention of aligning them better. They stated that one of their aims in doing this was to enable intuitive interaction. They based their understanding of intuitive interaction on our previous work [11], so their tool is largely intended to discover user familiarity. However, the GABO model does not through its structure or processes make intuitive interaction theory clear to designers who use it. Mieczakowski, et al. [25] reported a trial of the GABO approach using engineers, industrial designers and users to simulate the process of investigating users' and designers' models of a complex toaster. The results showed that designers' and users' mental models of the toaster agreed by only 41% for presence of "nodes" (actions or functions of the toaster) and just 36% for connections between nodes. This highlights the need for design tools which really allow designers to understand users rather than making assumptions about them.

A further trial involved designers using the GABO approach to re-design a household product. The eight designers in Mieczakowski, et al.'s trial scored usefulness of the GABO approach at 5.5 out of 7, and ease of use at 4.3 out of 7 [25]. The GABO approach appears to be useful for designers but not easy to use itself. Also, although investigating how users understand and use product features and creating users' mental models is one of its stated purposes, it lacks concrete investigation methods for eliciting user knowledge. In the trials mentioned by Mieczakowski, et al. observation was used, but no mention was made of coding tools to allow raw data from observations to be translated into users' mental models. In addition, there are as yet no tools provided for translating the mental models into a new design.

These methods and tools have promise for understanding and applying the experience and knowledge of real users to new interfaces. However, none of these approaches offer a theoretical or design process framework to guide designers in both investigating and applying users' prior knowledge to the design of new products and interfaces, although the GABO approach appears to be working towards this. In addition, there is evidence to suggest that uptake of tools intended to improve inclusivity of designs tends to be poor since the structure of the tools does not match the way designers work and understanding of how people understand and use everyday products is given low priority by many companies [25]. Our tool aimed to provide a complete solution based on the design process in order to address these issues. We conducted testing with it in order to evaluate how well it fulfilled this aim. We conducted two trials, which are discussed in the following sections.

2 Trials of the Conceptual Tool

Our conceptual tool (Figure 2) was trialled in order to answer the research questions:

- How useful is it in improving the design process?
- How effective is it at making interfaces more intuitive to use?
- How usable is it to apply to the design process?

2.1 Trial One

An undergraduate industrial designer was asked to design a digital camera using the tool. He designed the form and the interaction of the camera, including all the menu functions. The designer found that the tool forced him to spend a great deal more time investigating and analyzing the intended users than he would otherwise. It encouraged him to gain an understanding of information related to other products that the user group would already be experienced with. By looking at the other products that the intended user group interacted with, the designer was able to include key aspects of products they would already be familiar with, to enable the new design to be used more intuitively. However, despite having successfully produced a new design, this designer felt that the significance of the investigation component at the start of the process was not conveyed by the tool in its existing form (Figure 2). This trial is discussed in more depth elsewhere [9].

2.2 Trial Two

This trial was embedded into a postgraduate unit called "Advanced Ergonomics" as an optional part of the main project, which was a team project involving the re-design of an existing consumer product. The tool was applied by seven groups of designers, as their chosen methodology for the re-design project. They had more information and support for the investigation phase than during Trial One. The "user group" and "user familiarity" elements in the investigation component (Figure 2) were extrapolated with the use of suggested questions. Students were also provided with suggestions for how to answer these questions (e.g. relevant investigation methods, suitable library searches), and mentored weekly.

Methods the student groups used to investigate the user group and user familiarity included literature searches, product reviews, questionnaires, and recognition exercises to identify best icons/symbols. Literature search was fairly basic and based on recommended sources for demographic and market data. Some students found useful information but this was probably the most difficult data to find as so much market research is not in the public domain. Most questionnaires used were based on the Technology Familiarity questionnaire, which was originally designed to elicit information about experiment participants' use of various features of products [5, 8]. It adapted well to this task and students often got useful information from this kind of exercise. Using this kind of questionnaire before a product review helped students to establish which products might be suitable to review.

Most of the groups produced successful designs, with some particularly thorough. There were good examples of re-designs of products to make them more intuitive without changing the basic method of interaction, as well as some which were more innovative new products which were designed to be intuitive [10].

Students were asked to fill in a questionnaire at the end of the semester to evaluate the tool. There were 17 responses. Overall, effectiveness of the tool in making their new design intuitive to use was rated at a mean of 5.05 out of 6. The main body of the questionnaire was split into two sections; investigation and design process components of the tool (Figure 2). The investigation component covered the user group and user familiarity steps, while the design process component included the spiral section with the continuum alongside. The questionnaire ended with two more general questions.

A large proportion (82%) believed the investigation component of the tool made them do investigations they would not normally have done as part of the design process, and usefulness of information found through this process was rated at mean 4.52 out of 6. The tool has proven to be instrumental in helping designers to find useful information about users that they would not otherwise gather. An open ended question asked for any other comments or feedback on this component of the tool. Not many responded but some comments indicated that this component was difficult to understand at first, and that the technology familiarity questionnaire was useful although limited to the products chosen to go into it.

Usefulness of design process component scored a mean 4.58 out of 6, but ease of understanding the design process component scored lower at mean 3.79 out of 6. How easy it was to follow as part of the design process scored 4.2 out of 6, and how useful it was in applying the information they had researched scored 4.58 out of 6. The two layers in the design process (structure and features) scored 4.1 out of 6 for usefulness. The majority of students (58.8%) got confused or lost at some point in this component. Reasons for this included; not understanding the tool at first, difficulty understanding and remembering the five levels from the continuum (Figures 1 and 2), clarity of what needs to be done at each level, and need for examples for each level. The open ended question for this component elicited comments such as: I keep forgetting what the three layers (Figure 3) are; I do not go consciously through all layers for every feature; good for keeping structure and consistency in testing; I still find it difficult to understand; and it is easy to follow in design process as long as it is understood.

The student feedback shows some similarities with the feedback received by the GABO team [28]. Although our ratings were higher, our tool also appears to be more useful than it is usable and will need refinement in order to operate as a stand-alone tool for designers in industry to use, without the support that we provided to students during the trial. The investigation and design processes used by the students, examples of their work and more detailed results of their subjective feedback are discussed in detail by Blackler et al. [10].

Microwave Design

Most of the groups produced successful designs, with some particularly thorough. The microwave group followed the tool closely, and came up with an innovative new design. The conventional microwave worked in a similar way to most domestic microwave ovens (Figure 4). The re-designed microwave (Figure 5) offered a solution soundly based on the principles and tool for intuitive interaction.

Figure 4 Conventional microwave interface

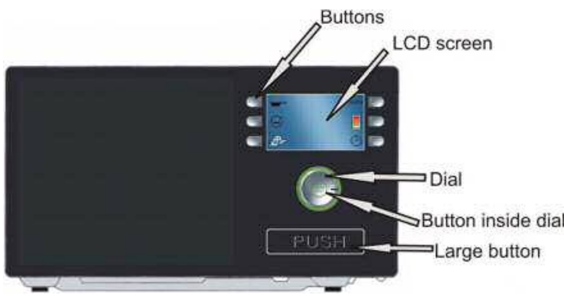

Figure 5 Re-designed microwave interface

These students discovered that microwave users are extremely diverse. They developed a TF-type questionnaire to find products that were commonly used in the everyday lives of 34 microwave users aged 14-69; stove tops, refrigerators, ATMs, Mp3/music players, and televisions. The group then used card sorting with potential users to specifically identify population stereotypes and familiar features for the interactive display on the microwave. Significant changes in this area were changing the power level ‘lightning bolt’ symbol to a coloured bar like that of a battery life symbol, and a change from the standard snowflake to an image of an ice-cube melting for “defrost” (Figures 4 and 6).

Figure 6 Chosen icons

The deeper (nested) menu and use of soft keys allowed more detailed information to be displayed, therefore helping to identify the function and use of each option (Figure 7). This soft key and screen combination was transferred from an ATM interface. The dial (Figure 6) was designed to comply with the population stereotype of clockwise to increase and red for stop green for go. The dial incorporated a central button with coloured lights to help the user understand what needs to be done next. The green “START” light illuminated only when enough information had been entered for cooking to start. The red “STOP” light illuminated when the user could stop or pause cooking.

Figure 7 Example sub-menu

The students’ observations with users and paper prototypes suggested that the new microwave was more intuitive to use than the original, and the students believed that the tool was a success in assisting them with the re-design [10].

3 Experimentation Methodology

An experiment was devised to compare the re-designed microwave interface with the conventional microwave interface. Other researchers have taken similar approaches to testing a single interface designed using their tools and methods against a commercial version of the same interface to see if they led to improved designs which were easier to use [25, 30]. There were two research questions which we aimed to answer with this experiment:

- Was the tool effective in facilitating the design of a more intuitive microwave interface?
- How does ageing affect intuitive interaction?

As this paper is focused on the efficacy of design interventions using the tool in facilitating intuitive interaction, it will discuss in detail only the results from research question 1.

3.1 Prototype Development

The re-designed and existing microwave interfaces were both prototyped on a touchscreen. The process of prototyping is discussed in depth elsewhere [4]. Our touchscreen prototypes were relatively high fidelity, and appeared to be very credible for participants, although there were some significant differences between them and a real microwave, which created some challenges.
These prototypes were made on MS PowerPoint. They were "vertical prototypes" – high-fidelity prototypes of a subset of the functions [36]. Using a 19” touchscreen, the prototypes were approximately half size. Therefore, the control panel on the conventional microwave and the dial on the re-designed one were increased in size so that they were proportionally bigger than the rest of the microwave (Figure 5 vs. Figure 8). Therefore, participants could easily see and use the controls.

Figure 8 Re-designed microwave prototype in use

The major issue with the prototypes was the two dimensional representation and use of features which in the real world would be three dimensional. The re-designed interface was particularly problematic as it involved the three dimensional dial. This problem was addressed through six strategies:

- The dial was developed with a reference line on it and participants touched next to the line in the direction they wanted the dial to move. It was not possible to get it to scroll around.
- The task times in the results were altered to allow for differences between the 2D dial on the touchscreen and a real 3D dial. This was to prevent any unrealistic difference in the times taken to do the tasks on the conventional and re-designed microwave interfaces, as entering the time into the keypad on the touchscreen took no more time than on a real microwave, but using the touchscreen dial was slower than using a real dial. The time it would take to turn a real dial was calculated using averaged times to do equivalent tasks with a variety of real dials.
- A warm-up task with a safe interface (Figure 9) was developed (also on PowerPoint) to familiarise participants with using the 3D features such as dials and microwave oven doors on a 2D interface. It was also a practice with the vertically orientated touchscreen. The safe task was designed to introduce participants to equivalent types of interaction without giving them clues about how the microwave interfaces might operate.
- 3D cardboard models were used in addition to the touchscreen prototypes (Figure 10). These included details such as raised buttons and a moving dial. Participants were encouraged to refer to and handle these models throughout the experiment.
- Labelled pictures with each feature named were provided as further support (Figure 5). Sauer et al. [38] found that enhanced labelling decreased the detrimental effects of lower fidelity.
- Each time participants touched the screen they received audio feedback (a beep) to replace the tactile feedback they would get from a real interface.

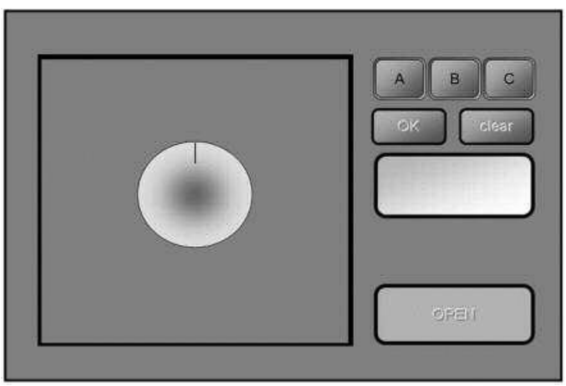

Figure 9 Safe interface

Figure 10 Cardboard model of re-designed microwave

3.2 Experiment Design

The experiment involved participants doing set tasks with one or other of the microwave interfaces while delivering concurrent (think aloud) protocol. This was a matched subjects 2x3 experiment design. Independent Variables (IVs) were age group and microwave interface and Dependent Variables (DVs) were time to complete tasks, mean feature familiarity rating, percentage of correct intuitive uses, and percentage of overall correct uses. This paper will report all the results due to the constraints of the 2x3 experiment design and in order to keep the overall picture clear. However, the discussion will focus on the comparison of the two interfaces in order to evaluate the tool. The age differences have been discussed elsewhere [7].

3.3 Participants

Participants were recruited from university staff and students, employees of local businesses, and a club for retirees. There were 36 participants, 18 in each microwave group and 12 in each age group. Age groups were Younger (Age range 20-39, Mean 29.08, SD 5.87), Middle (Age range 40-56, Mean 47.67, SD 3.31) and Older (Age range 57-74, Mean 63.17, SD 5.37). Participants were matched for highest educational qualification, gender and Technology Familiarity (TF) to ensure balance between the groups.

3.4 Apparatus and Instruments

A TF questionnaire was employed as part of the recruitment process, and the resulting TF score was used in the process of matching the participants in each group. The hypothetical minimum TF score was 0 and the maximum was 70.

Participants were asked to do set tasks with the microwave interface whilst delivering concurrent (think aloud) protocol. They were video and audio recorded using two ceiling mounted Canon VC–C50iR cameras and ceiling mounted Shure microphones. The equipment was controlled by the researcher from a separate booth. The participants interacted with the prototypes though a 19” touchscreen attached to a PC. Participants also had the labelled diagram and the 3D model of the relevant microwave to refer to during the experiment.

Rating scales (from 1-6) were utilised during the post task interview to rate familiarity of each feature that the participant had used during the tasks. Ratings were used to create the mean feature familiarity ratings.

3.5 Procedure

All experiments took place in an air-conditioned laboratory. Participants were first welcomed to the room and were given an information package and consent form. Then all the equipment to be used and the tasks to be performed were explained using a pre-determined script. The participants were asked to complete three tasks using one of the touchscreen microwave prototypes:

The time is 12.30 and you have a pre-prepared 500g frozen burger which you want to eat for lunch. You are going to prepare it using the microwave.

- Put the burger into the microwave. Defrost it.
- The burger needs to "stand" for 2 minutes and 30 seconds after defrosting. Set the kitchen timer so that the microwave times this standing time (without cooking).
- Now you are ready to cook your meal. Cook at medium power for 3 minutes and 30 seconds. Then remove the burger to eat it.

Participants were able to refer back to the tasks throughout the experiment as they were displayed on a document holder next to the touchscreen. They delivered concurrent (think aloud) protocol while they performed the tasks. They then completed a semi-structured interview during which they rated each feature they used on the prototype for familiarity on a scale of 1(low) to 6 (high).

3.6 Dependent Variables

Using the audio-visual data collected, every feature use for all participants was coded with Noldus Observer and later exported into SPSS (Statistical Package for the Social Sciences) for full statistical analysis.

Time to complete tasks is an important variable for measuring intuitive interaction, as intuitive interaction is rapid since it is generally correct, and also because it is a fast, non-conscious process that does not require reasoning [6]. This was simple to code using the Observer start and stop event function.

A "correct" feature use was taken to be one that was correct for the feature and also correct for the task or subtask at the moment of use. A "correct-but-inappropriate" use was one that was correct for the feature but not for the task or subtask. "Incorrect" uses were wrong for both the feature and the task or subtask and "attempts" were uses that did not register with the product, for example due to failure to activate a button on the touch screen.

The definition of intuitive use formulated for the purposes of this research states that intuitive use involves utilising knowledge gained through other experience(s), is fast and can be non-conscious. The coding scheme employed for this research assumed that various levels of cognitive processing occur during one task [3], and was designed to distinguish intuitive processing from other processes (such as fully automatic and fully conscious processes). "Intuitive use" codes were applied cautiously, only when the feature use showed two or more of these characteristics and the researcher was certain about the type of use. Any feature uses about which there was doubt were not coded as "intuitive". The main indicators of intuitive feature uses that were employed to make the decisions about types of use during the coding process are explained below.

Evidence of conscious reasoning

Since intuitive processing does not involve conscious reasoning or analysis [1, 2, 18, 20, 30], the less reasoning was evident for each use, the more likely it was that intuitive processing was happening. Commonly, participants processing intuitively would not verbalise the details of their reasoning. They may briefly verbalise a whole sub-task rather than all the steps involved; or they would start to press a button and then stop to explain what they were about to do; or perform the function and then explain it afterwards. Their verbalisation was not in time with their actions if they were processing

Expectation

Intuition is based on prior experience and therefore linked to expectations [16, 22]. If a participant clearly had an established expectation that a feature would perform a certain function when s/he activated it, s/he could be using intuition.

Subjective certainty of correctness

Researchers have suggested that intuition is accompanied by confidence in a decision or certainty of correctness [2, 20], and degree of confidence has been used in some experimental situations as an index of intuition [17, 40]. Those uses coded as intuitive were those that participants seemed certain about, not those where they were just trying a feature out.

Latency

When users were able to locate and use a feature reasonably quickly, it could be coded as intuitive. Intuition is generally fast [1, 2, 20, 37], and time to make a move can be used to measure thinking time [15]. If a participant had already spent some time exploring other features before hitting upon the correct one, that use was unlikely to be intuitive. Those uses coded as intuitive involved the participants using the right feature with no more than five seconds hesitation, commonly closer to one or two seconds.

Relevant past experience

Participants would sometimes mention during concurrent protocol that a feature was like one they had used before, or that they had seen a feature before, showing evidence of their existing knowledge.

4 Results

A t test showed no significant differences between males and females for the DVs time to complete tasks, $t(34)=-.456$, $p>.05$, intuitive correct uses, $t(34)=.767$, $p>.05$, or overall correct uses, $t(34)=.547$, $p>.05$. A one-way ANOVA also showed no significant differences between levels of education for time to complete tasks, $F(3,32 =1.064$, $p>.05$, intuitive correct uses, $F(3,32)=.269$, $p>.05$, or overall correct uses, $F(3,32)=.18$, $p>.05$. A two way ANOVA showed no significant differences in TF score between the microwave groups, $F(3,32)=1.47$, $p>.05$, or the age groups, $F(3,32)=1.305$, $p>.05$. This confirms that the groups were successfully balanced through the participant matching process. TF showed very strong positive correlations with the DVs intuitive correct uses, $r(35)=.650$, $p<.001$ and overall correct uses, $r(35)=.560$, $p<.001$, and a very strong negative correlation with time to complete tasks, $r(35)= -.601$, $p<.001$ (Figure 11). These correlations concur with findings from our previous work [5].

A 2 way ANOVA revealed significant differences between microwave groups for correct intuitive uses, $F(3,32)=4.882$, $p<.05$, and mean familiarity rating, $F(3,32)=13.329$, $p<.01$, and between age groups for correct intuitive uses, $F(3,32)=8.727$, $p<.01$, overall correct uses, $F(3,32)=6.541$, $p<.01$ and time to complete tasks, $F(3,32)=5.696$, $p<.01$ (Figures 12-15). There were no significant differences between microwave groups for time to complete tasks, $F(3,32)=.055$, $p>.05$, or overall correct uses, $F(3,32)=1.056$, $p>.01$ Means and standard deviations can be found in Table 1.

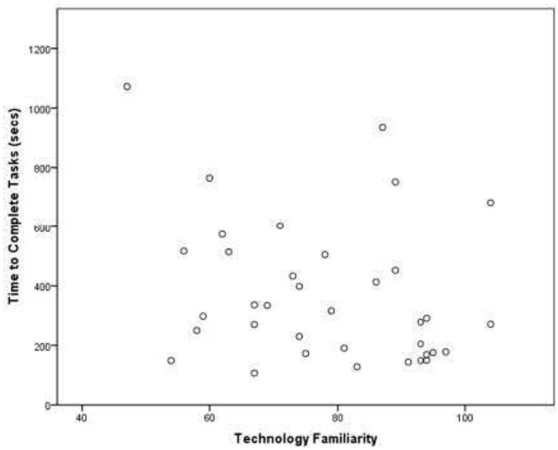

Figure 11 Time to complete tasks and Technology Familiarity

Table 1 Descriptive statistics

New Microwave								
Age Groups	Young		Middle		Older		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Time on tasks	258.50	73.13	330.33	159.04	502.92	190.55	363.92	175.59
% Correct uses	76.67	17.7	71.93	16.87	53.57	4.5	67.39	16.94
% Intuitive uses	77.83	15.01	68.69	13.9	56.12	6.91	67.55	14.87
Familiarity score	5.48	.19	5.6	.31	5.48	.33	5.52	.27
Conventional Microwave								
Age Groups	Young		Middle		Older		Total	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Time on tasks	202.67	154.11	383.00	162.16	557.08	410.67	380.92	294.09
% Correct uses	83.91	25.74	47.48	23.83	50.42	22.5	60.6	28.28
% Intuitive uses	79.46	21.88	42.75	24.63	38.31	25.07	53.50	29.4
Familiarity score	5.05	.35	4.90	.56	5.26	.40	5.06	.45

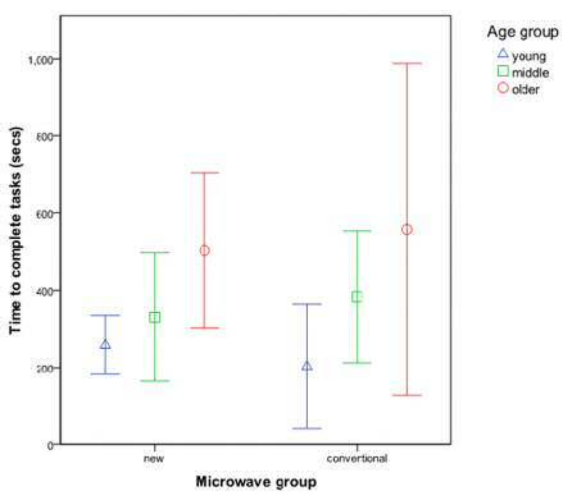

Figure 12 Time to complete tasks by microwave group and age group

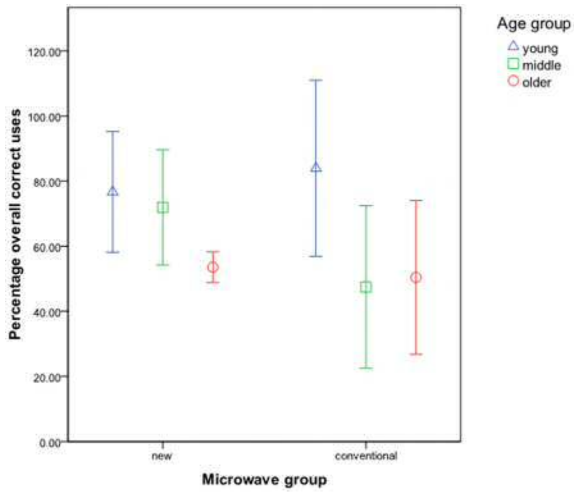

Figure 13 Overall correct uses by microwave group and age group

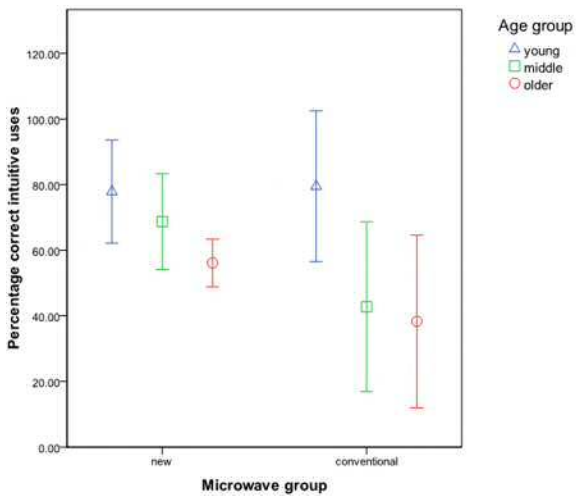

Figure 14 Overall correct intuitive uses by microwave group and age group

The new microwave group showed significantly more correct intuitive uses and significantly higher familiarity scores than the conventional microwave group. Tukey post hoc tests showed that the young age group was significantly faster to complete the tasks than the older age group ($p<.05$), while the young age group had a significantly higher percentage of both intuitive correct uses and overall correct uses than both the middle and the older age groups ($p<.05$).

There were no interactions between age groups and microwave groups for time to complete tasks, $F(3,32)=.251$, $p>.05$, correct intuitive uses, $F(3,32)=1.656$, $p>.05$, overall correct uses, $F(3,32)=1.995$, $p>.05$, or mean familiarity score , $F(3,32)=1.31$, $p>.05$

The three features which were considered to be the most directly comparable on the conventional and re-designed (new) interfaces were compared in detail. These were:

- start (conventional) and start/stop (new)
- power level (both microwaves)
- defrost (both microwaves)

A t test revealed that the re-designed start/stop had significantly more overall correct uses than the conventional “stop”, $t(34)=2.353$, $p<.05$. Similarly, the re-designed (melting ice) defrost icon scored significantly more intuitive correct uses than the conventional (snowflake) one, $t(34)= 2.146$, $p<.05$. However, the conventional power level (lightning bolt) symbol scored significantly more intuitive uses than the re-designed power level icon based on a battery life symbol, $t(34)=-3.486$, $p<.001$.

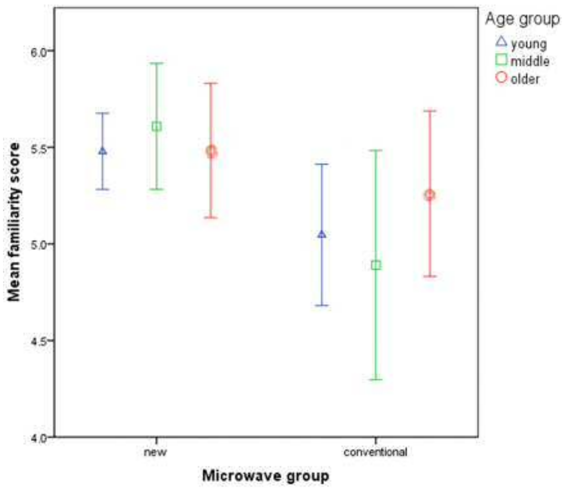

Figure 15 Familiarity score by microwave group and age group

5 Discussion

The new microwave design had not been prototyped or tested before, beyond very informal paper prototype testing done by the students, and it is possible to see some aspects which could be easily improved and which may then lead to significantly faster and more accurate performance over the conventional interface. For example, our prototype did not give much feedback during task three – after power level was correctly entered, the interface returned to the “home” screen but there was no indicator to show which power level was selected. Therefore, many participants wasted time re-entering power level and/or trying to search the menus to see if it was set or not. A simple indication of power level on the home screen would have prevented wasted time. The conventional microwave interface displayed the selected power level on the screen until cook time was entered, or another function was selected.

The number of steps required for optimal completion of the tasks was 15 on the conventional interface and 20 on the re-designed one (allowing three steps for time selection on both dial and number pad). As previously mentioned, we adjusted time for using the touchscreen dial, so that the three steps equivalent is comparable (rather than the 15 steps actually required to enter 2.5 minutes or the 21 steps actually required to enter 3.5 minutes), but the remaining 5 extra steps were caused by using the nested menu, and it is not possible to adjust for this time in any reliable and rigorous way. The correct uses and intuitive uses were calculated as percentages, but the disparity in number of steps may have affected results for the time to complete task variable.

Also, the prototype itself did cause some issues, as discussed previously. Although we corrected for these as far as possible it is unknown how much difference they made to participants' overall experience of and performance with the interface. Because the prototype for the new microwave interface had lower fidelity and was more complex to use than the conventional one, it is likely that the re-designed interface would perform better as a fully working prototype than it did as a touchscreen prototype, whereas the two dimensional conventional interface would probably perform similarly.

6 Conclusions

In this paper we have detailed our conceptual tool for designing for intuitive interaction and the trails we have performed with it. Feedback from students who used the tool suggested that it is useful but requires more refinement in order to be easy for them to apply to a design process. We then discussed an experiment we conducted in order to test

6.1 Microwave Interface differences

The new microwave group showed significantly more intuitive correct uses and a significantly higher mean familiarity score than the conventional microwave group. They also took less time to complete tasks and had more overall correct uses (Table 1), although the differences between the microwave groups for these two DVs were not significant. This suggests that the tool facilitated the design of an intuitive interface, as the re-designed interface scored significantly higher on familiarity ratings and intuitive uses, which are measures of intuitiveness [5]. However, time on task and correct uses are measures of efficiency and effectiveness [29], and the re-designed interface was not significantly better than the conventional one on these variables.

While it would be ideal for an intuitive interface to also be quicker to use and facilitate more overall correct uses, it is important to note that a student design developed in only a few weeks outperformed the commercial product, significantly in terms of intuitive measures, and somewhat in terms of speed (efficiency) and correctness (effectiveness). Also, even though it was a new approach to microwave design, its features were still rated as significantly more familiar than those on the conventional microwave.

Detailed feature comparison has revealed that some of the re-designed features showed significantly improved performance. The power level symbol, transferred from a mobile phone interface, was less intuitive than the conventional design, so it appears that the symbol did not transfer as well as hoped from the other domain, or was less familiar to users than the students had believed. However, the other two new icons showed significant improvement over the original design.

The defrost icon developed by the students was almost universally understood as everyone had had experience of ice melting, whereas the standard icon used on the conventional interface is based on a snowflake, similar to the icons used in freezers, which does not directly relate to the concept of defrosting. The start stop feature on the re-designed interface used colour coding to indicate stop and go, whereas the conventional "start" feature relied on a standard power symbol (vertical line within circle). Colour coding, based on the "red for stop and green for go" population stereotype, is understood by users of all sorts of signage, traffic symbols and products, whereas the power symbol is commonly used only in contemporary products. Thus it is likely that the re-designed feature based on population stereotypes was more universally understood, which led to it having significantly more intuitive correct uses.

This would be expected based on the position of these types of features on the continuum. Population stereotypes are further down and should be relevant for more people than familiar features – i.e., understood by a whole population rather than only by people who have used a similar feature. There is concurrence here with another intuitive interaction continuum developed by the IUUI group at TU Berlin. Their "continuum of knowledge" also has an inherent dimensionality. The frequency of encoding and retrieval of knowledge increases across the continuum (from universal innate knowledge through sensorimotor and culture to expertise). The further one rises towards the top level of the continuum (i.e. expertise), the higher the degree of specialisation of knowledge and the smaller the potential number of users possessing this knowledge [6].

6.2 Age Differences

Older people showed significantly slower times and less intuitive and correct uses than younger ones, for both interfaces. This experiment, along with others we have conducted before and since [12], showed that older people (60-plus) struggle with using contemporary products. They show slower, less intuitive interaction with more errors than younger people. Our past research has found that prior experience with a product is the leading contributor to intuitive use [5], but we have recently found that older people are less familiar and use fewer functions on the products they already had in their own homes than younger people [12, 23]. If older people are less familiar with microwave interfaces than younger ones, and use less features and functions, this would contribute to their poorer performance in the experiment, which required use of some complex functions. However, they did not have a significantly different familiarity score from younger people. It is possible that they over-rated their familiarity with the individual features during the interview (which followed the experiment during which they used them), or this could be related to our efforts to balance all groups for TF.

However, our results from this and other experiments suggest that past experience or familiarity is not the whole reason for the age differences. It is well established that physical declines such as changes in vision and hearing, as well as a reduction in dexterity, could affect the way that older people conduct all sorts of daily tasks. However, we also found that cognitive decline affects older people's accurate and intuitive use of technology [7]. Older adults vary considerably in their level of cognitive ability, but many demonstrate some decline in strategic, controlled processing at encoding and retrieval, thus affecting memory, and we found that lower scores on working memory tests correlated strongly with

6.3 Implications

As we have shown, the conceptual tool has successfully guided the design of a more intuitive microwave interface. In addition, responses to the tool from the students were very positive, they were enthusiastic about its potential to improve interfaces, and the scores they gave it were higher than those given for the GABO tool. However, student feedback indicated that the tool requires more flexibility but less complexity. For example, it may not be necessary to dictate the order in which function, appearance and location of features are addressed, or to rule that system structure or product form must be completed before any feature design can occur. The student feedback suggested that although the tool was useful it was not all that usable and they did require support in order to be able to effectively apply it. As a conceptual tool that is aimed at facilitating intuitive interaction, having an easy, accessible and intuitive format itself is essential.

Also, like the GABO tool, ours lacks concrete investigation methods for eliciting user knowledge. The students in trial two were given advice about how to do this, and methods the student groups used to investigate the user group and user familiarity included literature searches, product reviews, questionnaires, and recognition exercises to identify best icons/symbols. However, there are at present no easy to use techniques for this purpose built into the conceptual tool which designers in an industry setting could use simply and intuitively. This is something we are currently working on.

In this experiment, the new microwave interface design showed significant improvements over the conventional one for two out of four DVs. Therefore, design interventions for intuitive interaction based on the theory we have developed from our research can work, although the tool needs refining in order to be applied in industry. Our testing has gone further than many others by not only assessing how well designers used and responded to the tool [10], but also by testing an interface designed with the tool against one designed without it. We have shown empirically that design intervention can make interfaces more intuitive and that the intuitive interaction principles and continuum that we have created are relevant to doing this.

6.4 Future Research

Our tool is comprehensive in addressing all aspects of intuitive interaction and therefore various tools could be applied within it. For example, population stereotype production techniques such as those applied by Mudd and Karsh [26], Chong, et al. [14], and Ng, et al. [28] could form part of it, as could an affordance elicitation method like that developed by Hsiao, et al. [21]. The students in trial two used various user investigation techniques as part of the investigation component of the model [10], but these need formalising and aligning within the main tool to work well without support. Further work is ongoing on developing appropriate tools for industry, particularly for discovering user familiarity (the investigation component), and on cleanly amalgamating the conceptual tool with these types of investigation methods. Further work is also required in making the tool itself intuitive to use so it can be a stand-alone resource that any designer can use without help.

Acknowledgements

Marianella Chamorro-Koc allowed access in to the “Applied Ergonomics” class to facilitate running the re-design project. Rafael Gomez worked on the development of the touchscreen prototypes. Students who worked on the re-design projects and participants who took part in the experiment also deserve thanks.

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[1] **Beckett KL** and **Shaffer DW** (2004) Augmented by Reality: The Pedagogical Praxis of Urban Planning as a Pathway to Ecological Thinking, University of Wisconsin, Madison

[2] **Blackman, DA** (2001) Does a Learning Organisation Facilitate Knowledge Acquisition and Transfer? Electronic Journal of Radical Organization Theory, 7:2 [www.mngt.waikato.ac.nz/Research/ejrot/Vol7_1/Vol7_1articles/blackman.asp]

[3] **Buxton, W** (1997) Living in Augmented Reality: Ubiquitous Media and Reflective Environments. In: Finne K, Sellen A and Wilber S eds, Video Mediated Communication, Erlbaum, Hillsdale NJ, 363-384

[4] **Dixon, NM** (2000) Common Knowledge: How companies thrive by sharing what they know, Harvard Business School Press, Boston, MA

[5] **Djenidi H**, **Ramdane-Cherif A**, **Tadj C** and **Levy N** (2004). Generic Pipelined Multi-Agents Architecture for Multimedia Multimodal Software Environment, Journal of Object Technology, 3:8, 147-169
[6] **Gorard, S** and **Selwynn, N** (1999) Switching on to the learning society? Questioning the role of technology in widening participation in lifelong learning, Journal of Education Policy, 14:5, 523-534
[7] **World Bank** (2002) Social assessment as a method for social analysis, World Bank Group [www.worldbank.org/gender/resources/assessment/samethod.htm]

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