Swansea Institute of Higher Education

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MSc Multimedia

Emulation of a Real Life Environment via an Augmented Virtual Environment

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Abstract

This research explores the issues regarding appropriate environments for the user testing of a product during the development stage of the product design process. This project focuses on simulating the context of use (for user testing purposes) using real and virtual objects, known as an Augmented Virtual Environment (AVE). Previous work has been conducted on virtual reality and this ranges from low fidelity mock-ups of an environment to full virtual reality with relevant equipment and the scenarios are widespread from psychology to therapy.

To test an AVE appropriate design decisions were made and considered alongside existing research concerning virtual environments. Equipped with this information the author has developed an AVE that can be used during user testing.

Forty user tests of a common product have been conducted during this project. Some of the tests have used an AVE and some have not, in order to compare the effect an AVE has on user testing. The results have demonstrated that further questions need to be addressed when using an AVE for user testing, because using a product in its real context highlighted issues that need to be addressed in the AVE. If an AVE is to be used by design consultancies then the user testing results need to yield the same results as if tested in the real context of use.
Introduction & Background Research

The aim of this project is to explore how new products can be tested in the context of use during the product design process, by creating a virtual simulation of a product’s intended environment. This environment will be known as an Augmented Virtual Environment (AVE). To conclude this project an evaluation will be conducted assessing the value of the current user testing environments versus an augmented virtual environment.

The hypothesis is: Better user testing results can be yielded by conducting user tests during the development stage of the Product Design Process and in an AVE.

The success of a product is hinged on thorough development. Norman [1998] relates the frustration faced by users of under-developed products in everyday life and identifies them as ‘devices that lead to error’ and ‘products that are misunderstood’. Since Norman first expressed his views progress has been made in designing for intuitive use. This is predominantly achieved via User Centred Design (UCD) whose implementation during product testing has encouraged designers to improve the user ergonomics of everyday products. Rubin [1994] describes UCD as an iterative process whereby modification and continual improvement is vital. Likewise, in one of their three Principles of Design, Gould & Lewis [1985] highlighted that users need to be involved earlier in the development process of a product, so that users’ behaviours and attitudes can be documented, analysed and then fed back into the development of the product. This project is addressing how to maximise the user’s experience when product testing, and how to gain prompt results that can be fed back into the development process at the earliest possible stage [Nielson (1994)].
Bucheanu & Suri [2000] of IDEO recognised that products do not operate in a vacuum and so user testing should not be conducted in a vacuum either. Product tests should exert and reflect the same conditions and environment that the product would face in the real context of use. However, legislation and product confidentiality prior to launch often hinders the user testing of a product in context, and therefore testing is frequently conducted in in-house laboratory settings (Figure 1). As a result, the testing conditions do not truly represent the conditions in which the product will be used. Cost and time can also hinder the proper testing of a design and so change is only implemented when the next product in the series is produced and distributed. Norman [1998] supports this claim: ‘One negative force is the demands of time: new models are already into their design process before the old ones have even been released to the customer. Moreover, mechanisms for collecting and feeding back the experience of customers seldom exist.’ A virtual representation of the context of use might offer designers the opportunity to test the product in-house at low cost yet with rapid and accurate feedback. This process, however, needs to be conducted as an integral part of the development process and not as an afterthought.

AUGMENTED VIRTUAL ENVIRONMENT

The recreation of an environment using fully immersive virtual reality has been proven to carry too high a cost [Keller, Stappers 2001] and may jeopardise the implementation of emulating an environment at the user testing phase, hence the proposed use of an AVE. An AVE consists of a virtual representation of an environment accompanied by actual props. Kaur et al [1998] describe virtual environments as providing ‘a computer-based interface
representing a real-life or abstract 3-dimensional space’. An AVE goes one step further by also using actual props to increase presence and context.

The term ‘Augmented Reality’ is already recognised due to the work of Jun Rekimoto at Sony CSL. Moggridge (2006) describes Jun’s work as augmented because it was based on the use of a handheld computer and a camera, and interaction with the real word, for example, the computer was able to recognise bar codes and then feed the relevant information back to the computer / user. This, however, is distinctively different to what the author is proposing as it is a product in its own right, is used as a navigational device, and would, in itself, be subjected to user tests when developed.

To enhance the creativity process during the product design process Keller & Stappers [2001] explored the use of projecting video collages to test whether the use of a projection was ‘accepted as an environment’. Their research proved that it was.

The recreation of an environment should, as far as is feasible, be simple, particularly as Boorstin [1995] notes that the person who will be immersed in it will need to be focusing on the task at hand and not on the simulations. This should not be confused, however, with allowing the user necessarily to concentrate solely on interacting with the product. On the contrary, it is important to recreate the anxieties and natural distractions that would occur in real life.
OPTIMISING PRESENCE

Marsh [2001] defines presence as the experience of ‘being there’ or ‘being in’ a virtual environment. It is important to optimise presence so the virtual experience feels as realistic as possible. The use of olfactory, lighting, audio, narrative and pace [Boorstin (1995)] helps set any scene and increase presence, and may be particularly useful in re-creating feelings of stress and anxiety for the purposes of enhanced realism. The psychological hindrance triggered by these emotions in the product’s real environment is very important if designers are to gather accurate data. For example, a medical device used in a high stress environment but tested in a low stress laboratory environment may give very misleading usability test results. When testing the product stress, the real environment must be emulated so truer test results could be yielded from the user testing experience. Walshe [2005] conducted research with phobia patients and found that increasing the presence in a virtual environment increased anxiety and consequently stress levels were heightened. In the same vein (albeit referring to extreme situations) Ware [2004] discusses how stress causes tunnel vision whereby the user’s ‘useful field of vision is narrowed so that only the most important information, normally the centre of the field of view, is processed.’ Ware then goes on to explain this theory in the context of a disaster situation. Thus the element of stress would change the way a user interacts with a product, say a fire extinguisher or life raft. Without exerting stress of this type in user testing, dangerous products might result. James [2003] conducted research on ‘the extent to which social anxiety can be generated within a virtual environment’, and his research concluded that social anxiety can be generated in this context even though the virtual environment used in his particular case was not lifelike.

It is evident from the above that optimising presence does not necessarily mean creating a complicated virtual environment. Both Keller & Stappers [2001] and Reeves & Nass [2002] discuss optimum presence in low tech environments. Reeves & Nass go on to note that
'rather pathetic representations of real life; simple textual and pictorial material shown' can still produce realistic emotional reactions in users. Keller & Stappers [2001] were inspired in their approach to simplification by David Hockney’s photographic collages. Hockney uses partial and interrupted views to give the viewer's brain enough information to complete and compute the image. Similarly the use of lifelike (high fidelity) imagery in an augmented environment is not actually necessary since presence is achieved at low fidelity levels. Ware (2001) uses similar principles: ‘when data is presented in certain ways, the patterns can be readily perceived’.

SIMILAR WORK / BACKGROUND RESEARCH

Analogous development methods currently exist, but all of them either use different methods than AVEs or use AVEs in a different environment to the one planned to test this hypothesis. IDEO’s Experience Prototyping method for example uses low tech methods to emulate day-to-day user experiences. Bucheanu & Suri [2000] describe how Experience Prototyping uses role play for the design and development of products. Scenarios are created and observed by the design team who learn from users’ reactions to a given sequence of events and experiences. The approach involves the use of props but no media. One example discussed describes emulating air travel experiences by mocking up the interior layout of a plane. Simple chair arrangements meant that the ‘physical and social issues could be experienced’ and the authors go on to discuss the importance of ‘social circumstances, time pressure, environmental conditions’ etc. An augmented environment would aim to explore and exploit similar issues with some of the same techniques, but evaluate the appropriateness of this method versus the traditional laboratory testing and the AVE.
Walshe [2005] has developed an AVE but it has been developed for a different purpose. He explored the use of a virtual driving environment in dealing with exposure therapy for accident victims. Also, Keller & Strappers [2001] tapped into the recreation of the ‘context of use’ via video collages as a tool to gain an understanding of the product’s requirements to inspire and inform the design process. These existing practices have proven extremely valuable when researching the needs of an AVE as the research has served to eliminate the need to conduct certain tests on the differences and effectiveness of high and low fidelity virtual environments and demonstrates that there is scope in the development of a virtual environment.

Walshe’s research has much in common with the intentions of an augmented environment for user testing products. He discusses how he projected an image onto a large surface, (virtual element) augmented by props such as car seats to create an Augmented Virtual Reality (AVR). The aim of Walshe’s research was to generate a virtual environment with high presence. If he could achieve presence he reasoned that therapy could be conducted effectively. He describes augmenting the therapy environment by using a projection of a driving computer game: a windscreen through which the patient views the projection as they would in a car, and two car seats placed side by side to simulating a driver and a passenger seat. To increase presence sub-woofers were placed beneath the driver’s feet to re-create road vibration. Presence was monitored via heart rate monitors and verbal feedback throughout the experience. Results were positive and the environment was considered a success.

Keller & Strappers [2001] describe their intentions:

‘Product designers can use these video collages to re-experience their observations in the environment in which a product is to be used, and to
communicate this atmosphere to their colleagues and clients. For user-centred design, video collages can also provide an environmental context for concept testing with prospective user groups.’

The uniqueness of their research lies in the ‘concept testing’ aspect. Their research describes how video collages are used in place of mood boards to focus the design team on the proposed product’s intended environment. In some ways the work is very similar to Bucheanu & Suri’s as the environments are intended to be used during the concept design phase of the Product Design Process. Like Walshe, Keller & Strappers explored the viability of a projection to create a virtual environment and again the results were positive, although there was no mention of how they were collated or how ‘positive’ was measured.

Further research conducted by the author included a visit to Cardiff University’s EScience research centre. The author met with Nick Avis in the department of computing and was given a tour of the facilities and latest projects. Available to test was virtual reality equipment with a haptic feedback device. Although the high-tech and expensive equipment was interesting and useful, the author had already conducted research demonstrating that presence could be achieved in low fidelity environments and that design consultancies were not conducting user tests because of the current cost and time implications, therefore the additional costs of virtual reality equipment would not be appropriate. The author also experienced a stereoscopic screen that was embedded in a laptop. This screen was very interesting because it allowed the viewer to experience 3D depth without wearing specialist head equipment. With further developments this could potentially be embedded in an AVE, but currently the expense of this screen on a large scale would be extremely expensive and the Computer department at Cardiff University were in the process of researching the viability of
projecting the stereoscopic screen and creating a large surface area that was 3D with no additional specialist equipment.
Throughout this project the project plan evolved and were updated accordingly. The reason for the development was due to external influences affecting the progress of this project. Project plans used during this project can be found in the appendices. The plan shown below focuses on the last two months, as this is when the author resumed the project.
Methodology

‘If your goal is innovative design, your product or service has not even been thought of, so by definition it cannot be explained to research participants. This is where methods are needed to discover latent needs and desires that will help members of the design team define potential opportunities.’

Moggridge (2006: 664)

To prove the hypothesis either true or false, user tests of an AVE were designed and completed as such data cannot be collated by conducting market surveys or focus groups or such methods associated with market research. This is because the user test experience is not widespread or common, neither will it yield comparative results.

Rubin (1994) describes user testing as a research method that involves a representation of the product’s intended target market with the intention of identifying good and bad design in (predominantly) computer embedded products, but it has since been recognised that this activity should also be used with all product development. The sample size to be user tested is in accordance with research conducted by Nielsen and Landauer (1993) which highlighted a mathematical equation verifying most usability problems can be identified in the initial tests. Further research conducted by Rubin (1994: 128) demonstrated that four to five participants will highlight as many problems as possible, but on the chance that this is not the case then eight participants should be tested to ensure that problems are not missed. For the sake of this research eight participants were user tested.

Five different user tests (with eight participants each) were conducted. Each test was treated as an opportunity to analyse the user test environment. For the sake of this project a kettle was chosen as the product to evaluate. The kettle is a simple product that is used in a specific environment, therefore it would allow the author to focus on the user test environment and use the kettle as the vehicle. Also, participants would not feel intimidated by it as it is a
commonly known product. The same product was used in each task and where a foam model is used then it was a replica of the real kettle. The Augmented Virtual Environment was that of a kitchen. Design decisions are discussed in detail during the design and development section of this document.

The tests involved:

1. **A foam model being tested in a laboratory environment.**

   In this test a foam model was used as it is a low fidelity model and a typical output of the development stages of the Product Design Process. A laboratory environment was chosen as it is a standard user testing environment currently used as an industry standard. The test was conducted and the participants were given the opportunity to interact with the model for up to five minutes and then given the opportunity to complete a worksheet on the product (see example of worksheet in figure 2 below).

2. **A real model being tested in laboratory environment.**

   The laboratory environment remains constant and the choice of product remains constant but this time the product is an actual manufactured product but a replica of the previous foam model. As before, each participant was given a worksheet and once they finished interacting with the product they were tasked with completing the sheet.

3. **A foam model being tested in the augmented virtual environment.**

   The same foam model was used but in an augmented virtual environment that simulated the context the model would normally be used in. This test differed from the previous two as the participants were tasked with making a cup of tea in the AVE and then, on completion, to complete the work sheet about the model (as used in previous tests).

4. **A real model being tested in the augmented virtual environment.**

   This test is the same as the previous user tests but instead of using the foam model a real product was used in its place. During this test and the foam equivalent, the participants were
given the opportunity to familiarise themselves with the environment and when ready they started the test. This opportunity allowed them to understand how to interact with the environment and make them feel at ease with the use of technology and a different kitchen. This allocation of exploration also made the participants focus on the product and not on the environment.

5. A real product being tested in its real context.

For this test the real kettle was used by the participants. Their task was to make a cup of tea and then complete the same worksheet as used in previous tests (to maintain consistency).

It is important to recognise that each participant evaluated a product and the feedback sheets concerned the product. However, the observations and amount and type of comments on each sheet provided the author with results that helped determine the most appropriate environment for user testing.

Each test used advice taken from Rubin (1994) and included a recorder who was placed in the peripheral vision of the participant but not too close to distract the participant with non verbal communication. Props were used when appropriate, i.e. radio, smells, cups, teabags, spoon, bin, particularly to heighten presence in the AVE. A video camera was used so the recorder could capture as much observational detail as possible and review the footage during subsequent analysis. This was a valuable tool in interpreting an appropriate environment for user testing. Before the user tests were conducted, pilot tests were used to establish if any further developments needed to be made to the set up.

Before the tests commenced, each participant was asked to sign a non disclosure form (see appendices). This protected any intellectual property (IP) held on the product (although a new product is not being used for this research), but more importantly it stopped the participant
from discussing the tests with a third party (who might be involved in the tests) and consequently effecting the results. Also, the non disclosure document required the author to notify the participant if certain information was to be used in the public domain. Additional documentation collected before the user started the user tests was the bio data questionnaire (see appendices). This document was brief and aimed to establish the background of the participant and moreover, what type of kettle they currently owned. This question was particularly important because if the participant already had the kettle in question then they would be familiar with the product and it will hinder the overall pattern of results. Some participants might not know the make of their current kettle so images were shown and the participant could circle their current style. Amongst the styles shown was the kettle involved in the user tests. The last form to accompany the user test was the worksheet that informed the participant of their task and asked them to comment on specific aspects of the product they were evaluating during the user test, see figure 2 for an example. This form was used for each test and only differed for the AVE user test as it asked the participants to also comment on the environment.

Open questions were used as this research is concerned with the environments rather than the product being tested and the number of comments in each test was of more benefit to the author than the nature of the comments, as this will demonstrate if the impact was influential in problem finding.
<table>
<thead>
<tr>
<th>Good issues</th>
<th>Bad issues</th>
<th>Suggestions - improvements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Use</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 2. Worksheet completed by participants
Design & Development

During this project the author was tasked with designing a virtual environment that could be projected to create an environment that can be used in conjunction with user testing a product. The intended target audience is design consultancies, and research conducted by Light Minds (2005) commissioned by PAIPR (the author is a member of this research group) demonstrated that leading Product Design consultancies were failing to appreciate the importance of user testing products as they feel it is time and cost consuming. One leading design consultancy commented that, ‘They didn’t think through the usability. A senior worked on the interface design, and I worked on the screen! It was more design-led than usability. Well it’s stupid, and costs loads of money.’ Additional comments made by consultancies when asked if users were involved in user testing were: ‘Well it starts off just internal testing, but eventually the client takes it away and goes around the globe presenting it to investors and panels for review, so we have phases and they come back and we get feedback and work from there – depends on cost, schedule, and whether you have time for all of that.’ The consequence: the product is difficult to use, encourages poor use and is not found to be instinctive and, more importantly, problems are not found until the product has gone to market and problems are reported by the user and documented.

All the initial concepts created were composed in vector based packages, in this case a combination of Corel Draw and Illustrator. Original workings were animated in Director, but after discussions with interface designers, the author realised that Flash, was in fact, one of the industry standard software packages in organisations like Sony Ericsson, PAIPR, PDR to name but a few. Before starting the transition into Flash the author needed to plan a state transition chart for the intended interactions. However, the interaction evolved to work on a
concurrent theme, in that every function was available at the same time and a linear diagram (normally found in any interface design work) would not have been beneficial.

It was established that the virtual environment would need to be projected to increase the participants’ feeling of presence. The choice of appropriate environment and product was important, and after conducting initial brainstorming sessions the author arrived at the decision to design a familiar environment that had scope. For example, specific environments were explored, for instance, a ticket machine, train scenario, etc. but these were found to be too specific especially as this project was concerning emulation of a virtual environment versus the laboratory and real environment for user tests. Also, initial work on this project was focusing on computer embedded products. However, after conducting detailed research it transpired that every product needs to be user tested and at this stage of the research a computer embedded product was too complex and the use of an everyday product would help focus on the environment rather than the product. After conducting detailed research the author decided on designing a kitchen environment and the product to be user tested was the kettle.

Initial sketches included various kitchen designs; these were evaluated by projecting the concepts.
<table>
<thead>
<tr>
<th>Concept</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Concept 1" /></td>
<td>This concept is adhering to the Boorstin [1995] theory of simplicity as it takes the focus off the environment itself and onto the task of user testing. When tested as a projection the style was inappropriate because the participant would not be able to engage with the kitchen because the perspective was artificial and meant there was a void between the participant and the kitchen.</td>
</tr>
<tr>
<td><img src="image2.png" alt="Concept 2" /></td>
<td>This design was rejected for similar reasons as above. Once projected you physically couldn’t get near to the kitchen and this affected the presence needed to feel immersed in a virtual environment.</td>
</tr>
<tr>
<td><img src="image3.png" alt="Concept 3" /></td>
<td>This concept was overly complex and didn’t conform to the simplicity required. It shared the same issues as previous designs and would hinder interaction with the environment. In addition to this, the participants would not be able to see the contents of the cupboards and this would affect their presence.</td>
</tr>
</tbody>
</table>
On a similar theme, this concept hindered presence but eventually developed into the initial workings of the chosen environment.

This design evolved from previous sketches. The interactivity was enabled as the 3-Dimensional element was removed. From this design it was evident that further evaluation was needed before it could be integrated into interactive software. This concept was designed without taking into account the accurate proportions and projections.

Bold lines were used in the concept to define the boundaries and a concerted effort was made not to make it realistic as research conducted by Keller & Stappers [2001] highlighted that if it was too realistic then it distracted participants and more attention could be made to the environment and not the task.

Design and development were inevitable, especially as feasible proportions needed to be established when projecting the environment. The following table demonstrates the development and testing involved in refining the final design.
To successfully develop this concept the proportions were established – these were represented in the three bold sections. The original concept was then overlaid over these sections and edited accordingly. An attempt was made to work with the proportions but it was evident that some reworking was needed. The proportions were calculated and it soon became evident that a partial view of the kitchen would suffice.

This image was created as a result of the previous work. The bottom was removed to accommodate the projection but once it was projected the worktop was placed in an unrealistic place. Also the drawers were out of proportion and needed to be wider and a higher work top was required.
Only the middle section is visible as the top and bottom sections were removed. Proportions were accurate and were tested for feedback as can be seen in the photograph. Larger drawers were still needed.

Further development.

The worktop is higher, drawers are larger: the size and projection now mimic a real kitchen. Shadows were added for depth and colour was added because it's image needed differentiation from the projection material and a more defined image was required as light was diluted when creating a mirrored projection: the image diffused and contrast was needed to minimise this effect on the eye.

Figure 3. Initial plan view layout of the user test environment
Once proportions were established the author needed to develop the rig that would house the environment and define the equipment that would be used. A basic wood frame was made and initial mock-ups were tested. Figure 3 demonstrates the initial plan view layout of the user test environment. Initial feedback and research into peripheral vision highlighted that the users could still see the external environment and didn’t feel completely immersed in the environment. After further tests the walls were altered to 90 degrees and the users commented on feeling immersed in the environment by saying it felt ‘much better’.

Figure 4 demonstrates the difference and how increased presence can be achieved in this environment. A pending issue, at this stage of the project, was being able to interact with the PC whilst projecting the image. This was overcome by making only the front facing panel interactive and by using a wireless mouse to communicate with the PC: one wall would house a movie clip of a garden and the other was a jpeg of a kitchen. Figure 5 illustrates the entire kitchen before the development process was completed.

For the sake of the prototype, projections were made onto a white sheet. Appropriate materials were researched and a white cotton sheet was found to be the most appropriate as it was cheap and easy to manage on this scale. Likewise, when the room was immersed in total darkness the sheet did not hinder the graphics or usability of the environment.
Further development was made based on participants feeding back on the graphics and what they could see in the environment when projected.

<table>
<thead>
<tr>
<th>Development</th>
<th>Comments / Feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Development Image" /></td>
<td>The red blinds were developed so there was contrast between the walls and the blinds. When projected, the yellow walls were too bright and did not go with the red blinds.</td>
</tr>
<tr>
<td><img src="image2" alt="Development Image" /></td>
<td>The walls were made lighter – more of a realistic magnolia. It was noted that this kitchen did not have a fridge and that the original kettle base and plug was not intuitive to use as it felt as if the kettle should be on the right hand of the kitchen facing the taps.</td>
</tr>
<tr>
<td><img src="image3" alt="Development Image" /></td>
<td>The fridge hinges and handle were opening into a wall, so these were changed to the other side.</td>
</tr>
<tr>
<td><img src="image4" alt="Development Image" /></td>
<td>Grey walls were implemented based on user feedback because when the same colour walls were used the projectors changed the colour and the walls clashed – by opting for a multiple colour scheme this was avoided and as different colour walls are commonly used in real kitchen / home decorating environments then this was found to be acceptable.</td>
</tr>
</tbody>
</table>
This wall was developed using the same colour as the adjacent wall but with French doors. In the French doors a movie was played of a garden and it correlated with the garden movie found in the main kitchen window.

Further development included dials on the cooker knobs, more depth in the shadows, colour contrast of the books and the text. Note the use of red in the saucepan – this was intended to coordinate with the main kitchen.

It became evident that the tap was not big enough and would hinder the task of making a cup of tea. It was decided that a real and foam kettle would be used as a virtual kettle and radio were unnecessary at this stage as the real objects would be used instead to increase the augmented element of the environment. The blue in this image is an invisible button that is only visible in Flash.

See appendices for further design detail.

Initial research demonstrated that heightened presence could be achieved by creating as many sensors as possible when immersed in an environment.

‘Information becomes more vivid and engaging when it resonates with personal experience. If designers and clients can have informative personal experiences, it is easier for them to grasp the issues and feel greater empathy with both the people who will be effected by their decisions, and the experiences users may face.’

Buchenau & Suri (2000)
Increased presence increases the participant’s depth of engagement and this can be contributed to by adding smell, audio and interactive graphics. Anxiety was not required for this task as making a cup of tea is predominantly a stress free task. If anxiety was required this could have been achieved by a loud environment and intimidating use of graphics. Originally smell was going to be included by burning a coffee smell via a USB aroma device, but after conducting initial tests it did not appeared to offer anything additional to the smell of freshly made coffee. During the user test freshly made coffee was strategically placed around the test area ensuring it did not interfere with the test and was out of sight. Music was played accompanied by sound effects on each animation.

Before user testing could commence the virtual environment needed to be piloted. Figure 6 shows the set-up without any projection. A thin ledge was made for the actual kettle to sit on and a white box housed the wireless mouse. The wireless receiver was inserted into the lap top and unfortunately had to be relatively close to the mouse. Coffee was placed behind the white box. Initial tests were done in a spacious room but it soon became apparent that a darker room was needed. The bin was included based on feedback from the pilot test. Additional comments surveyed from the pilot were, the author had forgotten to mirror one of the projected images and the white box that housed the mouse needed to move closer to the kitchen. Further changes were needed as the platform that housed the real kettle did not line up with the virtual work surface. As a result, the Action Script code was activated and objects would fall off the screen (the action script was emulating a real cup
being dropped off a real work surface). This was rectified by altering the projector and matching up the two surfaces. Further results gained from the pilot were the need to allow the users a minute to acquaint themselves with the environment before starting the task and they could interact and handle the model being tested. Figure 7 shows the pilot participant asking if he could handle the model. Further developments based on the pilot included changing the mouse speed - the mouse needed to be extremely slow as it was far too sensitive and although the speed was not appropriate when used directly on the lap top it was perfect when projected.

Action script was used to code the Flash software interface. The author wanted to emulate real life scenarios, for example, if an item was released below a work surface then it would fall and smash (as in real life). The same rule applied in the AVE using a global function. Global functions allowed the author to have one code that was visible to all timelines in the Flash document and could be used economically, as the author didn’t have to duplicate the code (which elevates the chance of duplicating errors). Basic traces were applied to every item in order that the author could pinpoint the worktop in the Flash Stage, therefore when the item was released at a certain point the object would drop: this information was relative to every object. To ensure items had immunity to the drop code the author used the hit test code: if (this._parent.hitTest(_root.Rdoor_mc.rcupboardHit_mc)) {}. When an item was over a certain movie clip it would not drop, for example, the baked beans had immunity, when placed back in the cupboard they would stay put. Here is an example of the code:

```ActionScript
on (press) {
    this.startDrag(true);
}

on (release, releaseOutside) {
    this.stopDrag();
    //trace(this._y);
    if (this.hitTest(_root.Rdoor_mc.rcupboardHit_mc)) {
        _root.gravityDrop(this._y, 628, this._parent, this._name);
    } else {

```
Flash is a beneficial package as it allows different codes to be placed in different levels and in movie clips. This function meant that objects could be dragged within different layers. Flash uses a combination of timeline and object orientated elements and these two styles sometimes cause confusion as code can be placed in the wrong place and the author can be unaware of this. Ideally for this project an object orientated package should be used for example VB, but a package like VB does not offer the graphical and animation capabilities that Flash has to offer.

Basic animation was achieved by using the button function in Flash. This allowed the author to open cupboards and drawers. The video clip was compressed using a Flash 8 codec and then embedded into the document as a component. This allowed the author to control the sound, quality and size of the video.

Further code utilized in Flash was ‘onclipEvent’ code. This operated the blinds and the switch and allowed the author to embed basic feedback principles into the programme. For example, when the switch was mouse clicked another movie loaded showing the switch as on. Basic semiotic theory of red and green were used to communicate the switch’s status: red being the language code for stop / off and green being the language code for go / on (Chandler 2006).

Originally a kettle and radio was modelled in Flash as can be seen in Figure 8. The two items were later removed as the user tests required these to be actual objects and not virtual ones.
Figure 8. Example of products removed from Flash interface
**Final Design**

Figure 9 is an illustration of the final interactive wall of the AVE and figure 10 is an illustration of most of the animations when in operation. When developing the original concepts it soon became apparent that the projected image needed to be 2-dimensional, yet the author still wanted to portray a certain depth of field. This was achieved by creating 3D cupboard, fridge and drawer space as well as video footage found in the kitchen window. Achieving feedback was very important in this environment as the participants needed to know when a task was complete – taps were designed in order that a change of state was obvious. Sound effects were placed on moving parts and visual objects would react as if they were in the real world.

The environment was purposely designed to comply with initial research which highlighted that the environment should not be too lifelike or over complicated as it would distract the participant from the task at hand.

![Figure 9. Main interactive wall](image-url)
Figure 10. Main interactive wall showing all main animations

Figure 11. The right wall.
Figures 11 and 12 are illustrating the final designs for the right and left side of the AVE. Both are at different resolution to the main interactive wall and this was due to projector strength and size of the AVE rig. Both are designed in the same style. Both have picked up the colour cues from the main kitchen wall and the movie playing in the French doors corresponds with the movie playing in the main kitchen.
Evaluation of Final Design including results

Five separate user tests were conducted that involved 40 participants over a period of three days. The participants were all from a product design background so the results were consistent but also as this type of person was available in large quantities (although it can be argued that this type of participant is overly critical of a product as they have been trained using critiques).

Thirty-five males and five females participated in the user tests and the average age was twenty-three. Every participant completed the bio data and not one person owned the kettle under test, therefore the results were not compromised by unfair familiarity with the kettle. (All user test paper work can be found in the appendices.)

<table>
<thead>
<tr>
<th>User test</th>
<th>Average age</th>
<th>Number of comments</th>
<th>Average</th>
<th>Median</th>
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<tbody>
<tr>
<td>Foam Kettle in Lab</td>
<td>22</td>
<td>7 10 10 11 11 12 13 14</td>
<td>11</td>
<td>11</td>
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<tr>
<td>Real Kettle in Lab</td>
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<td>7 9 10 11 12 15 19</td>
<td>11.86</td>
<td>11.5</td>
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<tr>
<td>Real Kettle in AVE</td>
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<td>10.38</td>
<td>9.5</td>
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<tr>
<td>Real Kettle in real kitchen</td>
<td>21</td>
<td>13 14 14 16 16 17 18 18</td>
<td>15.75</td>
<td>16</td>
</tr>
</tbody>
</table>

The above table demonstrated how many comments were made for each of the user tests. The median was calculated as this is a more robust method of analysing statistical data particularly if one person skew s the result by not making any comments after the user test. This calculation method is more commonly used in engineering as it is more robust to noise. Further analysis was conducted on the type of comment yielded in each test environment.
The reason for this was to compare and analyse the type of comments to see if the environment can provoke different reactions, but also to see if the AVE can identify the same comments yielded in the context of use.

A comment was recognised as a distinct remark concerning the product and where a paragraph highlights two separate issues then this was treated as two comments.

As anticipated, the real kettle in the context of use averaged the highest number of comments at 15.75. This demonstrates that the environment and product highlighted the participant’s engagement in the test and as a consequence more issues were raised. The foam kettle in the AVE produced the least number of comments from the participants. Upon observing this test it was evident that the environment became the focus rather than the product and the foam model in a laboratory achieved on average three more comments.

Calculating the median has confirmed the average results and has only managed to demonstrate a small strength in the amount of comments made by the participants using the foam model in the AVE.

In the laboratory user tests each participant was given up to five minutes to evaluate the product. Props were made available if interaction was required. From the video footage the foam kettle user test participants, on average started commenting about the model in less than a minute. However, the participants in the real kettle...
user test finished interacting with the kettle and started commenting well over a minute and a half into the test and the interaction was extremely thorough. This demonstrates that the real kettle made the participants far more inquisitive and that any model user tested should be a good representation of the final design.

During the AVE user testing process, the participants testing the foam model appeared to have more appreciation for the virtual environment, see Figure 13. This was demonstrated when one participant was whistling along to the music and got distracted by the movie clip of the outdoors. All participants in the AVE observed the boundaries of the AVE kitchen and placed objects accordingly whereas the users testing the real kettle in the AVE had a tendency to put objects on the sink – something they would not do in a real kitchen.

Only one out of sixteen people attempted to make a cup of tea incorrectly but this participant soon corrected his ways. This demonstrates that the environment was successful because once all participants had familiarised themselves with the virtual environment it did not hinder or distract them from the way they had learnt to make a cup of tea. In addition to this, every person tidied up after them, closing doors and putting objects back in their original place. This was very interesting as they were almost adhering to social etiquette of tidying up as if they were in someone else’s kitchen. Further evidence of presence was achieved when participants released an object below the work surface. As in the real world the item dropped and all participants who experienced this looked down to pick the item up. This does indicate immersion in the environment but if the participant had associated the environment with reality they would not have contemplated letting go of an object when it was not safe to do so. This behaviour was conflicting as the participants could not relate the same logic in a virtual environment. Further observations highlighted that the participants testing the real kettle in the virtual environment struggled with the task as they had to be prompted to fill the kettle
with water when making a cup of tea. This suggests that they could not relate the real kettle with the virtual environment. In addition to this, objects were placed in unsuitable locations and the participant appeared dysfunctional when completing the task. Yet those testing the foam kettle thought nothing of making a cup of tea. It is therefore surprising that more comments were observed by those using the real kettle.

The purpose of creating the AVE was to see if distractions could change the way a user would react to a product. One participant became distracted by the dog (which was in a movie clip) and as a consequence they forgot to fill the kettle with water. In a real situation the kettle would not have boiled and although the environment demonstrated that it could distract the user, it could not give the necessary feedback to tell the participant that they had not filled the kettle.

During the real kitchen and real kettle user tests the feedback comments were in-depth and very relevant. Issues such as power-on feedback, spillages and participants moderately burning themselves when pouring the kettle could not be sourced from the laboratory session or the AVE. If these were to be obtained during the AVE then the designers would need to forecast the faults and allow for them. This would contradict the purpose of a user test, which is - to find problems with a product that the designers have missed.

On completion of the AVE user tests, participants were invited to complete the feedback form (Figure 14) concerning the product they had been testing (the same form as all the other user tests) but there was an

Figure 15. AVE user feedback
additional comments section on their form as it asked for ‘any comments about the environment?’ Some comments included ‘spent more time looking at the environment’ and others commented that it was difficult to see under the work surface. When the environment was set up the work surface did not appear to affect the environment but once the participants were immersed in the environment the work surface hindered their line of sight and initially the fridge and drawers went unnoticed. One participant commented ‘nice dog’, although not particularly helpful it does, however, demonstrate an awareness of the surroundings and further comments about, ‘how they felt like they were in a kitchen environment’ supported this.

An important point to raise is the interaction with the AVE. As mentioned previously the participants were all from Product Design backgrounds and were familiar with mouse interactions and mouse feedback and could recognise when to click an object. With participants who are less computer literate this might be a hindrance as they may have obstacles when it comes to interacting with the Flash interface.

The AVE was extremely time consuming and resource consuming and took a total of three hours to set up with two people. But once set up, the tests were extremely efficient and it was easier to find the next test person whilst the participant completed the forms. On average, each test lasted ten minutes long. The laboratory tests, however, were quick to set up but took, on average, twenty minutes per participant and the observer could not leave the room as the participants continually referred to the kettle. A total of sixteen tests were conducted in a laboratory and sixteen in the AVE. 11.43 was the average number of comments made in the laboratory and 9.32 was the average number of comments made in...
the AVE. The advantage of the laboratory environment was the difference of 2.11 comments, but if an organisation is consumed by ‘time to market’ and cost then the benefit of saving ten minutes a test, which equates to eighty minutes in total, will be appealing. However, the current AVE set up would need refining for industry and would only be appealing if technology like touch screen or interactive white boards were available in-house because this would reduce set up time considerably.

With further development the AVE could yield the results found in the actual context of use and consequently be a valuable tool for consultancies, but as it stands at the moment it requires further development and further comparisons of different scenarios.

The comments collated during the user tests were also analysed for the type of comment achieved in the respective environments (Tables can be found in appendices). A number of comments were collated from the participants and the author has elected to analyse the repetitive comments as they have some importance because user tests serve to pick up repetitive problems. During the AVE test the comments reoccurred more frequently than in the laboratory setting, for example, six people mentioned handle comfort but only two mentioned the grip during the laboratory user test experience. This suggests that the experience of making a cup a tea in the virtual environment has subjected the participants during the usability experiences that they obviously did not have in the laboratory user test. During the AVE user tests two users mentioned the weight distribution, again as they used the product, but during the laboratory user tests three participants mentioned the possibility of spillage. This is an important point. Granted, the comments were alluding to it ‘might spill’ as they themselves did not experience the kettle with water in it. These comments were ignored by the AVE participants. During the laboratory testing more emphasis was made about the
aesthetic of the kettle rather than the functionality ‘Strong product semantics’. Common points highlighted in both tests concerned the handle and the possibility of burning their hand.

When comparing the real kettle user tests, the comments were particular interesting, especially when correlated with the video observations. Most participants in the AVE filled the kettle up using the spout and as a consequence no comments were made about the lid, whereas in the laboratory test five participants commented on difficulties they had in removing the lid. With regards to filling a kettle, this demonstrates that most people would elect not to remove the lid. In fact, during the real kitchen user tests more than half the participants filled the kettle using the spout and not via the designated lid-hole. This demonstrates that the AVE incurred the same behaviour as the context of use. Comments that shared common ground between the AVE and laboratory testing of the real kettle were semantics, difficulty to fill with water, and burning.

When comparing the data collected from the real kettle in the AVE with the real kettle in a real kitchen user tests, only two common comments were collated and that was the burning issue and the product semantics and aesthetics. The burning did however transpire to be a critical problem as all eight participants experienced some burning during their task. Further comments yielded from the real kitchen environment were the issues concerning the water levels and visibility of this. The water comments transpired to be critical problems with the kettle as it concerns user feedback, but unfortunately no other test highlighted this issue. This demonstrates that the lack of physical water in the AVE was an issue as it could highlight vital flaws in the design. The key question to derive from these results is what should be real and what should be virtual? On reflection the author appreciates that the water should have been a real element as it plays an important role in the appropriate use of this product.
Conclusion

The hypothesis identified at the beginning of this document was: Better user testing results can be yielded by conducting user tests during the development stage of the Product Design Process and in an AVE.

Currently, the author’s results have highlighted that presence can be achieved in a virtual environment but at this stage of the research, better results can be achieved in the real context of use, and where this is not possible then in a laboratory user testing environment.

Research has demonstrated that users need to be involved as soon as possible in the development process of a new product and currently design consultancies are not taking the opportunity to user test their product due to shot term cost implications. Yet the long term cost implications are far worse as the market may lose confidence in dysfunctional products.

Already virtual reality is widely used on a number of different disciplines in particular Product Design but it is not currently being used during the user testing stage of the design process. The current user tests involve a laboratory environment. Legislation hinders consultancies from testing their products in the context of use, even though the author’s results highlight that this is the most beneficial test to finding more complex and relevant faults with a new concept. With refinement, the AVE could offer the same benefits as the context.

The author’s research also identified the importance of focusing on the task at hand and not the simulation. Results from the AVE user tests show that the environment did not hinder the tasks until an actual kettle was immersed in the environment. The conflicting realities of real versus virtual did not work together and hindered the tasks so much so that basic everyday functions were being forgotten. For example, filling the kettle with water.
Eight participants were involved in five different user tests. This is in accordance with research and what a consultancy would have to conduct when testing a product. The current set up time of the AVE would be a hindrance to a consultancy but the benefit of shorter test time and optimum feedback would be beneficial due to time and constraints.

Forty tests were conducted during this research and the results demonstrated that currently more comments can be gleaned from the actual real kitchen with a real kettle. The foam kettle relative to the real kettle under performed and that further research of different AVE scenarios was needed. However, participants reacted as if they were in a real kitchen when tested in the AVE. They tidied up after themselves, looking for dropped objects and reacting to the video clips used during the test.

To summarise, the key findings of the research are:

- The real kettle in the real context of use averaged the highest amount of comments and they were more in-depth and meaningful, ‘On light below eye-level and didn’t realise, water that poured out of the spout went all over the work top.’ Palmer (2007).
- Foam kettle in the AVE raised the fewest number of issues.
- Any model being used during user tests should be refined and emulate the intended manufactured product as much as possible.
- From the video observations, low fidelity models in the AVE were more successful than using the actual product.
- Presence was achieved as participants were mildly distracted by the environment. More specifically, the dog’s presence in the video footage played through a window and on occasion the participants whistled along to the music.
All the tea making tasks were successful.

Setting up an AVE is currently a time consuming exercise, but once set up the tasks are very quick to conduct unlike the laboratory user tests that were very time consuming.

Key findings also describe how critical problems are being missed in a user test laboratory environment, for example the water display on a kettle. The author's research has demonstrated that further evaluation is needed on how to define what can be modelled virtually and what needs to be real to replicate the context of use as close as possible. These findings could not have been yielded without conducting this initial project.
Recommendations & what’s next

Based on the initial findings there is definitely room for development for an AVE for user testing. A very broad environment was developed for this initial research, but next the author is interested in recreating more specific virtual environments, for example, the use of mobile phones on a train. According to Murtagh (2006) users interact differently with their mobiles when a train carriage starts to fill up with people. This is an example of where there is an opportunity to develop a virtual environment that would give the impression of people joining a carriage and, based on this, observations can be made. This would be a very specific task.

Specific recommendations concerning this project would include making the cups larger as they were out of perspective and using a tracking mouse for the interactions in the AVE. Also the participants, who were interacting with the foam kettle in a laboratory environment, should have been given a CAD representation of the concept design and this would have improved certain comments found on the feedback sheet. Further recommendations concerning the user tests would be to use the ‘speaking out loud method’ as detailed by James et al (2003). The author had recognised this as a valuable communication and data collection method during a user test, but unfortunately forgot to implement it and the research would have benefited from this additional feedback.

The main interactive wall could have been projected onto a white wall that had a sink and a tap in place and this would have added further realism and context to the user test and this will be investigated further. The next step in this project will include evaluating the question posed in the conclusion: what should be virtual and what should be real? Further work will involve researching into different projection technologies including interactive white boards, touch screen and even the new multi touch screens that are in development by Microsoft.
The author intends to pursue a PhD based on the initial findings in the document. The overarching aim for the author is to develop a toolkit that can allow design consultancies to create the context of use virtually and in-house. The author’s current research is only touching this issue, but will eventually evolve into a software and hardware tool kit.
References


Msc Multimedia PT

Emulating Real Environment via Augmented Reality


Bibliography


Appendices

- Initial Project Plans
- Comments from User tests
- Original forms used in User tests
- Additional sketch work

Project plan 2006/7

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<th>Activity</th>
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<tr>
<td>2</td>
<td>Research</td>
</tr>
<tr>
<td>3</td>
<td>Prototyping</td>
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<tr>
<td>4</td>
<td>User tests</td>
</tr>
<tr>
<td>5</td>
<td>Final submission</td>
</tr>
<tr>
<td>6</td>
<td>Evaluation</td>
</tr>
</tbody>
</table>

Bethan Gordon 49
User Test Comments

Foam Kettle in AVE?

- Handle comfortable x 6
- Easy poor control
- Modern shape
- Gives an idea of the product
- Access to lid a bit obstructed x 3
- Similar to current kettles currently on the market.
- Doesn’t convey actual kettle
- Too light x 3
- When tipping the water / steam could burn your hand x 4
- More room to remove lid
- More noticeable on/off switch
- Better handle position x 3
- Have to think about putting it down on charger.
- Position of the handle means you have to take the whole weight of the handle when tilting it x 2
- Possibly a splash pad charger.
- Easy access handle
- Traditional
- Centre of gravity
- Shape says fill from spout
- Heavier would suggest better quality.
- Short spout x2
- Small lid
- Bottom handle very wide, would cause making a cup of tea very difficult.
- You could hinge the handle so it splits for filling.
- Larger spout
- Changing the shape of the spout.
- Can hold a lot of water
- Smaller kettle
- Good weight balance
- Space between lid and handle – so you don’t burn hands.
- Old ladies might find it hard to lift with the water in it.
- Nice wide base
- Difficult to see water level.

Foam Kettle in lab?

- Strong product semantics x 2
- Traditional shape and style x 2
- Good grip on handle x 2
- Clear switch – obvious indicator
• Handle is safe.
• The handle is very near the spout
• Does it fit in a modern kitchen?
  • Could burn hands x 3
  • Move handle x 7
  • More streamline shape x 3
• Not comfortable
• Feels out of balance
• Shape is uninteresting
• Base is not flush – so it rocks.
• Too wide and fat x 2
• Stable shape.
• Hard to move the lid x 2
• Spillage could occur x 3
• Can only be placed on base in one position.
• Retro
• Weight is different
• Handle keeps hand away form spout.
• Switch doesn’t let me know when it’s on
• Small filling space.
  • Difficult to say which bits get hot x 2
  • Handle could get in the way of the lid x 2
• Obscure water levels
• Spout has no lip
• Spout could be larger
• Easy to use
  • Nice to look at x 2
• Put on / off switch on handle.
• Move lid.
• Water would be awkward to poor.
• Light weight
Real Kettle in lab
- May need to use two hands to use
  - Handle position makes it hard to pour x 2
- Retro looking
- Metal will transfer heat – burn user x 2
- Steam may burn user x 3
- Water could effect electronics
  - Move handle x 3
  - More organic look needed x 2
- Use different material
- Change connection
  - Good semantics x 3
- Easy to poor
- Easy to position kettle
- Handle is a good distance away from kettle
  - Lid is difficult to move x 5.
- Bulky shape
- Not a good grip
- Hard to get to the lid.
- Hard to use when full
- Switch further form the bottom
- Good grip on handle
- Aesthetically pleasing
- Indication on where you can touch the kettle.
- Clumpy design
- Lid needs to be moved
  - Handle gets in the way of lid x 3
- Spillage
- Bigger handle on lid
- Large handle
- Easy accessible switch
- Low centre of gravity
- Won’t burn
- Sleeker design
- Good water level indicator
- Cordless
- Power light not near switch
- Shape misleading when filling
- Clumsy power switch
  - Better lid x 2
- Wider pouring space
- Takes up large surface area
- Make it taller
- Arch the handle more.
• Need to hold at steep angle to empty
• Small hole to fill
• Can’t be submerged in water
• Re-filling involves taking handle off

Real Kettle in AVE
• Semantics x 3
• Comfortable x 2
• Classic looking
• Good texture
• Cordless
  • Tipping action is hard because of handle positioning x 2
  • Difficult to fill with water x 3
  • Raise handle x 3
• Lid on hinge or strap.
• Not aesthetically pleasing
• Water level out of sight line
• Have to rotate a long way to pour
• Move water level to front.
• Fill from side
• More parallel shape
  • Move spout x 2
• Easy to see the switch
• Pleasant shape x 2
• Feels sturdy
• Heavy – not good for old people x 3
• Might not appeal to everyone
• Change handle
• Lid was quite sticky
• Lack of grip on handle
  • Hands exposed to metal – could burn hand x 2
• Textured handle
• Good weight distribution
• Potential for a variety of styles
• Good ergonomics
• Less steam coming into contact with hand
• Lack of confidence in power switch
• Too traditional
• Power switch with definite action
• Change handle
• Indication that handle is hot.

Real Kitchen, Real Kettle [more of the same issues were identified]
• Intuitive switch
- Nice look x 3
- All electrics hidden
- Water level reads in half Litres
- Starts on half a litre and this is too much for one cup
- On switch is below eye line x 2
- Curious colour scheme and orange on light.
- Chrome lid gets hot x 6
- Water continues to boil for 20 Sec
- Water spilt everywhere when pouring x 3
- Should display in cups x 2
- Make ‘on’ light more visible - and near the switch
- Needs a colour scheme x 5
- Needs tighter timing on the off switch
- Good size on/off button x 4
- Window shows water levels
- Handle is awkwardly placed for filling x 4
- Good colour mapping
- Light indicates when on
- Need to pick up kettle to see water level x 3
- Burn hand from steam x 2
- Weight distribution was uneven
- Needs larger viewing window x 2
- Awkward to pour x 4
- Kettle could rotate on base – good x 3
- Handle not ergonomic
- Feels heavy
- Too bulky
- Handle is large – good x 3
- Good grip x 3
- Move handle
- Easy to hold x 2
- Change spout x 3
- Stable shape
- Handle in the way of filling up
- The power & base looks like an afterthought
- Help stop people burning their fingers.
- Lid comes off easily
- Change lid
Most recurring comments. Why? because these would have been identified by more than one participant and this makes them serious product problems.

<table>
<thead>
<tr>
<th>Foam Kettle in AVE?</th>
<th>Foam Kettle in lab?</th>
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<tbody>
<tr>
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<td>Should display in cups x 2</td>
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<td>Needs a colour scheme x 5</td>
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