Mime: An AR-based System Helping Patients to Test their Blood at Home

Tom Djajadiningrat
Philips Design
High Tech Campus, Building 33
5656AE Eindhoven
The Netherlands
tom.djajadiningrat@philips.com

Pei-Yin Chao
pei-yin.chao@philips.com

SeYoung Kim
seyoung.kim@philips.com

Marleen van Leengoed
marleen.van.leengoed@philips.com

Jeroen Raijmakers
jeroen.raijmakers@philips.com

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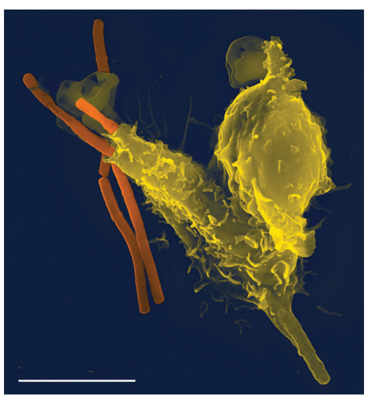
Abstract
Mime is a tablet-based augmented reality system which guides new chemotherapy patients through testing their blood at home. Starting from the socio-economic push towards home healthcare, we use blood analysis as a case study to illustrate the user experience challenges of unassisted care at home and how AR may support the user. We then show our explorations during an early ideation workshop, using low-fi prototyping and acting out. We also show steps from our making process in which we combine various tools, both physical and virtual, to further our understanding. We conclude with our final demonstrator and the discussions it triggered.

Authors Keywords
augmented reality; manuals; home healthcare

ACM Classification Keywords
H.5.2. User Interfaces: training, help and documentation
H.5.1. Multimedia Information Systems: Artificial, augmented, and virtual realities

Introduction
The rising costs of healthcare are a global concern. One approach to battle these costs is to reduce the number of times outpatients need to visit the hospital and the time that inpatients remain in hospital. This has led to a new area of ‘home healthcare’ in which patients are provided the means for continued care at home with an emphasis on self-care and telecare, if necessary with support

The Minicare Home system



A neutrophil engulfing a bacterium (Volker Brinkman, 2005)

from local care workers. Understandably, there is concern about the required continuity of care, and ensuring quality and safety standards away from the hospital.

Here we focus on one specific application in home healthcare: the blood test that chemotherapy patients undergo to check whether they can safely have their next treatment. Typically, chemotherapy patients have such a test done at the hospital prior to every treatment. However, recent advances in blood monitoring equipment made it possible for patients to monitor their blood at home, thus reducing the number of times they need to visit the hospital. In addition to the aforementioned cost benefit, this equates to less infection risk and directly translates into improved quality of life as hospital visits are both physically and mentally exhausting. These benefits are especially relevant for chemotherapy patients as treatments are notorious for making patients feel weak.

A side effect of chemo medication is that it can temporarily lower the number of white blood cells or neutrophils. Neutrophils help the body to fight infection. When this condition, called neutropenia, is too severe, patients are not allowed to undergo their next chemo treatment. A benefit of blood analysis at home then is that it allows for more frequent testing and helps avoid the disappointment of having a test at the hospital, only to hear that the next chemo treatment cannot take place.

In the next section we explain the use of a home blood analysis device (shown above) developed by our company and identify the user experience challenges that come with an unassisted self-test.

The blood analyzer in use
The patient is about to put the blood cartridge into the blood analyzer. From this picture it can be seen how the blood test requires quite a large number of objects and how the user needs to decide on the best order to handle them. Typically, patients need to walk to a sink to warm up their hands.

The use protocol

The basic process for using our current generation blood analysis device ("Home monitoring service", 2016) is seemingly simple: the user needs to desinfect a finger, lance the finger, place a drop of blood into the cartridge, put the cartridge into the machine and put on a band-aid where the finger prick took place. The results are then sent via the internet to the oncology team for review. However, there are two requirements which complicate matters. The first is that the drop of blood needs to be 'fresh' as once it starts to coagulate its analysis will be unreliable. The user is therefore given a time limit of 45 seconds between lancing and putting the cartridge with the drop of blood into the machine. When the required actions are carried out in the right order this should pose no problem. However, when actions are carried out in a sub-optimal order the user may exceed the time limit. This can happen, for example, when the user has already lanced and then still needs to take the cartridge out of its foil packaging. Missing the time limit means wasted consumables, which increases costs, and requires the user to lance again, which causes discomfort.
A second requirement is that the cartridge is filled with a sufficiently large drop of blood. Drawing a large drop of blood can be challenging, especially for elderly patients with low perfusion. It is therefore recommended that prior to lancing, patients dilate their blood vessels by immersing their hands in a sink with warm water. This is cumbersome and results depend on duration and water temperature.
Another complication is the number of objects that the user is confronted with: an alcohol swap, a lancet, a foil-packaged cartridge, a band-aid, the blood analyzer itself and possibly scissors to open the packaging. The disposables come from different manufacturers and are not that easy to recognize for a non-medically trained, novice user.
Regarding manuals, the current generation blood analyzer comes with a tablet which contains a number of movies which explain the procedure the user needs to go through.
A final complication is that patients undergoing chemotherapy do not only get a physical but also a mental blow: from a cognitive point of view they are not their usual selves. This phenomenon, known as chemo fog, makes it more difficult for them than normally to remember and interpret instructions. The instructions they get in the hospital will be hard for them to remember, even more so than for 'normal' patients.

Ideation workshop: exploring an AR-based, contextual manual

The essence of augmented reality is that it can display a virtual overlay on top of the physical world. Because a tablet is already used in the current set-up for internet connectivity and to show instruction movies, we were interested in using it to augment the scene.
Currently, patients have to look back and forth between the explanatory movies shown on the tablet and their own set-up. This means that they have to interpret the movie and relate the various objects and actions explained in the movie to their own. We envisaged that using augmented reality we could build a contextual manual, with the tablet providing guidance overlaid on top of the user's own objects and hands. The first ideation session was therefore aimed at exploring how virtual annotations could guide the user through the procedure.

Using low-fi physical prototyping to explore augmentation

Because the design problem is so physical—involving the user's body and various tangible objects—we re-enacted the scene using low-fi, physical prototyping, even for the augmentation (Burns 1994; Ylirisku & Buur, 2007). This set-up shows how we put a sheet of acrylic on top of some beverage cans. By putting writing and drawings on top of this sheet, we could quickly explore where and when to show virtual annotations on top of the real world.

A game board metaphor: optimizing the order of actions

Using the objects in a sub-optimal order increases the likelihood of not making the time limit. We therefore came up with the idea of a gameboard in which the first step is to place the objects in the right order of use. Here objects are ordered linearly from left to right.

Lancing behind the tablet: impossible due to disturbed hand-eye coordination.

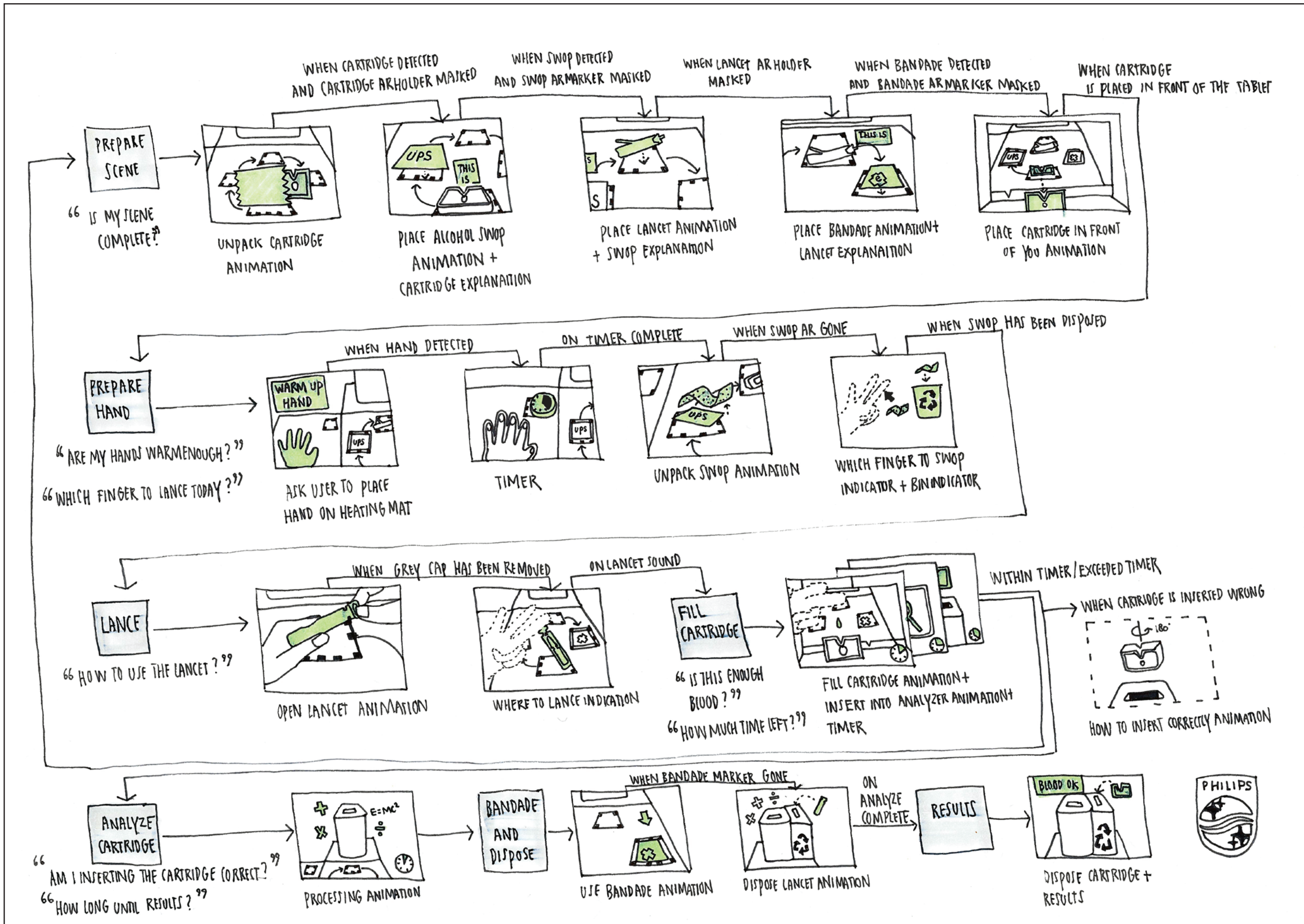
One aspect that we wanted to communicate to the user is which part of the finger to lance. We envisaged that the user would lance behind the tablet and that using augmented reality we would show an arrow on top of the real hand to indicate the ideal spot for the needle. When we started to experiment with this—simply by using the camera functionality of the tablet, programming not yet required—we found that unfortunately this did not work. Due to a combination of the tablet's camera being off-centre, the image not being stereoscopic, the lack of head-coupled motion parallax and delay, our hand-eye coordination was so messed up that when viewing our hands through the camera we simply could not lance accurately.

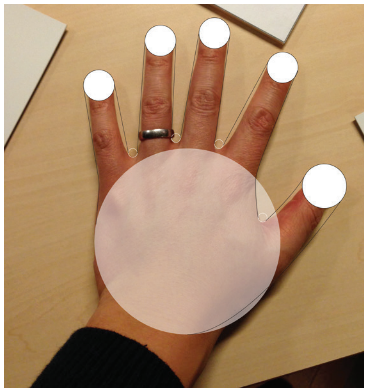
Lancing in front of the tablet: optimizing the order of actions

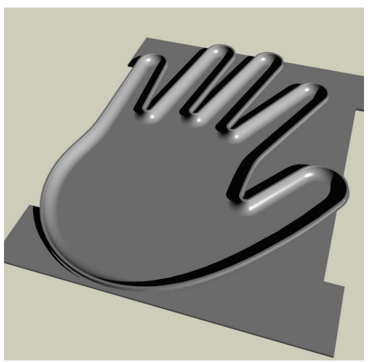
We therefore settled for showing an animated visual of hand and lancet on the screen of the tablet which the user can then follow in front of the tablet. This introduces a level of indirection and is thus a less sophisticated solution than AR guidance displayed on the user's own body. However, we felt it was the right approach as the limitations of tablet-based augmented reality made lancing behind the tablet too awkward.

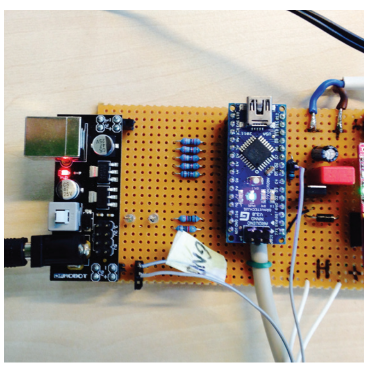
Storyboarding

We sketched out the complete interaction flow to identify at which points the use of AR could make sense.



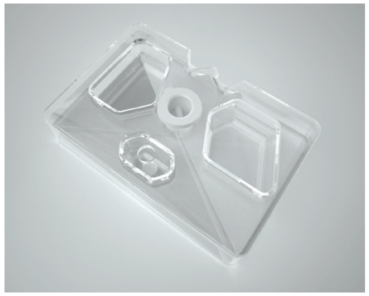


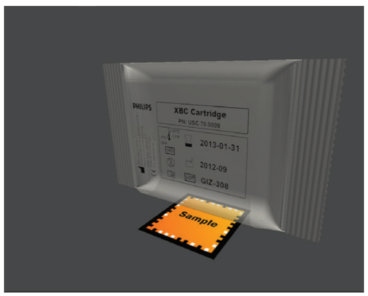




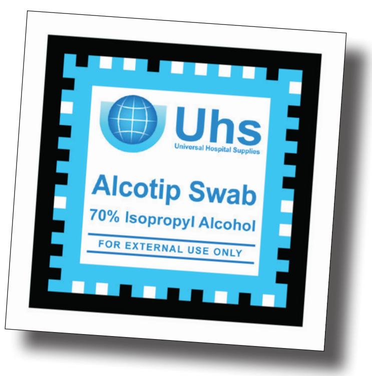
Hand warming unit

One of the things we were intent to improve upon was patients having to warm up their hands in the kitchen sink. It is not only cumbersome but also potentially unhygienic. We therefore developed a hand warming board. Because the best spot to lance is the side of the finger, we made a hand-shaped recess which heats not only the handpalm but also the sides of the fingers. As the cavity is smooth and rounded, it is easy to clean with an alcohol swab.
For our demonstrator we chose to 3D print the hand warming board in steel rather than mill it from solid. This was quicker, cheaper and allowed more form freedom.
One of the challenges was how to detect that patients put their hand on the heating mat. Clearly we could not ask users to put a marker on their hand. Ideally, the tablet would see the hand but recognizing hands through computer vision is notoriously error prone.
We therefore added pressure sensors underneath the hand warming board. These were connected to an Arduino microcontroller which communicated wirelessly with the tablet via Bluetooth. The weight of the hand informed the system whether the user's hand was on the mat or not.

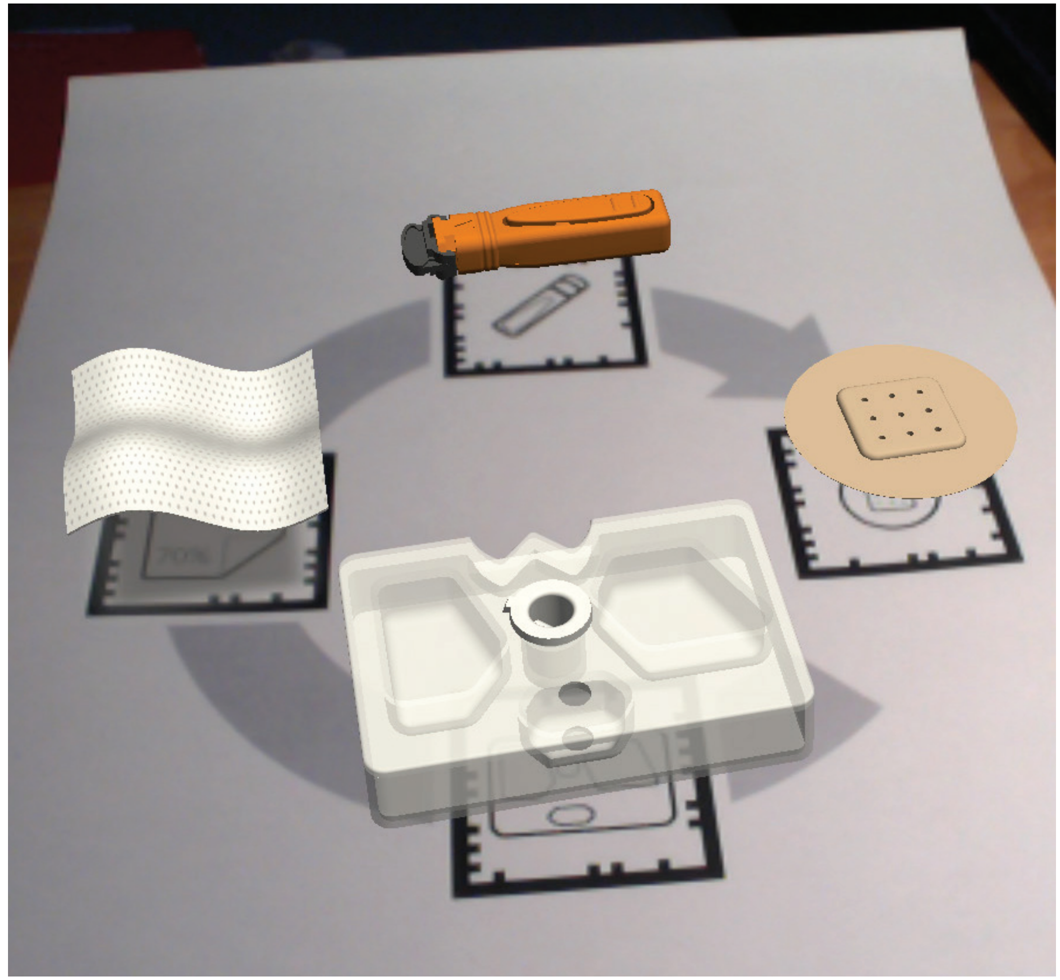




Virtually showing the next step
Our idea was to let Mime virtually show the next step so that the user could simply copy. To be as clear as possible we wanted realistic virtual objects animating in the right physical locations. For this we created virtual versions of all the disposables and their packaging.



Adding markers to packaging
To be able to augment the disposables we had to re-design their packaging to add AR markers which could be tracked by the tablet's camera. We placed the original graphics inside a AR marker edge to respect the corporate identity of the manufacturer.



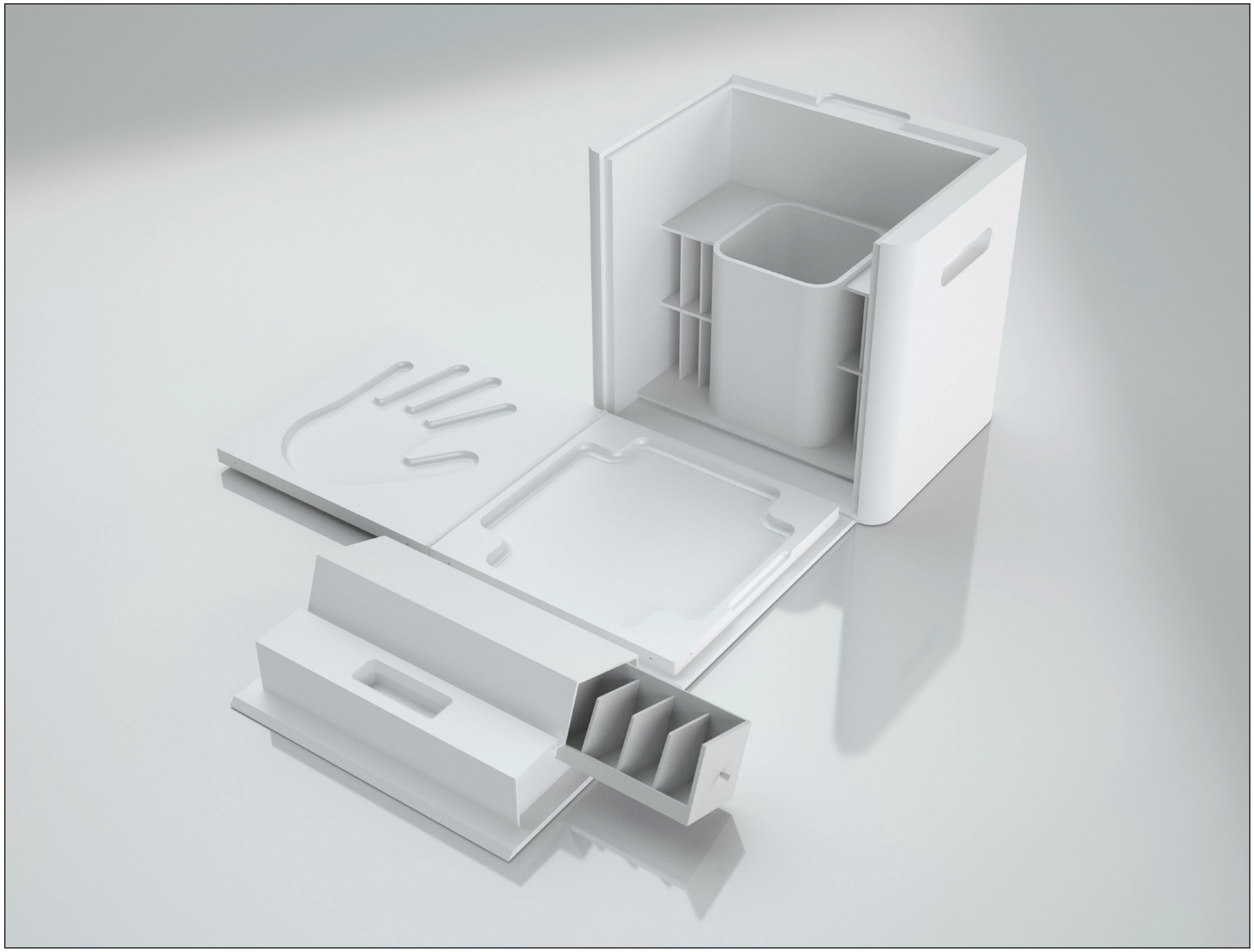
Virtual disposables on gameboard
Our first attempt at augmented the physical gameboard with virtual content. We had to compromise and replace the linear gameboard by a circular one as the field of view of the tablet's camera was too narrow to hold a linear strip of markers in view, even with the addition of a wide angle lens.

Cardboard model of the test set-up
The model includes the stand with the tablet (front), the gameboard (middle), the hand warming plate (left) and the blood analyzer (rear). This pre-model allowed us to test ergonomics and how to place the tablet so that all AR markers could be covered by its camera.

Screenshot of the cardboard test set-up
The blood cartridge has just been placed and has been recognized as shown by the 'text balloon'. The virtual alcohol swap animating down on the gameboard shows that this is the next step that the user has to take.

Product design of folding box

Once we had the interaction concept, we envisaged a folding box which would include all components: the blood analyzer, the game board, the handwarming unit, the tablet stand, the tablet itself and all needed disposables. Using a combination of cardboard and computer modelling we came to box which holds everything together and can fold out flat on the table.



When the user picks the case off the shelf she can be confident that she has everything needed for a blood test together.

Once the case has been folded flat, the user finds the tablet with AR software, the disposables, the analyzer and the handwarming unit.

To dilate the vessels and make it easier to draw a sufficiently large drop of blood, the patient is asked to put her hand on the heating mat. A virtual timer shows how long she needs to keep her hand there.

Through animated virtual objects, the patient is shown how to place the disposables in the best order. Mime always shows the next step, enabling her to simply copy. Once a step has been completed, Mime automatically advances to the next one.

Mime then shows the patient to pick up the lancet and unscrew its cap. Once she has lanced her finger, she can rub a drop of blood into the cartridge. A 45 seconds countdown starts from the moment that Mime hears the click of the lancet.

The final step is to put the cartridge into the blood analyzer. If the user holds the cartridge the wrong way, Mime will show how to correct this by means of a virtual arrow.

We shot a three minute contextual video explaining the purpose and use of Mime. This allowed us to circulate the concept more widely than by means of the demonstrator alone. We gathered feedback from various people within the company including business stakeholders and usability experts who directly work with the patient group.

Discussion

We highlight some points from the feedback we received and add our own reflections.

1. AR as an in-context manual for novice users
The current Minicare Home system uses tablet-based movies to instruct the user. Although this is an improvement on a paper manual, the indirection remains: users watch the movies to build an understanding of the objects and actions involved and then need to apply this to their own situation. In contrast, Mime shows guidance directly on the objects handled by the user and provides immediate feedback on the user's own actions. Whilst using AR to provide instructions has been proposed many times before (Weidenhausen et al., 2003), we feel that in home healthcare its use is particularly appropriate because of the target group. Unlike mechanics or service technicians, patients are novices who strongly benefit from contextualized instructions.

2. AR using a fixed display
AR is often associated with glasses, a technology which is not yet mature, or with handheld smart devices, which rob the user of one hand. With Mime, we make use of a tablet in a stand which already forms part of the current proposition and which leaves the user free to act with both hands.

3. Mime as a Virtual Nurse
When distances are large or traffic is busy, sending out a real nurse to assist the patient is costly in terms of travel time. From a business modelling point of view, this is how the added costs of the AR technology may be offset.

4. Mime as a way to improve scalability
Systems which first require explanation by a knowledgeable nurse during a home visit suffer from a scalability problem. It is much more costly to train and employ staff than to mass produce devices. Systems such as Mime may therefore help improve the scalability of home healthcare.

5. Mime's form factor is currently too big
Whilst the all-in-one solution was appreciated, many felt the folding box was too big. This makes Mime unwieldy for travel, e.g. a weekend trip. A possible alternative would be to print AR markers on a tablet sleeve that could double up as a 'gameboard' on which to order disposables.

Patenting

We filed an patent application on the working principle behind Mime as an 'Augmented Reality-based manual to guide timely object placement in the physical world'.

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References

1. Brinkman, V. (2005). “Neutrophil engulfing Bacillus anthracis”. PLoS Pathogens 1 (3): Cover page.
2. Burns, C., Dishman, E., Verplank, W., and Lassiter, B. (1994). Actors, hairdos & videotape—informance design. In Conference Companion on Human Factors in Computing Systems (CHI ‘94), Catherine Plaisant (Ed.). ACM, New York, NY, USA, 119-120.
3. Home monitoring service for patients undergoing chemotherapy (2016). Retrieved from http://www.philips.co.uk/healthcare/education-resources/publications/hotspot/minicare-home
4. Weidenhausen, J., Knoepfle, C., & Stricker, D. (2003). Lessons learned on the way to industrial augmented reality applications, a retrospective on arvika. Computers & Graphics, 27(6):887-891, 2003.
5. Ylirisku, S. and Buur, J. (2007). Designing with Video. Focusing the user-centred design process.