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Having Fun at Work: Using Augmented Reality in Work Related Tasks

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1. Introduction

Imagine driving down a windy road on a dark and rainy night. The rain makes it nearly impossible to see more than a few feet in front of the car. Now image that through this rain you can suddenly see the lines dividing the lanes as clearly as on a nice day. Or imagine opening a box full of parts that supposedly are the parts of furniture that you just bought from one of the bigger furniture houses in northern Europe. You try to figure out which part is which and how to follow the very simple instructions included in the box. You struggle to hold the paper in one hand and identifying where to put the pieces together with your other hand. Now instead imagine that you put on a pair of glasses and when you open the box you se an arrow pointing at the first piece you need to pick up and then you see how another part in the box is highlighted and how an image of that part is moved through the air showing you how, and with what tool, to put that part together with the first part. In this way you are guided with virtual instructions all the way until you finally can start putting books on the finished shelf or things in the finished drawer. This may sound a bit futuristic but actually it is a very real way of presenting information through a technique called Augmented Reality.

Augmented Reality (AR) is a technology that aims at merging the real and the virtual world, and thereby enhancing, or augmenting, the user's perception of the surrounding environment in varying aspects, as the examples above illustrate. Today there is a wide range of industrial and military AR applications, as well as applications for more entertaining or informative purposes. AR can be used in many different ways, not only to increase productivity in an assembly process (although there may be such effects), but also for the fun of it. However there is a lack of user focus in the development and evaluation of AR systems and applications today. This chapter aims at giving a short introduction to the technology of AR in general but foremost to give an example of an end user AR application used in a regular work related task in the natural environment of the user. We also discuss how usability should be addressed when designing a system without a traditional desktop interface. Current methods within the field of human-computer interaction (HCI) are largely based on findings from cognitive and perceptual theories, focusing on performance and quantitative usability measures. An AR-system, or any other novel mode of interaction is likely to receive poor results in an evaluation based on traditional HCI theories and methods, which are more favourable towards interaction methods the user already is familiar with. Therefore, other ways of evaluating and measuring user experience are more relevant for new ways of interacting with technology. For example, user experience in terms of enjoyment is a large part of user acceptance of a product, deciding if it actually is going to be used or not. In this chapter we describe how new technologies such as AR can be evaluated from a holistic perspective, focusing on the subjective user experience of the system.

2. Background: Augmented Reality and its applications

Augmented Reality is part of a field of technologies usually described as Mixed Reality (MR), which Milgram and Kishino (1994) described as a continuum of real and virtual information (see figure 1).

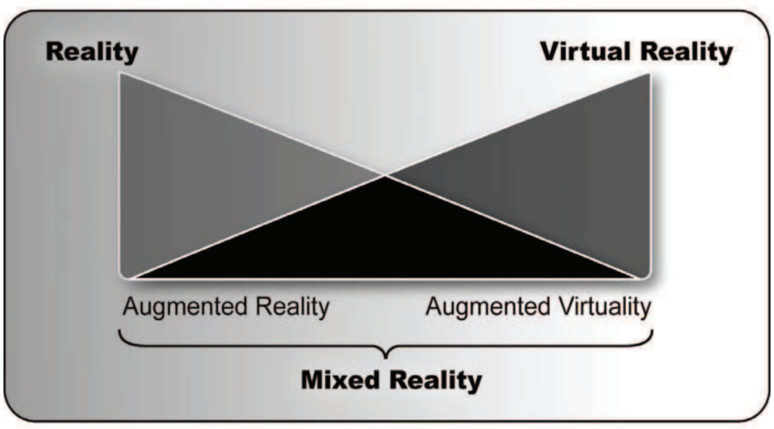


Figure. 1. The Mixed Reality continuum (Milgram & Kishino 1994)

The term 'mixed reality' aims at capturing the conceptual ideas behind the technologies used – the blending, merging or mixing of different realities. Even though it may be an interesting question, this chapter will not discuss the notion of 'reality' or go in to a philosophical debate about what is real and what is not. For the purpose of this text 'reality' is simply what humans perceive as their surrounding in their normal life. Given this definition of reality, 'merging realities' could simply mean merging two images of the world together. However, Azuma (1997) put some constraints on the term and mentions three criteria that have to be fulfilled for a system to be classified as an AR system: they all combine the real and the virtual, they are supposedly interactive in real time (meaning that the user can interact with the system and get response from it without delay), and they are registered and aligned in three dimensions. As an example, motion pictures with advanced 3D effects might have elements of AR, but they are not interactive so they do not qualify in the AR category.

AR applications can be found in diverse domains such as medicine, the military, entertainment and infotainment, technical support and industry applications, distance operation and geographical applications. A common application using AR is to provide instructions on how to operate new or unfamiliar equipment, or how to assemble a more or less complicated object. Tang (2003) describes an experimental evaluation of AR used in object assembly, Zauner et al. (2003) describe how AR can be used as an assembly instructor for furniture applications. The ARVIKA project illustrated several different applications for development, production and service (Friedrich, 2004).

2.1 Augmented Reality technology

The concept of merging realities in this way is not a novel idea of the 21st century. Military history, for instance, illustrates the use of blending real and virtual information by the use of predicted impact points when aiming a weapon, where static markers on a glass lens guides the aim of the shooter. When it comes to allowing a human to perceive immersion into virtual realities, Ivan Sutherland proposed the idea of an "ultimate display" already in 1965. The idea was to let a person wear a display and through that display see, and be in a virtual world. In fact a few years later he proposed and built the first head mounted display prototype (Sutherland, 1968). Technology has come a far way since the late sixties, and nowadays head mounted displays are easy to get a hold of and projecting images into these displays is relatively easy to do. The technology combining or merging real and virtual information does still create some difficulties however. One of the most important issues in AR is tracking or registration - a process necessary in order to align virtual objects with the real world as seen though the display. This chapter will not to great detail deal with technical issues of realising the concept of AR as other sources do a much better job of this (see for instance Kiyokawa, 2007). For an understanding of the technology and its possibilities and limitations some information must however be provided regarding tracking and hardware choices.

How to merge realities

Using a head mounted display there are principally two different solutions for merging reality and virtuality in real time today – video see-through and optic see-through (Azuma, 1997, Kiyokawa, 2007). In optic see-through AR, the user has a head mounted optical see-through display that allows the user to see the real world as if through a glass lens (Kiyokawa, 2007). The virtual information is then overlaid on the see-through display. Although the technique of blending virtual and real information optically is simple and cheap compared to other alternatives, this technique is known to cause some problems. For one, the virtual projection cannot completely obscure the real world image - the see-through display does not have the ability block off incoming light to an extent that would allow for a non-transparent virtual object. This means that real objects will shine through the virtual objects, making them difficult to see clearly. The problem can be solved in theory, but the result is a system with a complex configuration. There are also some issues with placement of the virtual images in relation to the surroundings in optic see through displays. Since the virtual objects presented to the user are semi-transparent they give no depth clues to the user. Instead the virtual objects seem to be aligned along the same focal plane whereas in natural vision, objects are perceived in different focal planes (Gustafsson et al., 2004; Haller et al., 2007).

A way to overcome some of the problems with optic see-through is by using a technique commonly referred to as video see-through AR, where a camera is placed in front of the users' eyes (see figure 2). The captured camera image is then projected to a small display in front of the users' eyes (Azuma, 1997; Kiyokawa, 2007). The virtual images are added to the real image before it is projected which solves the problem with the semitransparent virtual images described above, as well as gives control over where the virtual objects are placed.

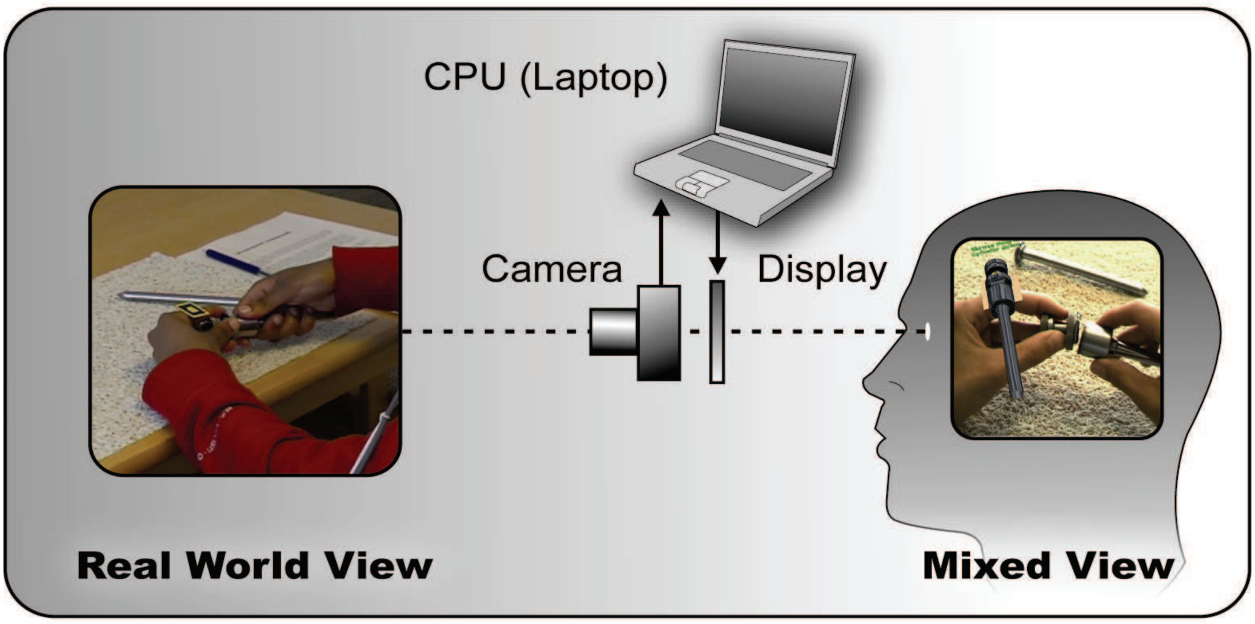


Fig. 2. A schematic view of a video see-through Augmented Reality system.

The video resolution of the camera and display sets the limit for what the user perceivesm The cameras and displays used today offer high-resolution images but unfortunately a field of view that is very limited compared to natural vision. A problem with video based solutions is that there is an eye offset due to the fact that the camera's position can never be exactly where the eyes are located, which gives the user a somewhat distorted experience, since the visual viewpoint is perceived to be where the camera is (Azuma, 1997). The difference between the bodily perceived movement and the visual movement as seen through the display can have effect on the user experience of the system, in some cases even causing motion sickness (Stanney, 1995). Despite these problems there are important vantage points with the video-see through solution. One has already been pointed out – the ability to occlude real objects - and another is that the application designer has complete control over the presented image in real time since it is run through the computer before it is presented to the user. In the optic see through design only the user will see the final augmented image. To conclude; there is a trade-off between the optic see through systems and the camera based systems, and the available resources often determine the choice of solution.

Marker tracking

Regardless of what display solution has been chosen for an AR application the most important issues to solve is how and where to place the virtually generated image. In order to place the virtual information correctly, the AR system needs to know where the user and user view point is. This means that the system has to use some kind of tracking or registration of the surrounding environment. There are different techniques to do this and several of them can be combined to ensure more reliable tracking of the environment (Haller et al., 2007). Tracking is normally done by using different sensors to register the surrounding environment. This sensor information is then used as a basis for placing the virtual information (Azuma et al., 2001). When using video see-through technique the AR system is already equipped with a visual sensor – the camera – which allows for vision based tracking. This tracking technique is one of the most commonly used today and it makes use of visual markers that can be recognized by feature tracking software (Kato & Billinghurst, 1999). Figure 3 below shows an example of a marker that can be used for this purpose.

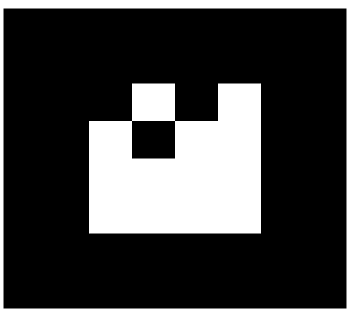


Fig. 3. An example of a marker for vision based tracking.

The marker tracking technique used in the studies presented in this chapter is based on ARToolkit, which is an open software library for building AR applications (Kato & Billinghurst, 1999). By tracking and identifying markers placed in the environment the algorithm calculates the position of the camera relative the marker and hence the virtual information can be placed in the display relative to the marker position. The images seen in figure 2 illustrate how a marker (seen on the user's finger) is used to place the virtual 3D object in the user's field of view.

3. Usability measures and the study of users in Augmented Reality

Although several projects in the AR domain strive to include an end-user perspective there are still few commercially available AR systems, and the research has mainly been focused on technological advances. Very few papers report on results of user studies or HCI evaluations (Bowman et al., 2002; Swan & Gabbard, 2005). Despite the potential of the technology, the research has still primarily focused on prototypes in laboratories, mainly due to the constraints of the hardware currently available to implement the systems (Livingston, 2005). This is also a reason why there are so few end user studies of AR techniques – the hardware constraints also limit the human factor research in the area. Still there have been a few user studies published, and the results point in the same general direction; there are several usability problems that are normally explained by hardware limitations, and despite these problems users respond positively to the use of AR for several different applications (see for example Bach & Scapin, 2004; Haniff & Baber, 2003; Nilsson & Johansson, 2006). There are other issues than hardware that affect the user experience of the

AR system, and these issues may become easier to identify when apparent hardware related issues (such as motion sickness, limited field of view and the lack of depth perception etc) are solved.

The methods used to study AR systems described in the existing literature are mainly based on usability methods used for graphical user interfaces, sometimes in combination with usability for VR applications (Träskbäck et al., 2003; Gustafsson et al., 2005; Dünser et al., 2007). This approach has some complications since it is not based on the experiences from actual AR systems users in actual contexts (Nilsson & Johansson, 2006; 2007b). Usability criteria and heuristics that are considered to be useful for designing new AR systems tend to be general, broad criteria, such as the ones Nielsen presented in his list of usability heuristics in 1993 (Nilsson & Johansson, 2006; Dünser et al., 2007). Usability methods such as cognitive task design (Hollnagel, 2003) where the design approach is based on observations of how a user completes a task in which the system or artefact is involved, also have to deal with the so called 'envisioned world problem' (Woods & Roth, 1998; Hollnagel & Woods, 2005). The 'envisioned world' problem states that even if a good understanding of a task exists, the new design/tool will change the task, rendering the first analysis invalid.

Designing systems based on heuristics developed for computer-based applications may be common practice in the AR field, but there are few examples of studies on how users actually perceive the system in actual use situations. During user studies in a smaller research project users were asked about their experience of the AR system, and none of them even mentioned desktop or laptop computers, or programs when describing what they were interacting through or with (Gustafsson et al., 2005). Instead, words like robot, video game and instructor were used to describe the interaction. The AR system was thus perceived as introducing other properties to interaction than "normal" desktop applications. This could hardly be attributed to the content of the interaction (which mainly was simple instructions of operation), but rather to the fact that the content was presented directly in the context of use. This of course raised questions of how useful it really is to base design of AR systems on desktop computer metaphors and usability criteria.

3.1 User acceptance of technology

When new technologies are introduced into a domain it may affect the user and the task on both a practical and a social level. The process of change requires knowledge, not only about the system introduced but also about the domain. The technical system or interface which is introduced should have as much positive effect on the user and her work as possible, while at the same time minimizing the negative effects of the system both for the user and other individuals.

Fundamental usability awareness implies that the interface or system should not be harmful or confusing to the user, but rather aid the user in her tasks. However, traditional usability guidelines, such as the ones presented by Nielsen (1993) or Shneiderman (1998) often do not include the context of use, the surrounding and the effect the system or interface may have in this respect. Being contextually aware in designing an interface means having a good perception of who the user is and where and how the system can and should affect the user in her tasks.

Davis (1989; 1993) describes two important factors that influence the acceptance of new technology, or rather information systems, in organizations. The perceived usefulness of a system and the perceived ease of use both influence the attitude towards the system, and hence the user behaviour when interacting with the system, as well as the actual use of the system (see figure 4).

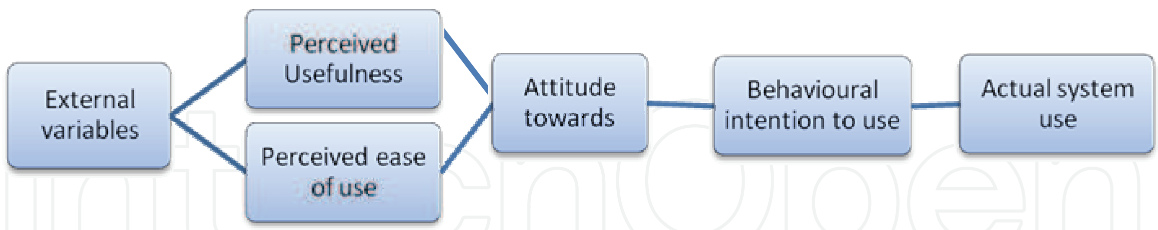


Fig. 4. The Technology Acceptance Model derived from Davis, 1989 (Nilsson & Johansson, 2007b).

If the perceived usefulness of a system is considered high, the users can accept a system that is perceived as less easy to use, than if the system is not perceived as useful. For AR systems this means that even though the system may be awkward or bulky, if the applications are good, i.e. useful, enough, the users will accept it. Equally, if the AR system is not perceived useful, the AR system will not be used, even though it may be easy to use.

3.2 Cognitive Systems Engineering as a basis for analysis[1]

Traditional approaches to usability and human computer interaction assumes a de-composed view with separate systems of humans and artifacts. As noted previously, the idea of the human mind as an information processing unit which receives input and generates output has been very influential in the domain of human computer interaction. A basic assumption in the information processing approach is that cognition is studied as something isolated in the mind. A problem with many of these theories is that they mostly are based on laboratory experiments investigating the internal structures of cognition, and not on actual studies of human cognition in an actual work context (Neisser, 1976; Dekker & Hollnagel, 2004).

A holistic approach to human-machine interaction has been suggested by Hollnagel and Woods called ‘cognitive systems engineering’ (CSE) (Hollnagel & Woods 1983; 2005). The approach is loosely based upon findings and theories from, among others, Miller et al. (1969) and Neisser (1976). The core of this approach is the questioning of the traditional definition of cognition as something purely mental: “Cognition is not defined as a psychological process, unique to humans, but as a characteristic of system performance, namely the ability to maintain control. Any system that can maintain control is therefore potentially cognitive or has cognition” (Hollnagel & Woods, 2005).

In the CSE approach is important to see the system as a whole and not study the parts in isolation from each other. The cognitive system can be comprised of one or more humans interacting with one or more technical devices or other artifacts. In this cognitive system, the human brings in the ‘natural cognition’ to the system and artifacts or technological systems may have ‘artificial cognition’. Hollnagel and Woods (2005) uses the notion ’joint cognitive system’ (JCS) to describe systems comprised of both human and technological components

[1] This section has in parts previously been presented in Nilsson & Johansson 2007a.

that strive to achieve certain goals or complete certain tasks. The JCS approach thus has a focus on function rather than structure, as in the case of information processing, which is the basis for most traditional HCI. A CSE approach to humans and the tools they use thus focus rather on what such a system does (function) rather than what is (structure). A consequence of that perspective is that users should be studied when they perform meaningful tasks in their natural environments, meaning that the focus of a usability study should be user performance with a system rather than the interaction between the user and a system. A design should thus be evaluated based on how users actually perform with a specific artifact, but the evaluation should also be based on how they experience that they can solve the task with or without the artifact under study.

Using tools or prosthesis

As stated above, the main constituents in a JCS are humans and some type of artifact. Hutchins (1999) defines cognitive artifacts as "physical objects made by humans for the purpose of aiding, enhancing, or improving cognition". Hollnagel and Woods (2005) define an artifact as "something made for a specific purpose" and depending upon this purpose and how the artifact is used, it can be seen as either as a tool or as prosthesis. A tool is something that enhances the users' ability to perform a task or solve problems. Prostheses are artifacts that take over an already existing function. A hearing aid is a prosthesis for someone who has lost her/his hearing while an amplifier can be a tool for hearing things that normally are too quiet to be heard. Another example is the computer which is a very general tool for expanding or enhancing the human capabilities of computation and calculation, or even a tool for memory support and problem solving. But the computer can also be used not only to enhance these human capabilities but also to replace them when needed. A computer used for automating the locks of the university buildings after a certain time at night has replaced the human effort of keeping track of time and at the appropriate time going around locking the doors. The way someone uses an artifact determines if it should be seen as a tool or prosthesis, and this is true also for AR systems. AR systems are often very general and different applications support different types of use. So as with the computer, AR systems can be used either as tools or as prostheses, which can have effect on the perceived usability and hence the appropriate design of the system. It is very rare to evaluate a computer in general – usability evaluations are designed, and intended to be used for specific applications within the platform of the computer. This should also be the case for AR systems – to evaluate and develop usability guidelines for the general AR system platform is both impossible and pointless. Evaluating the AR applications however is necessary to ensure a positive development of future AR systems so that they better support the end user applications.

4. Two examples of end user applications

In this section two end user studies are described as examples of AR applications developed and evaluated in cooperation with the end users. The studies are grounded in the core CSE idea that users should be studied in their natural environment while solving meaningful tasks. The AR applications developed for these user studies were both developed in cooperation and iteration with an experienced operating room nurse and a surgeon. This professional team of two described problematic issues around which we used the AR technology to aid them in performing the task of giving instructions on two common medical tools.

The basic problem for both applications was how to give instructions on equipment both to new users, and to users who only use the equipment at rare occasions. Normally a trained professional nurse would give these instructions but this kind of person-to-person instruction is time consuming and if there is a way to free up the time of these professional instructors (nurses) this would be valuable in the health care organisation. The AR applications were therefore accordingly aimed at simulating human personal instructions. It is also important to note that the aim of these studies was not to compare AR instructions with either personal instructions or paper manuals in any quantitative measures. The focus was not speed of task completion or other quantitative measures, the focus was instead on user experience and whether or not AR applications such as the ones developed for these studies could be part of the every day technology used at work places like the hospital in the studies. The results from the studies have been reported in parts in Nilsson & Johansson 2006, 2007b and 2008.

4.1 The first study

The specific aim of the first study was to investigate user experience and acceptance of an AR system in an instructional application for an electro-surgical generator (ESG). The ESG is a tool that is used for electrocautery during many types of surgical procedures. In general electrocautery is a physical therapy for deep heating of tissues with a high frequency electrical current. The ESG used in this study is used for mono- or bipolar cutting and coagulating during invasive medical procedures (see figure 5). When using this device it is very important to follow the procedure correctly as failing to do so could injure the patient. Part of the task is to set the correct values for the current passing through the device, but most important is the preceding check up of the patient before using the tool – the patient cannot have any piercings or any other metal devices on or in the body, should not be pregnant, and most importantly, the areas around the patient must be dry as water near electrical current can cause burn injuries.

The AR system used in this study included a tablet computer (1GHz Intel®Pentium® M, 0.99GB RAM) and a helmet mounted display with a fire wire camera attached. The camera was also used for the hybrid tracking technology based on visual marker tracking (Gustafsson et al., 2005). A numeric keypad was used for the interaction with the user (see insert, figure 5).

Fig. 5. To the right, the helmet-mounted Augmented Reality System. To the left, the electro-surgical generator prepared with markers for the tracking.

A qualitative user study was conducted onsite at a hospital and eight participants (ages 30 – 60), all employed at the hospital, participated in the study. Four of them had previous experience with the ESG, and four did not. All of the participants had experience with other advanced technology in their daily work. First the participants were interviewed about their experience and attitudes towards new technology and instructions for use. Then they were observed using the AR system, receiving instructions on how to start up the ESG. After the task was completed they filled out a questionnaire about the experience.
The instructions received through the AR system were developed in cooperation and iteration with an experienced operating room nurse at the hospital in a pre study. The instructions were given as statements and questions that had to be confirmed or denied via the input device, in this case a numeric keypad with only three active buttons – 'yes', 'no', and 'go to next step'. An example of the instructions from the participants' field of view can be seen in figure 6.

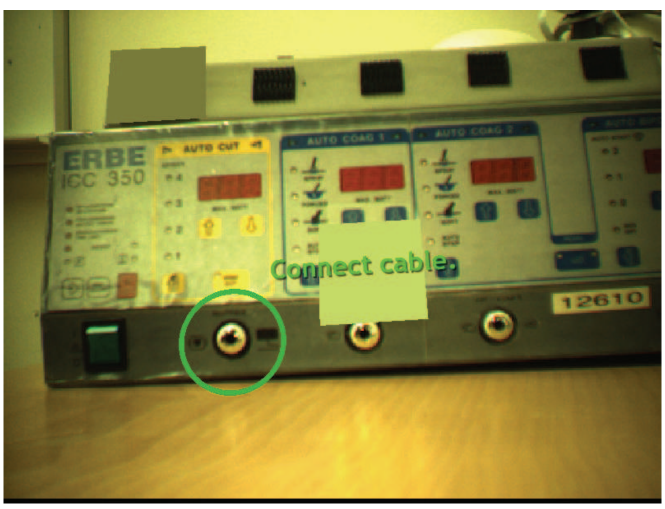


Fig. 6. The participants' view of the Augmented Reality instructions.

Data was collected both through observation and open ended response questionnaires. The questionnaire consisted of questions related to overall impression of the AR system, experienced difficulties, experienced positive aspects, what they would change in the system and whether it is possible to compare receiving AR instructions to receiving instructions from a teacher.

Results of the first study[2]
It was found that all participants but one could solve the task at hand without any other help than by the instructions given in the AR system. In general the interviewed responded that they preferred personal instructions from an experienced user, sometimes in combination with short, written instructions, but also that they appreciated the objective instructions given by the AR system. The problems users reported on related both to the instructions given by the AR system and to the AR technology, such as problems with a

[2] A detailed report on the results of the study is presented in Nilsson & Johansson, 2006.

bulky helmet etc. Despite the reported problems, the users were positive towards AR systems as a technology and as a tool for instructions in this setting.

All of the respondents work with computers on a day to day basis and are accustomed to traditional MS Windows™ based graphical user interfaces but they saw no similarities with the AR system. Instead one respondent even compared the experience to having a personal instructor guiding through the steps: "It would be if as if someone was standing next to me and pointing and then… but it's easier maybe, at the same time it was just one small step at a time. Not that much at once."

Generally, the respondents are satisfied with the instructions they have received on how to use technology in their work. However, one problem with receiving instructions from colleagues and other staff members is that the instructions are not 'objective', but more of "this is what I usually do". The only 'objective' instructions available are the manual or technical documentation and reading this is time consuming and often not a priority. This is something that can be avoided with the use or AR technology – the instructions will be the same every time much like the paper manual, but rather than being simply a paper manual AR is experienced as something more – like a virtual instructor.

The video based observation revealed that the physical appearance of the AR system may have affected the way the participants performed the task. Since the display was mounted on a helmet there were some issues regarding the placement of the display in from of the users' eyes, so they spent some time adjusting it in the beginning of the trial. However since the system was head mounted it left the hands free for interaction with the ESG and the numerical keypad used for answering the questions during the instructions. As a result of the study, the AR system has been redesigned to better fit the ergonomic needs of this user group. Changes have also been implemented in the instructions and the way they are presented which is described in the next study.

4.2 The second study

The second study referred to here is a follow up of the first study. The main differences between the studies are the AR system design and the user task. The AR system was upgraded and redesigned after the first study was completed (see figure 5). It included a head mounted display, an off the shelf headset with earphones and a microphone and a laptop with a 2.00 GHz Intel®Core™ 2 CPU, 2.00 GB RAM and a NVIDIA GeForce 7900 graphics card. Apart from the hardware, the software and tracking technique are basically the same as in the previous study. One significant difference between the redesigned AR system and the AR system used in the first study is the use of voice input instead of key pressing. The voice input is received through the headset microphone and is interpreted by a simple voice recognition application based on Microsoft's Speech API (SAPI). Basic commands are OK, Yes, No, Backward, Forward, and Reset.

The task in this study was also an instructional task. The object the participants were given instructions on how to assemble was a common medical device, a trocar (see fig 7). A trocar is used as a port, or a gateway, into a patient during minimal invasive surgeries. The trocar is relatively small and consists of seven separate parts which have to be correctly assembled for it to function properly as a lock preventing blood and gas from leaking out of the patient's body.

Fig. 7. To the left, the separate parts of a trocar. Tot he right, a fully assembled trocar.

The trocar was too small to have several different markers attached to each part. Markers attached to the object (as the ones in study 1) would also not be realistic considering the type of object and its usage – it needs to be kept sterile and clean of other materials. Instead the marker was mounted on a small ring with adjustable size that the participants wore on their index finger (see figures 8 a and b).

Fig. 8a) The participant's view in the HMD. b) A participant wearing the head mounted display and using the headphones and voice interaction to follow the AR instructions.

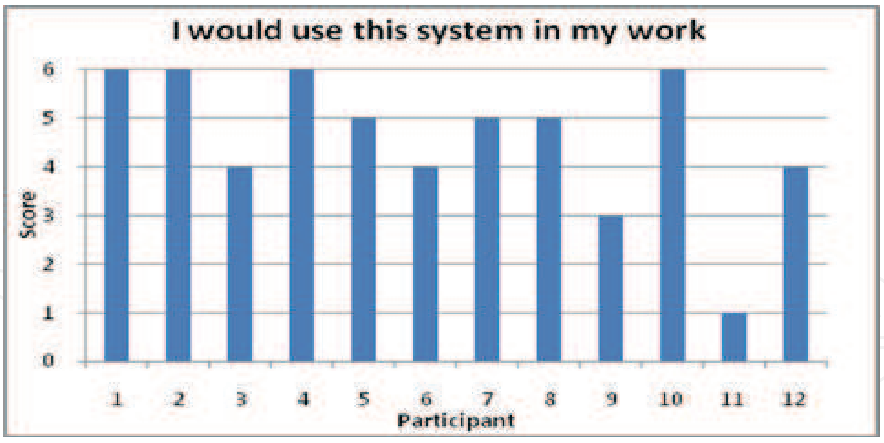
Instructions on how to put together a trocar are normally given on the spot by more experienced nurses. To ensure realism in the task, the instructions designed for the AR application in this study was also designed in cooperation with a nurse at a hospital. An example of the instructions and animation can be seen in figure 8a. Before receiving the assembly instructions the participants were given a short introduction to the voice commands they can use during the task; OK to continue to the next step, and back or backwards to repeat previous steps.
Twelve professional nurses and surgeons (ages 35 – 60) at a hospital took part in the study. The participants were first introduced to the AR system. When the head mounted display

and headset was appropriately adjusted they were told to follow the instructions given by the system to assemble the device they had in front of them.
As in the previous study, data was collected both through direct observation and through questionnaires. The observations and questionnaire was the basis for a qualitative analysis. The questionnaire consisted of 14 statements to which the users could agree or disagree on a 6 point likert scale, and 10 open questions where the participants could answer freely on their experience of the AR system. The questions related to overall impression of the AR system, experienced difficulties, experienced positive aspects, what they would change in the system and whether it is possible to compare receiving AR instructions to receiving instructions from a teacher.

Results of the second study[3]

All users in this follow-up study were able to complete the task with the aid of AR instructions. The responses in the open questions were diverse in content but a few topics were raised by several respondents and several themes could be identified across the answers of the participants. Issues, problems or comments that were raised by more than one participant were the focus of the analysis.
Concerning the dual modality function in the AR instructions (instructions given both aurally and visually) one respondent commented on this as a positive factor in the system. Another participant had the opposite experience and considered the multimedial presentation as being confusing: "I get a bit confused by the voice and the images. I think it's harder than it maybe is".
A majority among the participants were positive towards the instructions and presentation of instructions. One issue raised by two participants was the possibility to ask questions. The issue of feedback and the possibility to ask questions are also connected to the issue of the system being more or less comparable to human tutoring. It was in relation to this question that most responses concerning the possibility to ask questions, and the lack of feedback were raised.
The question of whether or not it is possible to compare receiving instructions from the AR system with receiving instructions from a human did get an overall positive response. Several of the respondents actually stated that the AR system was better than instructions from a teacher, because the instructions were "objective" in the sense that everyone will get exactly the same information. When asked about their impressions of the AR system, a majority of the participants gave very positive responses and thought that it was "a very interesting concept" and that the instructions were easy to understand and the system as such easy to use. A few of the participants did 7however have some reservations and thought it at times was a bit tricky to use.
The result of this study as well as the previous study, indicate that the acceptance of AR instructions in the studied user group is high. To reconnect with the idea of measuring the usefulness of a system rather than just usability the second study also included questions about the use of AR as a supportive tool for learning how to assemble or use new technology, both in work related tasks and in other situations. The users were in general very positive as these diagrams illustrate:

[3] A detailed report on the results of the study is presented in Nilsson & Johansson, 2007b.



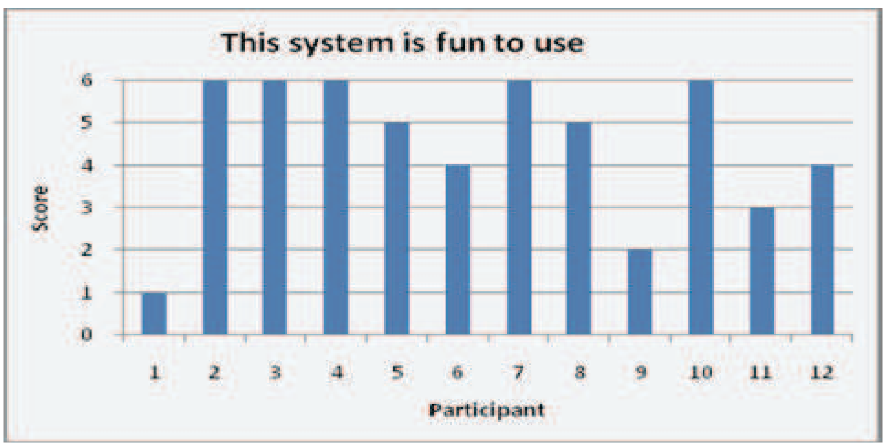


Fig. 9. a) Top, the responses to the statement "I would like to use a system like this in my work". b) Bottom, the responses to the statement "This system is fun to use" (6 is the most positive grade and 1 the most negative for further details see Nilsson & Johansson 2007b).

As can be seen in the graph to the left in figure 9 one of the participants definitely does not want to use this kind of system in their work, while four others definitely do want to use this kind of system in their work. Interestingly enough one participant, who would like to use the AR system at work, does not find it fun to use (see figure 9 above). In general though the participants seem to enjoy using the system and this may be an indicator that they see it as a useful tool in their normal work tasks.

4.3 Lessons learned in the two user studies

The overall results from both studies shows a system that the participants like rather than dislike regardless of whether they received instructions in two modalities or only one. Both studies indicate that the participants would like to use AR instructions in their future professional life. Despite some physical issues with the AR system all users but one did complete the task without any other assistance. However, effects of the physical intrusion of the system upon the users' normal task should not be ignored. Even if the system is lightweight and non-intrusive, it still may change the task and how it is performed. This may not be a problem in the long run – if the system is a positive influence on the task, user and context, it will with time and experience grow to be a part of the task (much like using computers have become part of the task of writing a paper).

Interactivity is an important part of direct manipulating user interfaces and also seems to be of importance in an AR system of the kind investigated in these studies. A couple of the participants who were hesitant to compare AR instructions to human instructions, motivated their response in that you can ask and get a response from a human, but this AR system did not have the ability to answer random questions from the users. Adding this type of dialogue management in the system would very likely increase the usability and usefulness of the system, and also make it more human-like than tool-like. However, this is not a simple task, but these responses from real end users indicate and motivate the need for research in this direction. Utilizing knowledge from other fields, such as natural language processing, has the potential to realize such a vision.

In a sense AR as an instructional tool apparently combines the best from both worlds – it has the capability to give neutral and objective instructions every time and at the same time it is more interactive and human like than paper manuals in the way the instructions are presented continuously during the task. But it still has some of the flaws of the more traditional instructional methods – it lacks the capability of real-time question-answer sessions and it is still a piece of technical equipment that needs updates, upgrades and development.

5. Concluding discussion

AR is a relatively new field in terms of end user applications and as such, the technological constraints and possibilities have been the driving forces influencing the design and development. This techno-centred focus has most likely reduced the amount of reflection that has been done regarding any consequences, other than the technical, of introducing the technology in actual use situations. The impact of the way AR is envisioned (optic see-through and video see-through) has largely taken focus off the use situation and instead lead to a focus on more basal aspects, such as designing to avoid motion sickness and increasing the physical ergonomics of the technology. However, these areas are merely aspects of the platform AR, not of the applications it is supposed to carry and the situations in which they are supposed to be used. Studies of AR systems require a holistic approach where focus is not only on the ergonomics of the system or the effectiveness of the tracking solutions. The user and the task the user has to perform with the system need to be in focus throughout the design and evaluation process. It is also important to remember that it is not always about effectiveness and measures – sometimes user attitudes will determine whether or not a system is used and hence it is always important to look at the actual use situation and the user's attitude towards the system.

The purpose of the system is another important issue when evaluating how useful or user-friendly it is – is it intended for pleasure and fun or is it part of a work setting? If it is somewhat forced on the user by it being part of everyday work and mandatory tasks, the system needs to reach efficiency standards that may not be equally important if it is used as a toy or entertainment equipment. If the system is a voluntary toy the simplicity factor is more important than the efficiency factor. On the other hand, if a system is experienced as entertaining, chances are it may actually also be perceived as being easier to use. It is not a bold statement to claim that a system that is fun and easy to use at work will probably be more appreciated than a system that is boring but still reaches the efficiency goals. However, as the technology acceptance model states – if the efficiency goals are reached (i.e. the users find it useful) the users will most likely put up with some hassle to use it anyway. In the case of the user studies presented in this chapter this means that if the users actually feel that the AR instructions help them perform their task they may put up with some of the system flaws, such as the hassle of wearing a head mounted display or updating software etc, as long as the trade off in terms of usefulness is good enough.

As discussed previously in the chapter there is a chance that the usability focused methodology measures the wrong thing – many interfaces that people use of their own free will (like games etc) may not score high on usability tests, but are still used on a daily basis. It can be argued that other measures need to be developed which are adapted to an interface like AR. Meanwhile, the focus should not be on assessing usability but rather the experienced usefulness of the system. If the user sees what he can gain by using it she will most likely use it despite usability tests indicating the opposite.

The field of AR differs from standard desktop applications in several aspects, of which the perhaps most crucial is that it is intended to be used as a mediator or amplifier of human action, often in physical interaction with the surroundings. In other words, the AR system is not only something the user interacts with through a keyboard or a mouse. The AR system is, in its ideal form, meant to be transparent and more a part of the users perceptive system than a separate entity in itself. The separation between human and system that is common in HCI literature is problematic from this point of view. By wearing an AR system the user should perceive an enhanced or augmented reality and this experience should not be complicated. Although several other forms of systems share this end goal as well, AR is unique in the sense that it actually changes the user's perception of the world in which he acts, and thus fundamentally affects the way the user behaves. Seeing virtual instructions in real time while putting a bookshelf together, or seeing the lines that indicate where the motorway lanes are separated despite darkness and rain will most likely change the way the person assembles the furniture or drives the car. This is also why the need to study contextual effects of introducing AR systems seems even more urgent. When evaluating an AR system, focus has to be on the goal fulfilment of the user-AR system rather than on the interface entities and performance measures gathered from evaluation of desktop applications. This approach is probably valid in the evaluation of any human machine system, but for historical reasons, focus often lays on only one part of the system.

AR as an interaction method for the future is dependent on a new way of addressing usability – if the focus is kept on scoring well in usability tests maybe we should give up novel interfaces straight away. But if the focus is on the user's subjective experience and level of entertainment or acceptance, AR is an interactive user interface approach that surely has a bright future.

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