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Display Scale in a 'Document' perspective: size matters

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Preface

The work reported within this thesis is both scientifically and personally an exploration. It is somewhat of an exploration of the subject in question: 'display scale' in a medical- and document-(ation) context, but also an exploration of the landscape of contemporary science. I am inclined to point out that this thesis is authored in two particular 'styles'; the first summary is written in a somewhat personal and to a certain degree 'biographical' fashion, while the papers follow a more stringent scientific style. For readers interested in the full picture of this work I would suggest reading the introduction chapter (Chapter 1) and proceed with the collection of papers (Paper 1 through Paper 9) before continuing with the rest of this document.

My personal journey in this effort to learn to know and do research started from skills within engineering and specific knowledge about distributed systems and applications. This has been the specialty-field of our Computer Science department (at UiT) for over 20 years, and so basically most students with an engineering degree from this faculty have had a quite thorough education within this subject. The specific work-description for the funding of my work, however, has required me to learn the methods and skills from other computer science fields, such as CSCW and HCI (which I consider the more general umbrella term) – while also trying to make use of my professional training from engineering – and keep on expanding my knowledge of Medical Informatics.

I asked one of my advisors in the beginning of my work what his opinion was on whether I should go in-depth or in-breadth when designing my research. I explained that I was rather confused and also overwhelmed by a subject (large, high-resolution displays) that was fairly immature in my profession (Computer Science) and, to make a grave understatement, much less explored in the multidisciplinary context of Medical Informatics. His answer, which surprised me at that time (or rather – educated me), seems overwhelmingly rational in retrospect; if little research exists, there is little use of going in-depth. However, he remarked, that research should always seek to reach to depth, even if a project – as a whole, needs to spread its attention to several issues. I feel that I have used this piece of advice, and this frustrating situation, to my benefit and visited several other fields of study along the way and also several layers of scientific work: I have worked with people from the faculty of humanities and joined their work in developing theories and models suited to understand the nature of digital information and human nature on the one side. On the other side I have joined forces with people from the social science of psychology to study human perceptual nature, at a basic level, and finally, I have used engineering methods from the field of Computer Science to try and use this new-gained insight into different aspects of the same topic: design of large, high-resolution displays for medical purposes; although the work reported here did not reach as far as into the Display Wall project. Underway I have also learned to know the science of medicine and something about how to apply our knowledge and engineering efforts to a common good. In this regard, I feel that I have 'commuted' between basic and applied science at occasions. All I can hope for at this point – is that readers of this work will feel that I have not drifted too far astray, but that the travel is pleasant and that I reach a relatively safe harbor in the end.

All in all it has been a fascinating journey for which I am deeply grateful to all the knowledgeable people and researchers that have taken me inside their home of research and patiently helped me along the way.

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Naming conventions and abbreviations

CSCW Computer Supported Cooperative Work: multidisciplinary field of study reaching within and across Computer Science, Sociology, Anthropology and several related within the Social Sciences.

HCI Human Computer Interaction: multidisciplinary field of study reaching within and across Computer Science, Psychology, Ergonomics, Human Factors Engineering and related fields of study.

LaHiRD Large, High-Resolution Display

FOV Field Of View

OSS Open Source System

PACS Picture Archiving and Communications System (medical imaging)

RTP Radiation Therapy Planning

UNN University Hospital of Northern-Norway

UiT University of Tromsø

VNC Virtual Network Computer

Display Wall (Capitalized first letters) "*The*" display wall (our reference technology) at the department of computer science in Tromsø: a tiled display consisting of 28 projectors and an equal number of cluster nodes (Dell PCs), see description below. I will also use Wall for short.

display wall A general tiled display (mainly those vertically built, in this context)

Extended Summary

The work summarized in this thesis has its basis in technology to support human collaboration. I have investigated how large, high-resolution display (LaHiRD) technology, implemented using display wall technology (large, tiled displays implemented as one coherent display surface) could support clinical work. Hence, I have worked with the topic of technological support for human collaboration (or –interaction) in a medical context.

Furthermore, I have tried to perform this research from what I label a 'document'-perspective. This implies that I have tried to look at this technology, the vast display-surface and with the potential to display colossal amounts of information simultaneously, through a *document-lens*. By a 'document-lens' I mean utilizing document theory (Lund, 2009), starting with what constitutes a meaningful 'whole' when collating information (-fragments) to be displayed onto one large display.

In the beginning I surveyed the state of large, high-resolution display research – both from a technological perspective, as well as a human-factors perspective. At the same time, we initiated collaboration efforts with the local university hospital (UNN) in order to elucidate promising venues to implement LaHiRD technology. At the start of the PhD project I also established a close cooperation with Document Studies at UiT, basically establishing the mentioned document lens. This initial work led me to investigate what kinds of particular uses LaHiRD technology could be of in a clinical context, and how the size of the display changes the document – even though the underlying information sources do not change. Establishing what other researchers had found LaHiRDs to be useful for – and some limitations with the technology as well – I found the large physical size *and* increase in inherent data *content* (amount of visually available information) in the documents on the Display Wall to afford social-interaction and, hence, group-work particularly well. In this initial work, I looked at the Radiation Therapy Planning (RTP) process, because it is display-intensive (much data to be presented in the process), but this process is, by default, not particularly 'social'[1].

Summarized, I found LaHiRD technology's most prominent and interesting features to be the possibility for arbitrary sized displays and vast pixel-counts achievable. This affords a wide-range of uses, but is particularly interesting for group work situations and enables a more 'natural' and embodied 'arena' for reasoning[2]. Consequently, I provide a hypothesis for clinical 'gain-potential' (from LaHiRDs)[3].

It was decided to focus on group-work situations within hospitals and I turned to the Radiology Department. With this effort, I wanted to explore both the potential with the technology as described above, and also probe for expert

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[1] The RTP process involves several people, but do not require simultaneous work but rather is a pipeline-process.

[2] LaHiRDs "… create an environment that blurs the lines between physical and virtual. space …"(Andrews et al., 2010)

[3] *"More (additional) visually available information can aid/improve the cognitive (shared/distributed) decision making process" (Lund et al., 2007)*, p. 403.

clinicians' opinions and visions for LaHiRDs – in a clinical context. In collaboration with the Radiology department at UNN I decided to pursue the implementation of a prototype radiology interface for the Display Wall. The radiologists provided a patient case, selected by them. I designed a crude interface example, which was presented in a demo for the UNN radiologists and a couple of other invited specialists. I tried to resemble a clinical presentation when performing this demo in order to try and 'lure' the clinicians into a professional mode (if at all necessary). That is, I made an effort to stimulate a discourse regarding the potential use for LaHiRDs, rather than that the demo would be perceived as technologists trying to 'sell' novel technology. This demo was videotaped and transcribed and the main results were extracted from these data, and others from the notes and interviews made in the design process for the radiology interface.

I found that yes: the clinicians were quite positive towards the clinical potential for LaHiRDs, such as the Display Wall. During observations I noticed that much patient (case-) information was shared orally by the radiologist presenting the case. This information, along with biographical information, as well as patient-logistical information; referrals and referral-letters, patient history – were suggested – could well be visible as contextual information on extra display area provided by LaHiRDs. It was also quite interesting to learn that in their presumably first encounter with this kind of technology, these clinical specialists were quite critical to cascading of image series, spreading the images throughout the wall[4]. This leads me to believe that using the extra display surface available in LaHiRDs for cascading image series (like tradition was before digital imaging) is probably not very useful for radiologists in particular. Focus in future studies should be information design with more diverse and currently (visually-) unavailable information – and specific information to support the workflow and specific cognitive processes of group work-settings.

I also realized (along with many others before us) that display size – that is – the size at which something is displayed has cognitive consequences. Having such a large display available: how large should objects be – and how much room can you spare for additional information, when display resolution allows for it? Much of contemporary research was at this time focusing on cognitive effects of display size. For instance: how does it affect our experience of the documents displayed that size increases? Does increasing size help our problem solving? Does increasing size help some groups of users more than others? Which tasks are affected by display size in this regard? Such questions have been posed and answered during the last decade and some of the results were intriguing for my work as well.

I initiated contact with Department of Psychology at UiT and in a collaborate effort we found that we could try and figure out how tasks similar to those performed at a Radiology department is affected by display size. We decided to design an experiment to test how display size affects a spatial ability called 'mental rotation' (MR). Mental rotation is the task of deciding whether two

[4] Cascading was used before digital imaging in Radiology and novel interface models (image stacking) has replaced this regime

images of arm-like structures, made from cubes attached face to face, are the same (see Figure 8). The images are two-dimensional illustrations of three-dimensional objects, where the two objects may be the same (isomorph), but one is rotated compared to the other (by a certain amount/degrees) – or it can be a different object (often, in experiments – a mirrored object is used for the 'different' object). This task is intuitively similar to the kind of work performed at a radiology department. 'Objects' (organs, body-parts, blood vessels, etc.) are viewed from different angles ('coronal', 'sagittal', 'transverse') and 'healthy objects' are compared to 'pathological'[5].

Previous studies of related work I found were inconclusive at best regarding how this ability is affected by display size. In our research design we decided to test performance on a regular laptop display to performance on the Display Wall in the mental rotation task. We designed two separate experiments. Both were a mixed design with Display Size and Angle (-of rotation between the MR stimuli objects) were within-subjects factors, while Sex was between-subjects factor. Our first study included 40 subjects of 4 groups where we alternated the two groups of males/females of which display condition they were tested first in. We also added one between-subjects factor labelled "Expectation". After consideration of related research we found that none of the previous studies had controlled for a "Hawthorne Effect" – that is – subjects' awareness of working hypothesis – or simply the fact of being in an experiment and testing *novel* technology. Hence, we presented half of the participants in the first experiment with a hypothesis stating that large displays should yield better performance, while the other half were presented with the opposite hypothesis – that smaller displays provides better performance. We found that females *were* indeed *faster* than males on the large display (but no difference in accuracy). However, the group of females who had been presented prior to the experiment with the hypothesis that large displays are *better* were performing significantly faster than all other three groups (females 'believing' that small displays are superior and both male groups).

In order to strengthen this finding, or reject the hypothesis that the display size was affecting female performance (and that 'belief' alone was making females better), we designed a new experiment where we left out any explicit information regarding hypothesis. In the second experiment we also recruited more subjects in order to provide more evidence to our finding. We had 36 males and 32 females perform the same task as in the first experiment and we improved the research design. We used a high-speed camera to compute – and 'control' – a network delay in stimulus onset for the large display condition. This made within-subjects comparison in performance on small contra large display more reliable. Again we found that females significantly outperformed males in the large display condition. On average, females were about 20% faster than

[5] An interesting finding with the MR task is that since its discovery in the early 1970s (Shepard and Metzler, 1971), a robust and persistent sex difference in performance has been observed, where males tend to outperform females in both speed and accuracy (Linn and Petersen, 1985, Peters, 2005). This sex difference in MR also seems to transcend cultural differences, as a recent study reports of this finding in 53 of 53 countries (Lippa et al., 2010). Related research on (cognitive-) effects of display size had also found that females may improve performance on large displays, compared to males (Czerwinski et al., 2002, Tan et al., 2003a).

males in the large display condition. However, females did not perform faster on the Display Wall than on the laptop display. What we found, rather, was that males and females performed similar in the smaller laptop display condition and that the Display Wall condition had a significant detrimental effect on male performance, actually deteriorating their small-display performance by 20%.

In summary, we have found that visually enlarging objects may have a detrimental effect on work-tasks that involve mental rotation of three-dimensional objects – a task that resembles the work typically performed in Radiology departments. This effect was observed with objects about twice the size of typical object sizes used in the traditional Shepard-Metzler MR task (comparing two objects at a time).

At a time in this PhD project where it would have been natural to try and scale the Radiology prototype up to an installation at the local university hospital (UNN), the focus was turned to Californian health issues. The radiology demo was, in fact, performed only weeks before my departure for a research stay of one year's duration at UC Davis. The objective, in the document lens, was – so to speak – pragmatically changed from LaHiRD technology to telepsychiatry in northern California. The natural progression for my PhD work without this turn of events would have been to try and develop the document analysis framework within the context of a (potential) LaHiRD installation at UNN[6].

Establishing the *document lens*; processing (and 'extracting) 'document theory' and developing a model for systems analysis had at this time produced the skeleton for a model. The document model which I have assembled is comprised of 7 components: agent, means, modes, configuration, connection, construction and results (Olsen et al., 2012). This model encompasses all issues that have been a part of this thesis; the **agents** (Radiologists/other healthcare personnel) the technical infrastructure (**means** and **modes**; the 'what' and the 'how'), the perceptual qualities of the Display Wall (how 'larger' may not always better – i.e. the perceptual **Configuration** of the document) and the social affordances (**Connection**) and finally – the **Result** (resulting document): the radiology interface (although only a crude prototype)[7]. -Although *assembled*, the document model was not ready to answer my research questions; I needed to figure out what a document analysis (DA) could contribute to systems design – and *how*. The research stay at UC Davis, however, made me unable to fruitfully apply the model to a possible display wall installation (or other LaHiRD implementation) at UNN.

At UC Davis I was most generously included in a novel telepsychiatry project, where the objective was a validation of the store and forward concept for consultations in psychiatry. I approached this project by starting to analyse the novel telepsychiatry system in a document context. I attended psychiatric consultations both with and without videotaping, made notes and had informal interviews with the researchers in the project and primary healthcare providers

[6] More on the 'pragmatics' of this process in chapter 5.4.4
[7] Basically, the document model encompasses all 'four levels of system design' that e.g. Enrico Coiera describe Sociotechnical Systems to be comprised of (Coiera, 2007).

doing the clinical interviews. This work eventually provided feedback to a modelling process of the document model.

The document model, I found, is a holistic and broad model that arguably encompass traditional 'physical objects' (a printed book; a contract) and all novel, digital documents. I have tried to explicate- and place this model, concept and the theory behind in relation to other 'sociotechnical methodology'[8]. In the Document Analysis (DA)[9], we use the framework of traditional document analysis to try and analyse, or predict novel documents. Analysing present documents (already created), or historical documents may create a basis, or casting mould for experimental analysis. A document analysis, as presented in my work, may well have value as a communicating artefact, or Boundary Object[10] in the requirements phase of systems development and –design, especially for sociotechnical systems where non-technical (non-functional) requirements are important. As for *how* to utilize DA in this context, the novel document model provides a framework and a template for document analysis. I enclose (in Chapter 11. Appendix C) a crude document analysis of the Store & Forward Telepsychiatry system as an example of an 'instantiation' of the model (to use the object-model metaphor – in systems engineering-jargon).

[8] I here use 'sociotechnical' as an umbrella term for technical systems to support and facilitate social interaction.

[9] Document analysis, as it has been performed within the social sciences and the humanities, has traditionally been *historical* or *structural* document analysis. What I argue has greatest potential in a sociotechnical systems engineering- and design-context is what we label *experimental* document analysis.

[10] "*Boundary objects are objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites. They are weakly structured in common use, and become strongly structured in individual-site use. They may be abstract or concrete. They have different meanings in different social worlds but their structure is common enough to more than one world to make them recognizable, a means of translation. The creation and management of boundary objects is key in developing and maintaining coherence across intersecting social worlds" (Star, 1989).*

1. Introduction

1.1. Background

When buying a new TV today, the prevailing question seems to be: "what size?" Most people would reply: "as big as possible" ('possibility' being here dependent on either economy or available space). The same question also arises when buying a computer, even a laptop computer. Clearly, displays are getting larger. In the 1990s, it was not unusual to have a cathode ray tube (CRT) computer monitor of 14' across, and a CRT TV of about 28'. Today these figures are 20'-24' and 36' to 50+', respectively, and these figures are still growing[11].

Our inherent craving for larger displays and consequential engineering efforts to create them has seemingly lead to a subsequent need for more pixels – or more inherent 'visual information', as the larger the pixels become, the more this pixellation disturbs our visual experience of the depicted object. From early on, there has been a need for large visual 'signs' or objects, like big paintings or works of art, monuments - as symbols of power (statues) or symbols of communities or spirit, or monuments of historic value. More recently, large signs have had an important impact within marketing and the commercial domain. Making things large, signs in particular, make them more visible, easier to spot and to grab our attention. However, the size of a sign – or display (dynamic sign-fabric) has generally been designed with a particular viewing distance in mind. Take Mount Rushmore National Memorial in Keystone, SD, for instance.

Figure 1 Mount Rushmore National Memorial, SD[12]

[11] Moreover, the newer technology also has more *pixels* than the old displays. The TV standards PAL/NTSC (European and American standards) had 414,720 and 345,600 pixels respectively, while the new standard called High Definition (HD) has either 921,600 pixels (called 720i/p) or 2,073,600 (called 1080i/p). The latter is often referred to as 2 mega pixels (MP), as the amount of pixels is close to 2 millions. The old CRT computer screens typically had resolutions of 800 by 600 (480,000) pixels or 1024 by 768 (786,432). This means that the physical size has increased by a factor of around 1.5 but the pixel count has increased by a factor of up to4. The same trend has been observed in the recent development of projector-technology as with LCD displays: An increasing number of pixels, with high-end projectors also projecting 2 MP.

[12] Picture reused under Creative Commons Licence http://creativecommons.org/licenses/by/3.0/

The about 18 meter high, carved-into-rock faces are easily recognizable from a long distance (Figure 1), but it is probably not meant to be looked upon from up-close (Figure 2)[13].

Figure 2 Mount Rushmore, closer, different angle

In our physical world the scale of objects is an issue, but one that nature has dealt with on its own. If you move very close to an object, you will see other aspects of it, compared to from a distance. If you keep enlarging (the visualization of-) an object you will see different grains of detail, from a macroscopic view of Mount Rushmore and the four historic presidents down to sub-atomic particles of the rock-compounds – if you have the right equipment – and interest. When leaving the physical world and entering the virtual – or digital world, objects, such as Mount Rushmore – or pictures of Mount Rushmore, as in this context – the amount of inherent detail gets finalized[14], with upper and lower boundaries of the amount of detail that goes into the objects. There are even 'virtual' objects that cannot exist in real life, so-called 'impossible' objects. These are representations (drawings) of two dimensional figures that our visual system interprets as three-dimensional, even though these objects cannot exist as such (physically)[15]. Another thing that differentiates 'real' objects from virtual ones is the amount of visual field that they occupy. Physical objects have the potential of occupying almost all of our visual field, while virtual object are relatively fixed to the size of the display – and, of course, the distance between our head/body and the display. It is a slight paradox that virtual objects, inherently de-coupled from the laws of nature, are limited to the physical size of

[13] Note that these images also have different aspect angles

[14] "Finalization" is here relative to the particular object. Retrieval of additional information or "merging" of information from different sources (objects) is of course possible post-capture of the object in question

[15] See Wikipedia for a description of Impossible objects: http://en.wikipedia.org/wiki/Impossible_object, (accessed Aug 2010)

a computer display and its, to a certain degree – still quite inadequate- properties with regards to physical size, pixel-count and resolution (dpi).

Common *sizes* of typical (computer)-displays today range from about 20-inches, up to about 30 inches wide and, hence, occupy from 10-15% of our visual field. If you include the area visible by turning our neck, this figure drops to about 1-2% (Grudin, 2001b). In the human visual-system, with regards to visual capability, combined horizontal field of view (FOV) is about 180-190º, with 30-35º monocular vision on each side (Sawant and Healey, 2005). *Visual acuity* is capability of our visual apparatus to see detail. In a recent technical report, Sawant and Healey (ibid.) argue that in order to match the visual ability of the human eye, a 20 inches monitor at 22-inches away would need 5400 pixels – across one scan line. Even though this figure only regards being able to judge the collinearity of two fine lines and does not include issues of colour, texture and motion – it does paint an interesting picture of human visual capability. It is suggested that a normal human eye is capable of the equivalent of several hundreds of megapixels – depending on light- and other conditions[16]

As the size and number of large displays available has increased, this has spawned an interest in both building larger displays and investigating their properties. Swaminathan and Sato (Swaminathan and Sato, 1997) envisioned in 1997 that "large displays will become commonplace for home and office computers before the turn of the century" (p. 15)[17]. At that time (late 90s) there were also other research efforts being done and already available regarding large, interactive displays – such as the CAVE environment, originating from the virtual-reality domain (Cruz-Neira et al., 1993). The CAVE environment was originally designed to overcome the contemporary limitations of VR systems, *"such as low resolution, isolation from the real world, and inability to simultaneously share virtual experiences with multiple users."*(ibid. p59). In brief, a CAVE environment generally consists of 3 or more surfaces (walls) that enclose the viewer in a 'room', potentially using both the floor and roof for display purposes. The display surfaces are accomplished by back-projecting (or front-projecting) the images on the canvas, using high-resolution projectors. Furthermore, the viewer has special glasses to experience the stereoscopic images projected in the CAVE, effectively making the experience of 3-dimensional objects more potent. Sensors of different kinds are also used to track the person or people inside the CAVE in order to support interaction with the projected (virtual) environment.

While the CAVE environments may be regarded as an industry-driven technology where consumers today typically are large companies with special visualization- or control-room needs, the general-consumer and mass-market counterpart can be seen in a move towards larger LCD displays, presently peaking around 30 inches and around 3.x mega pixels, -and multi-monitor configurations. Just before the turn of the century, in what might be considered a

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[16] http://www.clarkvision.com/articles/eye-resolution.html (retrieved Feb 2012)

[17] Their work is one of the very first that describes the interaction issues that are different when displays become a certain size and resolution. Of course, their prototype was crude in terms of both hardware and software – in today's standards, consisting of 6 29-inch CRT monitors with 800*600 pixels each, totalling a 2400 by 1200 pixels display of about 70+ inches across.

convergence between a very costly CAVE technology, and a commodity-need for more than a couple of displays in one contiguous 'desktop' mode, the concept of (re-) configurable tiled displays emerged (in i.e. tutorials at conferences like (Hereld et al., 2000)). A wall-sized tiled display (Display Wall) is generally constructed from commodity components, most often projectors pixel-fed by a cluster of interconnected (networked) computers and accompanying graphics cards. An implementation of such a Display Wall has been the basis and inspiration for the current project and research. The Display Wall in question was assembled and operative during 2004 (see (Jensen, 2006) for an updated description of the equipment).

Figure 3 The Display Wall at The Department of Computer Science, picture courtesy of Otto Anshus

Figure 3 depicts the Wall in use, here illustrated by meteorological data visualized. The current Wall facilitates us with a working area of about 230 inches across and a total resolution of 7168*3072. Most often, the 'workspace' is provided by a modified VNC-server[18] that distributes the framebuffer to each of the respective 28 cluster-nodes and the connected projects.

Common for Large, High-Resolution Display (LaHiRD) technology is that it basically provides us with improvements in two different dimensions: physical size and inherent information content (pixel-count). Larger (in effect arbitrary-) physical size affords more people viewing the display simultaneously. A larger display also affords a greater distance between viewer and display. Higher resolution displays generally affords reduced distance between viewer and display – provided that the display-size is equal. Increased size *and* a

[18] Virtual Network Computer: http://en.wikipedia.org/wiki/Virtual_Network_Computing, accessed March 2012

proportional increase of pixels, hence, makes possible to afford large physical size *and* close-up interaction. This makes it particularly suited for social interaction, affording several people simultaneously viewing large datasets.

Today[19], the Display Wall at the CS dept. is approximately eight years old. Since its completion, many novel software components (basically research artefacts) have made the Wall significantly more 'user friendly', and many implementations have been made to demonstrate the capabilities of such a large and high-resolution display. The Wall now features a 'touch'-interface, as well as an audio-interface (for instance reacting to the snapping of fingers – in order to select position/focus). From the past four-five years of research it also features a quite thorough range of demo's that demonstrate different capabilities, such as cluster-rendering of for instance 3-D scenes; video-playback on virtually all of the wall; a 'laptop interface' – bringing your laptop screen to the wall; a 'paint interface' for drawing on the wall with support for multiple 'artists' (which also utilizes the auditory interface for positioning of the cursor) – and several other 'applications' or demos.

1.2. Motivation and Problem-Statements

As seen from section 1.1, the history of large, high-resolution displays such as the Display Wall is rather brief. Now, after over half a decade of experiences and research with technology such as the display wall, (Ni et al., 2006a, Wallace et al., 2005, Robertson et al., 2005), the technology is starting to mature. Maturation is happening basically in two ways, one being the technology, meaning that we are developing hardware and software components and systems that support such large displays. On the other side of the new technology, the user-experience, or perceptual/interactional part of it is also developing, empirically (studies of using it), as shown is studies like (Czerwinski, 2003, Tan et al., 2006, Tan et al., 2003b) and within engineering, e.g. (Kelvin and Kevin, 2003, Seokhee et al., 2006, Stødle et al., 2007), and many more. In my work, I have focused on the human factors of the technology, as these are the aspects that are particularly interesting for the medical domain when taking new technology into use, searching answers for questions such as what is the potential *impact* or *significance* of the new technology – rather than looking at the infrastructural- or systems-requirements that will have to be accommodated – although these will surely have a substantial impact on for instance future hospital information systems (HISs). In essence I have been drawn into three directions of research as described by the separate chapters following. The three main questions, containing sub-questions have been the following:

[19] As of early 2012

R(I). What kind of use can the novel, large, high-resolution display technology (LaHiRD) be of in clinical settings, such as oncology or radiology:

- **a. What qualities of LaHiRDs could be most interesting in such a clinical context?**
- **b. What potential benefits (over existing technology) could one expect out of introducing technology as the display wall into a medical setting?**
- **c. To what degree will clinicians think this is useful technology? –And if so:**
- **d. In what clinical situations (in the above defined context), will the LaHiRD technology be considered most useful (by clinicians)?**

R(II). Based on R(I) – in the context of clinical radiology conferences – are there specific relevant cognitive benefits from LaHiRD technology, or could there be exceptions to the belief that "larger is better" with regards to display size (i.e.: are there potential disadvantages with large displays)?

R(III). In the context of R(I) and large displays as venues for common work tasks: what role can Document Studies (DS) play in the context of sociotechnical systems design and -analysis? -Specifically, in order to reach a general understanding regarding the role of DS within systems analysis and -design I will try to address the following subquestions:

- **a. What is 'a document', in a medical- and engineering context?**
- **b. How can document-theory and document-analysis in particular contribute to the design of socio-technical systems, in particular a display wall in a hospital - or such systems in general?**
- **c. In regards to question III.b) - how do we go about "using" document theory in this regard? What kind of processes need to be undertaken and what frameworks need to be applied to the (design-) problem?**

Some of these questions are rather general, and will later in this thesis be partitioned into more specific sub questions or hypothesis.

A research task will generally try to do one out of two: (1) test a hypothesis or (2) answer a question (Hartvigsen, 1998, pp 205-206). My approach in this thesis is to a degree of a mix of the two; I have utilized hypothesis testing where this has been appropriate and also tried to answer, or elucidate possible answers to relevant questions where this has been considered more fruitful.

As a general note to the underlying issues serving as a basis for this project, the starting point of the currently reported PhD project was a work-description saying: "the candidate is to work within computer supported cooperative work within distributed electronic health records (DEHRs)". -A quite open-ended work description. It was also implied in the work that the efforts could very well be related to the recently build Display Wall at the Computer Science department (the Wall was completed 2004). Although the work regarding electronic health records was toned down during the initial phase of the project, the focus on CSCW and the Display Wall as an example, or case-study of LaHiRD-technology has been there throughout the project. In retrospect, it is easily argued that I have moved closer to 'traditional HCI' (with regards to methodology and research questions) underway in this project, both due do the paths that were chosen, and due to the nature of contemporary large display research. Nevertheless, I consider all the work regarding Research question R(III) to fall within the scope of HCI methodology, in a wide sense.

1.3. Methods

The point of departure for the current project was from an applied science, and an engineering science (Computer Science) on a specific issue, namely display size – within the context of medicine. As this document will report, the work has not been structured as a controlled experiment, and the choices of methodology and venues for research has quite opportunistically been chosen from presently available means and known approaches and methods within the current research-group. Sometimes I have had to reach beyond my closest research group, searching for input and knowledge to solve problems and answer questions that arose.

I have used literature review in order to ground my research on contemporary findings and methodology, mainly within computer science and the related subfields of computer supported cooperative work (CSCW) and human computer interaction (HCI).

I have, to some degree, facilitated a case-study approach when investigating the Display Wall as an artefact within Medicine; while I have facilitated a scenario-based approach when moving on to build a prototype interface for Radiology on the existing Display Wall within a CS-lab at the University of Tromsø. Within this endeavour, I have also used a qualitative approach, conducting observations of presently used technology at the local university hospital (UNN) in Tromsø. Through our scenario and subsequent prototype I used radiologists and a small selection of other medical specialists in order to assess both the potential value of the novel display technology, and to inform future designs of such displays in a medical context. The medical expertise has, hence, been used as a kind of a focus group, and their inclusion in the scenario-design could well be seen as a form of participatory design (Muller, 1991, Muller, 1992), although the design was concluded at an early stage (after one prototype).

Further application of qualitative methods was done in a research project within telepsychiatry, at my research stay at University of California, at Davis. Observations were used to study a potential novel telepsychiatry service model, and the observations was used both as input into an analysis of potential system(s) (to be built), and as a case study informing the development of Document Analysis as a tool for sociotechnical systems design.

Chronometric methods have been described as a widely used method of studying human performance within information processing (Proctor and Vu, 2003). I have used such quantitative methods in order to study the effects of screen size on gender and expectations in regards to reaction time (RT). I have conducted controlled cognitive experiments, and collected response times as well as accuracy data for this purpose. I have also investigated potential issues of speed-accuracy tradeoffs in this regard.

As for my work on research question R(III), I have used literature review within several fields of study, and also used 'scientific reasoning' in order to deduce a document model as a tool for sociotechnical analysis in order to inform design of systems to operate within a social context. This reasoning is also based on experience and knowledge from engineering and computer science in general.

1.4. Limitations

This thesis focuses on a few selected issues of displays with relatively much higher resolution that currently available in selected areas of medicine. A general topic of display scale and resolution has been investigated within these areas – not as an effort to solve particular medical issues, but rather to serve as examples of the general affordances of such displays – and cases to provide input as to what kinds of issues that might be amended in the future – and to a certain degree – elucidating what kinds of issues that will be relevant for such displays and designs.

A PhD thesis contains findings from a process of one person learning the 'trade' of research, or one – or a few flavours of research. In general, it seems that this task originates from a couple of scenarios: In some cases, a PhD project is decided from a larger project where the candidate is to solve – or address a specific problem – or try to answer a limited set of questions; however – predefined before the undertaking of this process. In other cases – such as the present one – the candidate is given a topic to investigate, where the questions are still to be asked – or discovered. In my case, the context of the work was more or less given, in the topics of CSCW and the subsequent focus on Display Wall technology as a possible facilitator in this context. However, given the personally large educational factor implied in the Preface, the work presented here has a quite substantial exploratory nature. 'Exploratory', in the meaning that the questions that are raised as "problem-statements" above have been discovered underway, based on both review of relevant literature, as well as maturation, scientifically, and within the relevant subjects of study (HCI/CSCW). In retrospect, the personally developing proficiency and skills relevant to the work predefined in the general topics for this work has been a 'limiting' factor for the project as a whole. The limitations imposed by this factor are mostly relevant for the time-consumption of the research conducted and have resulted in a longer duration of this project than normal[20]. The limitations of the work in

[20] The timeline of this project also includes two paternity leaves, each of circa one year duration

this regard is, hence, the educational nature of the PhD project that in this case has been perhaps more prominent.

A further limitation of the work is imposed by the decision of reaching "wide", practically implying following a couple of research-trails, instead of reaching deep into a single, focused problem, as also discussed in the Preface. Given the relative open-ended work-description this rationale for this choice of width is the relative immaturity of research on large, high-resolution displays in a medical context. From a wide topic of LaHiRD technology in medicine, I have narrowed the focus towards radiology and a specific cognitive task related to this work. As for the medical context of this project, I have primarily focused on clinical uses of LaHiRDs. Issues dealing with educational aspects or medical research have not been investigated per se. Scientific visualization and data-mining are instances of relevant topics for research-issues in this regard, and immersion, along with the increased potential "information-count" in LaHiRDs are the same for educational purposes.

1.5. Contributions

Regarding research question ***R(I)*** (**a.** and **b.**) I have elucidated features of LaHiRD technology that are of specific interest in a medical context. Based on review of contemporary literature concerning several aspects of LaHiRD technology I have found that LaHiRD technology could be especially interesting for medical scenarios involving groups and decision making within such.

Based on these findings and to try and answer research questions ***R(I) c.*** and ***d.*** we have built a crude interface prototype for radiology conferences as a 'case-study' for LaHiRD technology in a clinical context. Based on a demo of the prototype for specialist clinicians within Radiology and Pathology, I have found that these selected medical specialists acknowledge potential clinical benefits from this technology – especially in the context of multi-disciplinary medical meetings. I also surmise that the most promising feature of LaHiRD technology is the ability to display more diverse patient-information simultaneously. This is further supported by observations of oral sharing of information during these meetings, especially patient information.

Related to research question ***R(II)*** With the nature of work performed within medical domains regarding visual models of the human body and the organs within as a point of departure, and the apparent need for more understanding of the implications of object scale on cognition, we have demonstrated an apparent difference in the effects of object size between the genders (Olsen et al., 2009c, Olsen et al., 2011) on the cognitive motor task of mental rotation (cf. e.g. (Peters et al., 2006) and the original discovery of MR (Shepard and Metzler, 1971)). We have observed female superiority in this task, where males traditionally tend to outperform females, in terms of task efficiency (speed) on wall sized display of 220 inches across (Olsen et al. 2009, 2011). This phenomenon was observed consistently over two separate studies, and it seems that larger object size negatively affects male performance so as to make females significantly faster in the task of mental rotation. This finding is both remarkable, given that the traditional reverse gender superiority (male-) consistently observed for this task in the past (Peters et al., 2006, Voyer et al., 1995, Linn and Petersen, 1985), but also an important reminder that increased display size need not always provide (cognitive) improvements, and may even reduce performance. Task accuracy was not affected by display-/object size.

As for the work concerning research question ***R(III)***, I have found that document analysis, in the form that we have presented it, may provide a very holistic approach to systems analysis. The document model in its broadness and complementarity presents Document Studies as a form of meta-science, where I argue that the details of document analysis is dependent on tools and methods that are inherent in other fields of study. This is to say that the document model may bring structure to a systems analysis on a higher-level, especially in a sociotechnical context

Regarding the detailed question of what document theory can *contribute* to the design of sociotechnical systems such as a display wall in health care settings, the answers – at this point – is difficult to establish with certainty. My analysis was done on a novel telemedicine system, which is quite different from my initial scenario of a display wall for use in clinical radiology conferences. The common factor in both systems is that they represent novel document systems that do not exist today. S&F Telepsychiatry is by all means also a sociotechnical system, in that it includes advanced technology in a novel social system of delivery of psychiatric services. The concrete contribution of the document model that we have presented is a *holistic model*, which – despite the potential for detailed analysis – is quite apprehendable with relatively few components and a quite 'commonly known' syntax and concepts[21]. I have proposed that Document Analysis (DA) may have a role as a boundary object (Star, 1989); a communicating artifact in sociotechnical systems design. Furthermore, it may provide a framework for cognitive and social analysis of systems and a method of integrating these into requirements engineering, also communicating these aspects of the system between analysts, stakeholders, managers, users and engineers.

As for research question R(III).c, regarding the 'use' of document analysis, we have created, as far as contemporary document theory goes, a complete document model, at some level applicable to systems analysis. We have developed this model based on reasoning from literature in both documentation and human computer interaction/CSCW. The model has been created and used at the same time in our joint project with the Store and Forward Telepsychiatry project and the result is a rather crude document analysis with an "explanatory nature" towards the model used for its creation. My hope is that this model may provide grounds for more detailed analysis of other sociotechnical systems and a basis for more research, perhaps focused on a mapping between a document model (a template for analysis) and more detailed methods for analysis. In the main work related to this research question (Olsen et al., 2012) I propose that the DA may have a role in the development process in a *requirements document.* However, at present, 'Human Factors' (in the form of 'Usability' or 'Ergonomics') has still some way to go in order to be sufficiently included in development

[21] Especially if we compare it to Computer Semiotics and similar efforts from a humanistic point of reference.

models and processes (Jerome and Kazman, 2006, Bygstad et al., 2008). Inclusion of a DA in such models is probably at best 2nd priority at this time, but the conceptual document model – in a broad sense – could play a part in grasping and communicating other aspects than the 'technical' in systems development, such as human- and social/cultural aspects.

In Table 1 I provide a list of included papers in this thesis and their respective titles. The following table (table 2) is a list of paper numbers and the main finding(s) reported and a reference to the related Research Question(s).

Table 1 List of paper numbers and titles

Paper No.	Paper Title
1	*"Watch the Document on the Wall!" An Analytical Model for Health Care Documents on Large Displays* (Lund et al., 2007)
2	*A large, high resolution tiled display for medical use: experiences from prototyping of a radiology scenario* (Olsen et al., 2008a)
3	*Spatial Tasks on a Large, High-Resolution Tiled Display: Females Mentally Rotate Large Objects Faster Than Men* (Olsen et al., 2009a)
4	*Spatial Tasks on a Large, High-Resolution, Tiled Display: A Male Inferiority in Performance with a Mental Rotation Task* (Olsen et al., 2011)
5	*Remember to Control for the (un)expected while Designing Controlled Experiments in HCI: The case of Sex Differences in the Spatial Ability of Mental Rotation and Display Size*
6	*Size Does Matter: Females Mentally Rotate Large Objects Faster Than Men*
7	*Documents in medicine: From paper documents to quality-healthcare?* (Olsen et al., 2007)
8	*Leaving twentieth-century understanding of documents. From book to eBook to digital ecosystem* (Olsen et al., 2010)
9	*Document theory for the design of socio-technical systems: A document model as ontology of human expression* (Olsen et al., 2012)
10	*Large, high-resolution displays for co-located collaboration within healthcare: information proliferation for medical decision-making* (Olsen et al., 2009b)

Table 2 Papers, main findings and related research questions

Paper Number	Main finding(s)	Related Research Question(s)
1	Provides a "selective review" and a simple case study for LaHiRD technology. Discusses attractive qualities unique to such displays and how I rate group-work contexts and most promising 'situatedness' for LaHiRDs.	R(I).a, R(I).b, R(I).d
2	A prototype display wall interface was designed in cooperation with clinical experts. A demo of the prototype was presented to the clinicians, videotaped and analyzed. Radiologists and pathologists found LaHiRDs promising for their workflow, in particular for interdisciplinary clinical work groups.	R(I).c

3	In an effort to elucidate particular (cognitive) benefits from LaHiRD technology in the context of Radiology conferences, we found that females mentally rotate larger objects (occupying a wider field of view) faster than males, specifically when expecting such stimuli – from the novel display wall technology – to afford better performance than normal sized displays.	R(II)
4	Males mentally rotate larger objects (occupying a wider field of view) slower than normal sized stimuli; females perform equally with larger stimuli and 'normal-sized'	R(II)
5	Researchers should be aware of effects such as the "Hawthorne effect" in controlled experiments in HCI regarding novel technology. This paper discusses how we (-incorrectly[22]) interpreted results after a first of two controlled studies in this regard.	R(II)
6	This paper presents the details from our results of testing of how the visual cognitive task mental rotation (MR) was affected by larger object sizes provided by LaHiRD technology. Along with higher level of detail describing method and research design, this paper is authored for a wider audience than the previous three. We also try to discuss possible explanations for the observed effect.	R(II)
7	This paper basically provides a discourse of what constitutes a document from a medical standpoint. A definition is provided and several examples of novel medical documents are discussed in light of contemporary research projects.	R(III).a
8	This paper takes a scenario as a point of departure and discusses the future eBook as a digital ecosystem. My intention is to debate how the digital nature of the future, world-wide-connected eBook changes the concept of a (e)book and how this situation calls for novel frameworks for understanding the nature of such artifacts. I indicate that our novel document model is suited for such a task – which motivates the next paper, from one particular perspective.	R(III).b
9	In this paper I describe the novel document model and try and explicate its role as a tool or framework to analyze and aid design of sociotechnical systems (STS). The main finding argued is that a document model is a very holistic approach to systems analysis in that it encompasses all four levels of sociotechnical systems design. The model and method for analysis of STSs may provide means to amend a gap between traditional systems engineering and human-factors/HCI methods as a potential *boundary object.*	R(III).b, R(III).c
10	The last paper provides background for future work regarding research question R(I) based on the work contained within this thesis.	R(I) (future work)

1.6. Outline and organization of this thesis

In chapter 2 I describe related research to my work. I have tried to include general research within the topics of this thesis as well as specific related research to the different sub-projects that my work has pertained to. An exception is made for the work regarding chapter 4 (cognitive aspects of display size), which has its own related work-section (for reasons discussed in Chapter 2).

[22] In light of the second experiment, our interpretations of the results in experiment 1 were wrong. At that time, we thought that expectation alone made females perform better than males.

Chapter 3 provides an overall discussion of display-size and resolution with the first paper (Paper 1) as a basis. This chapter is based on frameworks from contemporary review-papers (on LaHiRD technology/issues) in the context of the radiotherapy treatment planning (RTP) process. I argue that Paper 1 provides a selective review of relevant LaHiRD issues and features and related literature and this chapter provides a discourse relating to R(I).a and R(I).b.

In Chapter 3.2 I present the work with a Radiology prototype interface for the Display Wall. Our collaboration with the Radiology department at UNN made it possible to design a crude Display Wall Radiology interface. I describe the work that lead up to a demo for an expert- clinical panel. The demo was videotaped and discussion and advice for further work that did not fit into the published paper (Paper 2) is provided.

The prototyping for target clinical end-users lead us to the investigations of Cognitive effects of larger displays. In Chapter 4 I provide the background for our studies of the effects of display size (or Object Size) on the cognitive motor task Mental Rotation (MR) and the details of our studies. We conducted two separate experiments and both studies are reported, as well as the results from Papers 3-6.

Chapter 5 takes somewhat of a 'turn' from the preceding chapter and revisits the concept of 'documentation', which we started out exploring in Chapter 3, especially in Paper 1. In this chapter we return to general engineering issues related to LaHiRDs and how to design systems to support sociotechnical requirements. In chapter 5 I provide background for our collaboration with Documentation Studies at UiT and how this work lead up to a novel document model arguably usable for analysis of sociotechnical systems and subsequent design.

In Chapter 6 I try and elucidate contributions to new knowledge within my work and in chapter 7 is a list of the research papers written to be included in this thesis. Appendix A contains additional documents used in the Mental Rotation experiment, while in Appendix B are additional documents to the Prototyping of the radiology interface. Appendix C provides a crude document analysis of a novel telepsychiatry service, with references to the document model in Paper 9.

2. Related Work

This chapter is organized according to the different aspects of the topic of this dissertation. Literature reviews have been done according to the specific topics that I have chosen to focus on, with regards to search-venues and, of course, choice of search-terms and phrases. For reviewers' and readers' convenience I will recap some of these details before proceeding:

'Large, high-resolution display (technology)' as a research topic has mainly been reviewed through technical research-channels like the ACM digital library[23], IEEE Explore[24] in addition to Google Scholar[25]. Examples of search terms used have been "Large", "high resolution", "display", "screen", "display wall" and "tiled display". These kinds of searches have provided the general background of related large display research. Those search criteria have been combined with "design" and "interaction" to pinpoint research that focuses on display design issues and size alone, and to exclude the more technical research regarding the engineering of the display technology.

The first part of this chapter provides generally related research for my research as a whole, while the subsequent part describe detailed related research to the respective parts of this thesis – and its content. The first part describes Large Display Research in general, specifically from within the field of Computer Science. The second part relates to specific 'control room' research, or research pertaining to small-to medium size group collaboration and display technology to support such. I touch upon research regarding large displays within medicine in the third part and in part four I discuss research relating to cognitive effects of screen size, limited to that which is relevant to our studies. This section is also left in large to chapter 4. The last section in this chapter relates to design methods and tools to support engineering of collaborative systems and – technology related to my effort to introduce document theory to the HCI community.

2.1. Large Display Research

For the topic of "large display research (and –technology), there are a couple of review articles that summarize this research topic quite well. The most thorough work does not focus on (at that time-) current research, but rather on the technology and applications for it – as the title implies: "A Survey of Large High-Resolution Display Technologies, Techniques, and Applications" (Ni et al., 2006b). As for large display *research*, Mary Czerwinski from Microsoft research published the same year "Large display research overview" at a Human Factors in Computing Systems conference (Czerwinski et al., 2006). Between the two works it is possible to gain a fairly good overview of the area of display size and – resolution[26]. Of research of particular relevance to my work, some mentioned within these papers, I would in particular mention Desney Tan's dissertation of 2004[27], where he reported in "Exploiting the Cognitive and Social Benefits of

[23] http://portal.acm.org/dl.cfm (accessed March 2012)
[24] http://ieeexplore.ieee.org/Xplore/guesthome.jsp?reload=true (accessed March 2012)
[25] http://scholar.google.no/ (accessed March 2012)
[26] None of these works were, however, available at the start of my project in 2004.
[27] The dissertation is not mentioned per se in these papers, but work contained within it is.

physically large displays" (Tan, 2004), that large displays do provide benefits compared to smaller. Herein, Tan argues to isolate and study specific cognitive benefits unique to large displays; provide an exploration of social affordances of large displays and develops tools to take advantage of these affordances. Finally he provides a specific investigation of interactional aspects of large projection displays and a remedy for issues introduced by (the nature of) this technology. As the title implies, Tan has also found both cognitive and social aspects of large displays worthy of research- and engineering efforts. Considering that the research issue of large displays was (and, to a certain degree, -still is) in its initial stages my work has to a large degree been inspired by the efforts of Tan and colleagues, prior to this thesis – but also subsequent research originating from this work. The fact that conclusion of this work also coincided with the initiation of my project, the inspirational value – and its influence on the choices of research subjects, I hope, seems quite rational. My work, however, originates from a quite different place than that of Tan and colleagues. I have had a special focus of LaHiRD technology's potential in a medical context throughout the project, even though sub-problems have been of a more general nature.

Prior to the work of Tan, Czerwinski and colleagues at Microsoft Research had started elucidating why larger displays would be beneficial (Czerwinski, 2003) and before this, Jonathan Grudin, raised similar questions regarding multi-monitor use (Grudin, 2001a). Gruding did a small 'ad-hoc' qualitative study within the offices of Microsoft and some reference-CAD designers in order to survey how additional display surface is used. Gruding reflected that multi-monitor does not only offer additional display area, but also affords partitioning the work for the user, where non-immediate information may be located in the periphery. He also concluded that users prefer the extra display area if it is offered and that they would not wish to return to the single display with less area. Czerwinski found that larger displays improve efficiency of ordinary, but complex office tasks by almost 10%. Czerwinski and colleagues also found, in a related study, that females in particular seems to benefit from a larger display surface with wider field of view in the task of virtual world navigation (Czerwinski et al., 2002).

From a slightly different perspective, the development of scalable- (flexible-) sized display systems started to gain pace, for instance in the Scalable Display Wall project at Princeton University (Li et al., 2000). This project was inspiration for the UiT display wall project. In the aftermath of these assembly- and engineering efforts, we started seeing empirical studies of tiled, large displays in use, such as (Ball et al., 2005), where significant effects of more pixels and larger display was observed when playing popular strategy games. The larger display offered significant performance enhancements compared to the small, which was credited the larger information-content available in the large, tiled-display condition. Ball and North subsequently observed user behaviour on a tile display over the course of a six month period in order to study potential benefits, interaction issues and usages of such displays, specifically targeting benefits over normal displays (Ball and North, 2005). They identified, among other benefits, time saved not needing to switch windows, increased ability to spatially position applications for quick access and recall, increased ability of working collaboratively and increased ease of access ("awareness") for secondary tasks (such as email, etc.) – the latter similar to Grudin's observations for multi-monitor configurations (Grudin, 2001a). Robert Ball describe how large, high-resolution displays impact geospatial visualizations positively for human cognition, along with *generic spatially oriented visualizations* in his PhD thesis (Ball, 2006). Yost and North have subsequently collected evidence that the limits of human cognitive abilities are not challenged by currently available display walls, in terms of observed decreases in task completion along with no decrease for accuracy (Yost and North, 2006). The latter result should imply that larger is better in terms of improvements in task completion, at least for the visualizations they used up to 32 mega pixels (9ft wide, 3.5 high). These results were also confirmed in a later study where the authors conclude that limitations of visual acuity (the limitation imposed by our visual apparatus) are "outweighed by the advantages of additional data" in the context of potential productivity gains for large displays for spatial visualizations (Yost et al., 2007). In her PhD thesis, Yost concludes by attributing performance gains in LaHiRDs compared to normal sized displays to reduced need for physical navigation (Yost, 2007).

2.1.1. Large Displays for Collaborative Environments

In the design of collaborative workspaces, research has pursued large display technology and -surfaces (Tani et al., 1994, Chou et al., 2001, Elrod et al., 1992, Raskar et al., 1998, Streitz et al., 1999). These important contributions in the shape of systems, visions and scenarios like Courtyard, BlueSpace, Liveboard, "Office of the future" and iLand, respectively – have become important landmarks in the HCI literature showing the way to engineer and design large displays and workspaces. Large display surfaces are required to support typical group problem-solving behavior, for instance sticking illustrations, post-its, diagrams and likes on the wall or any other surface (Guimbretire et al., 2001).

These kinds of projects mentioned above and -research is also related to 'control room'-contexts, where large display areas, or multiple displays in particular have been of critical importance in order to inform specialist staff in a real-time and time-critical environment. Subway-control- (Heath and Luff, 1991), Air-traffic control-settings (Bentley et al., 1992) and military control rooms (Kaempf et al., 1996), along with control-stations for real-time monitoring of nuclear plants or similar (c.f. (Mark, 2002) describing an "extreme" version) is both technology and research that is relevant for this project, very interesting and educating. Most of the papers from the field of CSCW are studies of systems in use or information contexts that provide support requirements for systems to support human cooperation in these contexts. Many describe design-implications from ethnographic studies of these sites and contexts, or describe how qualitative studies; ethnographic in particular, can inform design of- and research in such environments. *The main reason why we cannot - in this project - readily either use these design-suggestions directly (collect them all, select and implement or prototype them) in our project is that these findings describe environments where such displays and display-systems are already in use and their usefulness is almost "a priori" knowledge.* -Nor is our interest in the phenomenological issues of information technology and its role in collaboration (even though this issue clearly has impact on potential success or failure of introducing such technology in a specific setting), *but rather how a particular form of technology can possibly "augment" certain work in certain clinical settings.* Hence, studying other similar settings, such as military control-rooms or airport control rooms has not been considered particularly useful, since our problem is to some extent reversed, compared to those mentioned. We have a technology (or rather group of technologies providing larger displays with relatively much higher resolution) which we aiming to identify 'affordances' particularly positive and relevant in specific context. In my view, the most relevant related work in this context is, rather, visions of future technology or scenarios of such in use. Examples of such 'related work' are for instance "office of the future" (Raskar et al., 1998), or even Vannebar Bush's "As we may think" (Bush, 1945). However, these examples – and other similar work – are either very generic in the applications described, or too specific and distant to our primary focus: clinical use of LaHiRD-technology – mainly within Radiology.

2.2. Displays and Display-Size and Resolution Within Medicine

Similar and related research regarding LaHiRD-technology within medicine – for both research, education and clinical purposes – have been pursued through the publication channels indexed in for instance PubMed[28] or ISI Web of Knowledge[29]. Search words and phrases used have been for instance "large", "high-resolution", "tiled display", "display wall", "display technology". At the outset of this project (2004), these kinds of searches provided little or no relevant related research. Yes – there were traces of systems built with need for high-resolution data and collaboration, especially remote collaboration – such as Zhang et al. report of in (Zhang et al., 2000), where they report a design and implementation of a teleconsultation system where referring doctors and specialist-radiologists share high-resolution data. However, this system did not utilize high-resolution display technology. There was little or no existing relevant research that could explicitly guide my work regarding clinical implementations of LaHiRD technology.

Today, a search with ISI Web of Science (WoS) with the search parameters topic=(high resolution large display) will yield **2 254** results[30]. Refine the results by: Subject Areas=(BEHAVIORAL SCIENCES OR RADIOLOGY, NUCLEAR MEDICINE & MEDICAL IMAGING OR PATHOLOGY OR SURGERY OR ONCOLOGY) and the number is reduced to 117. As a note, In Jan 2011 these figures were 914 and 115, respectively. It seems that the body of research pertaining to LaHiRD technology is growing – quite fast, but not so much within the subject areas that are most relevant to ours. Even though these keywords are defining my work, very few – if any of the search results returned with the above search are particularly relevant (or even containing our publications). In the above search, swapping "large" with "tiled" makes some difference. This changes the document-count (total) to 168 *and* includes our work (at least Paper 2)[31]. Most of the research papers retrieved using this search lies with typical Computer Science or general engineering topics and very few in the medical sciences. As noted in (Bakker, 2008): we may conclude that medical applications

[28] http://www.ncbi.nlm.nih.gov/pubmed (accessed March 2012)
[29] www.isiknowledge.com (accessed March 2012)
[30] as of March 2012.
[31] From this search, Paper 2 is classified as "HEALTH CARE SCIENCES SERVICES" and "MEDICAL INFORMATICS" in WoS; Paper 3 as "COMPUTER SCIENCE ARTIFICIAL INTELLIGENCE" and Paper 1 as "COMPUTER SCIENCE THEORY METHODS"

for LaHiRD technology is quite novel, or has not been published in scientific journals.

Lately it has started to appear some implementations of LaHiRD technology for medical purposes. One recent example is Goodyer et al. (Goodyer et al., 2009) who built a high-resolution display system for high-resolution cardiac data. This is a good example of a problem domain with fundamental requirements that cannot be met by standard displays of today. Their system was comprised of 28 LCD panels totalling a 53.7 mega pixel (Mpixel) tiled display. As the authors argue, the tiled display approach is the only one capable of displaying visualizations of data at the scale that the rabbit heart used in this study; MR-data totalling 1.5GB and a 1.4TB histology stack of serially sectioned microscopy. This study seems to be more proof of concept at the current stage, and does not contain user-testing of such a system, nor does it contain references to actual medical benefits apart from speculations related to the capabilities of the system. It does, however, provide an excellent example of concrete usage of "how high-resolution displays can be applied to the large datasets that emerge from modern life science applications" (ibid. p. 2676).

Treanor et al. (Treanor et al., 2009) have used a display wall ("powerwall") to compare pathologists' performance on a regular microscope to a "virtual microscope" using the full wall-resolution to display complete pathology slides on the wall. The issue that these researcher were trying to amend is the fact that clinicians working with digital "virtual" microscopes can take up to 60% longer time to make a diagnosis compared to a regular microscope (due to display size limitations along with awkward user interfaces). They found comparable performance in the display wall condition to that on the regular microscope, illustrating that the larger display area on the display wall improved virtual pathology-slide performance to that of regular microscopes. The authors envision that future, improved display-wall systems for pathology could outperform conventional microscope technology. As for distributed conference settings telepresence-solution based on display wall technology is also starting to emerge (Ebara and Shibata, 2009).

I have found one report of a PACS system which utilized multiple displays and high-resolution. It is quite peculiar that this system was built before 1999 (Kolodny et al., 1999) using OpenPACS. The report describes quite thoroughly the technical specifications of the system[32], but unfortunately no reports of uses of it. It seems that this research project was a result of an early adoption of a digital PACS.

Even though the count is very low at present, I would expect that the coming years will bring quite a few reports of implementation and use of LaHiRD technology for a range of medical uses. A recent thesis from University of Amsterdam provides good example (Bakker, 2008). In this work the topic has been medical imaging and fMRI in particular and focus has been on prototyping

[32] It is actually quite amazing what they managed to assemble of technology and implement systems to support a 16-monitor configuration using 4 graphics-adapters, each able to supply 4 displays of 1200x1600 pixels using Pentium 266MhZ CPUs and Windows NT.

of a system to utilize capabilities of LaHiRDs that make them preferable to ordinary displays.

2.3. Cognitive Effects of Display Scale

Details of previous research on this part are entirely left to chapter 4.1. This is also partly because it is difficult to reveal the background of this part of my work, which is related to research question R(I), without talking about the results of our work with the Radiology department of UNN. Hence, I argue, that the details of related work on this part of the project is better placed in Chapter 4, where all related research is placed in the appropriate context.

2.4. Design Methods and –Aids for Sociotechnical Systems design

Human Computer Interaction is a broad and diversified field and its history includes many introductions of methods from other fields of study for both doing research on how humans relate to computers and information systems and how this interaction affects human relations. The latter issues has been notably introduced under the umbrella term Computer Supported Cooperative Work (CSCW), starting in the late 1980s (Bannon and Schmidt, 1989). Examples of introductions of novel concepts and methodologies that are often mentioned in this context are for instance Lucy Suchman (Suchman, 1987), famous for her introduction of field-study concepts and techniques taken from anthropology, ethnomethodology and sociology in particular, and Susanne Bødker's (Susanne, 1991) application of activity theory within HCI. 'Activity theory' has its roots in a group of Russian psychologists in the 1920s and 30s (Bannon and Bødker, 1991). Activities can be analyzed hierarchically where goals or *objectives* are broken down into sub-goals and the activities, actions and operations leading towards the goal. In this way, the hierarchical structure of higher-level goals into finer-grained descriptions and explanations of how the goal is to be achieved, one can learn in detail how the document becomes a mediating tool – an artifact, and how it is perceived as such. However, neither the artifact nor the person using it exists in a vacuum. There are potentially other people involved in the activity, possibly collaborating with each other, partitioning the work to be done and the activities between them – often using the tools or artifacts in the process. The artifacts sometimes become symbols and communication-means between the people involved. The group of people, if there is more than one person involved in the process (which there more often than not is), also live and act within a society with cultural rules and regulations to consider. The work on activity theory within HCI has since been continued and extended by a community or researchers (c.f. (Nardi, 1996)). Another example of introduction of methodology and concepts into HCI is *computer semiotics* (Andersen, 1990, Andersen, 2001, Souza, 2005). Semiology is the named the study of *signs* and *sign-processes*. Computer semiotics, hence, is the study of the computer engineer as a *designer* who communicates with the user through the user interface.

Moreover, John M. Carroll has edited a complete volume (Carroll, 2003) dedicated the issue of multiplicity of concepts and theories applicable to HCI issues. What may be considered common for the issue of introducing theories or concepts into HCI is one or a couple of studies to apply the theory and subsequent discussion and sometimes modification of the original ideas to apply to a HCI context, either for research purposes or as tools for design – or both.

Carroll (ibid. pp. 4-10) also briefly discusses how the multiplicity of HCI is both a blessing and a curse at the same time: Multiplicity means many and powerful concepts, theories and tools to apply to a problem – and prospective ways and perspectives to gain insight from. Scientific multiplicity also leads to (or can lead to-) fragmentation of the field, and one of the dire consequences is that is it almost impossible for one person alone to gain complete overview of the field, especially for the younger generation of researchers who have not experienced the development of the field at the natural pace, but are faced with an overwhelming wealth of knowledge at the entrance.

What I later will argue is that using a document analysis as a basis for systems design can bridge what is experienced as a gap (Kazman et al., 2003) between a traditional systems- or software engineering (SE) perspective and a human-computer interaction- (HCI-) or sociotechnical approach to engineering. Furthermore, a document analysis (DA) of a system can also be made a tool for systems engineers, in that it can provide a mapping between the different aspects and components of the document and viable methods to study these parts of the document. As far as we understand at the present time there are few tools available today in that regards. This means that if the human factors- and social factors -analysis of a system are integrated into the engineering process today, the question remains as to what methods are chosen and for what reason? Although a recent study shows that the processes seem to be perceived as integrated in the same process today (which is sort of good news), there seems to be a mismatch between an intention of wanting to include concepts such as *usability* into the product development and what is realized in projects (Bygstad et al., 2008). Furthermore, there seems to be agreement that a gap exists between the developers and the users (Borgholm and Madsen, 1999, Grudin, 1991). Several proposed solutions to amend this gap revolve around the issue of how to integrate usability or human factors analysis into systems design (i.e. (Goransson et al., 2003)), and in the middle we find the 'usability expert' who is more or less supposed to build this bridge, communicating with both prospective users and developers/designers and also management. The latter includes management of Software Design Inc. and the principal's management (Gulliksen et al., 2006). The report by Gulliksen et al. also reflects upon the important issue of communicating opinions and needs of the users to the system developers and talks about communication and communication-needs in this respect. Our hope for the DA is that its impact would amend such gaps, but also go beyond the issues between engineering paradigms and become a communicating artifact between all stakeholders as well.

Methods to analyze and incorporate human- and social factors need to be integrated into systems engineering. Andrew Walenstein (Walenstein, 2003) suggested that the boundary object concept introduced by Susan Leigh Star (Star, 1989) could be a viable and appropriate way of bridging gaps between the human-computer interaction and the software engineering processes. Boundary objects are defined by Star as objects that

" … inhabit several intersecting social worlds (…) and satisfy the informational requirements of each of them. Boundary objects are objects that are plastic enough to adapt to local needs and the constraint of several parties employing them, yet

robust enough to maintain a common identity across sites. (…) These objects may be abstract or concrete" (italics in original).

As Star defines boundary objects, they are first and foremost communicating artifacts within and across 'social worlds' (communities, diverse groups), where they have different meaning across the communities, but have a enough 'common structure' to communicate and translate between groups of people. At the same time these objects are 'strongly structured' in individual site use to accommodate different communication needs within a group than between groups. Walenstein proposes the building of such objects to "mediate activities between SE and HCI practitioners or researchers". There seems to be a tension between the different conceptions within the paradigms of HCI and SE (Jerome and Kazman, 2006, Seffah and Gulliksen, 2006), which needs bridging.

The idea of using boundary objects in this regard has been picked up by several people, i.e. (John et al., 2004, Fischer et al., 2005) and i.e. lately in Eriksson (Eriksson, 2008). Eriksson's mentioning of how their design-tools are meant to act as boundary objects in a participatory design context (ibid. p. 213) is particularly interesting, as our suggestion for use of the document analysis is not only between the typical SE-people and HCI-specialists, but also between those engineers, all potential 'users' (actors) and other stakeholders. The boundary object concept has, since described in (Star, 1989) and later in (Bowker and Star, 1999) been used in research within different fields of study, expanded and not the least debated (Lee, 2007). Charlotte Lee (ibid.) gives a history of the term and concept and its development, while also questioning its completeness and how it may be problematic to name any artifact that moves between communities a boundary object. Her argument in re-establishing a focus on artifacts in this context, in particular what she labels *boundary negotiating artifacts*, is partly that the boundary object concept has already seen several amending efforts to it, like (Henderson, 1999) and (Subrahmanian et al., 2003) and she therefore argues that the concept is incomplete (Lee, 2007) p. 313. My intention is not to debate the term and concept any further, but rather point out that there are nuances to the term that we see as important, as both the boundary negotiating artifact and the intermediary object (Blanco 2003) could be suitable as a framework to discuss the potential of document analysis. The standardization that Lee mentions as important for boundary objects is clearly relevant for a document analysis.

The main difference of the currently reported work from most of – or, to my present knowledge, all of the above mentioned introductions of other fields of study to HCI, apart from being an *introduction* of something new (document theory has never been used in such a context before) - is the 'incompleteness', or rudimentary- and undeveloped nature or status -of document theory. Even though the document concepts and some of its ideas are already quite old (Briet, 1951, Rayward, 1975), the field of study has in many ways been forgotten, ever since the birth of 'Information Science', and the re-introduction of some of the old ideas, along with novel developments, in the light of developments in other, related fields of study within the social sciences and within the natural sciences – and not the least – technological advances, the 'neo-documentalist focus' has only been developing for 10-15 years lately (Lund and Buckland, 2009). What more is, some of the ideas that I have found most fruitful have actually not been documented before my work on document theory as a conceptual tool for HCI-studies and IS-design. Hence, my work has not only been to try and introduce a concept and a field of study (in)to HCI, but also to assemble the necessary ‘pieces’ of it into, in my opinion, a usable concept – and necessarily relating it to other concepts and theories along the way. The latter has been necessary as document theory – as I have ‘borrowed’ it and used it for systems design, arguably, may function as a ‘meta-concept’, including many other concepts, methods and theories. I will re-visit and discuss many of these issues related to research question R(III) in chapter 5 and within the papers that pertain to this chapter.

3. "Affordances" of the display Wall in a medical context

Why is it that we sometimes would like to make use of a large blackboard when we discuss a matter? Why is it that in brainstorming, trying to find a solution to a problem, we often would like to surround ourselves with pieces of information that we believe will help us reach the solution? We make use of overhead projectors, video projectors, drawing boards, bulletin boards and the hanging up of pieces of information on walls. Similarly, sometimes we would like to print a document, even though the whole document is available from the computer screen – only we have to scroll through it or zoom- and pan in order to find the pieces information of current interest. Sometimes the information we need is scattered, but still available on the computer in different documents and perhaps at different web-locations. Perhaps some of the information we need is in a word-file, some is at several websites – but we still want to print it all. Why is that? Jonathan Grudin (Grudin, 2001a) reflected on the fact that ordinary displays occupy only about 10% of our visual field, meaning that all of our peripheral vision is left unused – and that such a field of view in our "natural habitat" (i.e. in the nature) would make us feel quite hampered. Smaller displays combined with a limited resolution may even limit our natural ability of making use of information in our peripheral vision. In my work I would in this regard focus on the questions presented above: potential benefits that the technology would have over existing, how to introduce the technology into "medical settings", and try to figure out what clinicians would want from the technology. In pages (p 1-22), I gave the main question to be addressed within this part of the theseis, and in I recap them for ease-of-reading:

R(I) What kind of use can the novel, large, high-resolution display technology (LaHiRD) be of in clinical settings, such as oncology or radiology:

R(I).a What qualities of LaHiRDs could be most interesting in such a clinical context?

R(I).b What potential benefits (over existing technology) could one expect out of introducing technology as the display wall into a medical setting?

R(I).c To what degree will clinicians think this is useful technology?

R(I).d In what clinical situations (in the above defined context), will the LaHiRD technology be considered most useful (by clinicians)?

As for the title of this section, I use the word 'affordance' cautiously in this context, as the word has had a very particular role and history within HCI. The concept originates from J.J. Gibson (Gibson, 1977), who defined it as "action possibilities" latent in the environment. As this term, affordance, seems to be quite debated in HCI literature, I will add that I follow the 'Normanian' (Norman, 1988) definition of 'perceived affordance', rather than the classic 'Gibsonian' – as probably most people within HCI. In this particular context I was interested in the perceived affordances of large displays in several ways, both perceptually (from an individual point of view) and socially. Affordance is basically perceived qualities of an object that allows – or suggests some or several kinds of actions to be performed on or with it. 'Affordances' in the current context are the qualitative attributes that a LaHiRDs hold and what specifically make them useful for medical decision-making.

This chapter and the next contains in many ways one half of the project reported in this dissertation. Although a project for a doctoral dissertation contains many smaller sub-problems, and the current project is no exception in that regard, the current work has been more or less separately focused around two different aspects of large displays in a medical context: (1) what is it good for (what can we expect to gain from the technology), and (2) how do we go about engineering (information-) systems to facilitate the large displays? Even though this chapter is more or less dedicated to report my efforts belonging to (1), the first, introductory part (3.1) covers some of the incentives that led me to pursue the topics that I ended up doing in relation to the other (2) part of the work. A natural place to start investigating such issues is a literature review on large displays and large displays in a medical context.

3.1. The Role of the Display Wall as an artefact in a Medical Context

A natural point of departure for any research is a literature review on the topic of the research. This approach will ensure that the research community will not engage in more or less redundant re-invention of knowledge, and that any endeavour to try and extend our current knowledge will be done from an 'informed standpoint' – hopefully ensuring the quality of the new research and learning from previous mistakes. Literature review is also seen as the task of finding the 'edge' of research, thereby identifying what the research community has identified as important areas for future research (where the current paths should lead).

The first paper that we wrote, and which is enclosed in this dissertation serves as a selective review on research topics that I considered relevant for my purposes. The paper is entitled: *"Watch the Document on the Wall!" An Analytical Model for Health Care Documents on Large Displays*.

3.1.1. Rationale for "Watch the Document on the Wall"

As input to this work and this paper we have identified, from the technical viewpoint, a couple of other recent reviews available in Tao Ni, et.al. and their "Survey of Large High-Resolution Display Technologies, Techniques, and Applications" (Ni et al., 2006a), and Czerwinski and collaborators' "Large display research overview" (Czerwinski et al., 2006). The latter provides a basic overview, while focusing more on human factors/usability issues and cognitive effects of large displays, and the former provide a more basic technical review in the technologies, both hardware and software, available and the potential applications of large displays. Ni et al. also provide a brief overview of interface and interaction techniques and conclude with a numbered list of the top ten research challenges, which they hope will *"inspire future research projects involving large high-resolution displays"* (Ni et al., 2006a), p. 9. Together these two reference works provide a bibliography of over 150 scientific works and technology developments related to this topic.

-From a different perspective than Czerwinski and Ni and their collaborators, O'Hara et.al. (O'Hara et al., 2003) provide in one volume an overview of the "Social and Interactional Aspects of Shared Display Technologies". Although this anthology presents an overview of large displays and their properties from a quite radically different angle than the other works mentioned above, the aspects presented seem to complement the technical and interactional issues quite well. Especially relevant in this context, in chapter 8, Clarke and colleagues (Clarke et al., 2003) have looked at a traditional public display in a hospital ward. They studied how a shared beds-board was used at a hospital ward, using an ethnographic approach. This paper presents 'preliminary findings', and – hence - *cautiously* concludes that designers *"revisit their unexplicated assumptions regarding the uses of new ICTs."* (ibid. p.207). They argue that an investigation of the nature of the organization may be of crucial importance to the success of introducing a digital display in the place of such displays as the beds board.

Although the volume by O'Hara and partners mentioned above contains some limited accounts of displays in a medical context, my current project has had a focus on a particular kind of displays introduced to the medical field: large, high-resolution displays (LaHiRDs). If you do a search for related literature in for instance PubMED, this should provide for a descriptive body of research to illustrate previous research within the subject. As it turns out (still – as of April 2009), there were very few relevant hits; the empirical work concerning displays in medicine seems to be concentrated around display technology for use in radiology workstations. For radiology in particular there is one report of a built system by Kolodny et al. (Kolodny et al., 1999) using OpenPACS (but no report of it in use). In general, display systems research in medicine seems to concern ergonomics – as the recent studies like (Goyal et al., 2009, Krupinski and Kallergi, 2007) demonstrate. It would seem that research regarding LaHiRDs is currently done from a technical (i.e. natural/engineering sciences) or from a social perspective. There is, however a novel field, called "visual analytics", focusing on real-time analysis of large datasets. Most applications within this field will have quite severe display-requirements, but PubMED contains no references yet of display systems developed for this purpose. Applications of large, tiled-displays within this domain have been forecasted[33] in both clinical biology and public health, amongst several application areas.

Based on the lack of literature on the topic of display size and resolution within medicine, I chose to approach this problem by writing a paper that introduced the issues (size + resolution), based on the existing relevant literature reviews mentioned above. I also decided to select a relevant case from the medical domain as context for our review. This case was selected from an ad-hoc survey among the senior researchers within our Medical Informatics group, basically asking the question: what problem domain would likely benefit significantly from LaHiRD technology? Based on the general perception within our research group on what benefits are 'significant' from such technology, in general, information intensive tasks were identified as particularly relevant, and the radiation therapy planning (RTP) process was selected as a case for this literature review.

Time-constraints did – in this situation – prevent us from doing more thorough inquiries into the RTP process, other than learning to know it from literature. What I wanted to do, and what should be done in this situation, is to seek the domain specialist's opinion (oncologist) and to seek to understand the tasks that they perform – in order to be able to reflect adequately on an issue such as potential interesting attributes of the current technology (LaHiRD), compared to the current situation. I initiated contact with the Oncology department at the local hospital, UNN, and I did perform an initial observation at the Oncology department prior to the use of this case. However, this observation was done in the context of a different project (regarding use of handheld devices in the hospital, such as PDAs), where I was allowed to follow more experienced researchers in their observation. However, I was able to follow a team of oncologists in their daily routine, starting with a staff-meeting and an educational seminar with a remote part of the local Oncology department (in Bodø, 500km south of Tromsø) using videoconferencing equipment. I also observed a junior staff-member in interaction with patients (on his rounds) at the Oncology department and acquired an 'incidental' (unstructured) interview

[33] http://www.vismaster.eu/news/largedisplayenvironments/, accessed Aug 2010

with that oncologist, where I tried to gain insight into the details of the day-to-day tasks of an oncologist. Probably as a result of being my first encounter with the insides of the hospital as an observer, I was too overwhelmed to learn other than basic insights in the daily routines of oncologists.

3.1.2. Approach

In "Watch the Document on the Wall!" (Paper 2) we start out with a presentation of the basic affordances of LaHiRDs, asking questions such as: (1) does it matter whether we view a document on a PDA, compared to large, wall-sized display and (2) are there usage-scenarios where such technology has qualities that profoundly impacts the process requiring displaying (of something)? We discuss such questions in light of the issues of physical size of the display, and the resolution offered by the display 'medium'. If one pixel conveys one bit (unit-) of information, adding pixels should add to the (potential) amount of information visually available. We discuss the issue of pixel size (or its inverse, points per-inch PPI), and how this relates to our perceptual capabilities; at some point our vision fails to differentiate between pixels, and the relation between pixel-count and information content (amount-of) ceases to exist. This latter issue is also tightly coupled with viewing-distance, that is – the distance between our eyes and the display. Even a quite coarse-grained (pixellated) image can seem coherent from a distance – an effect used in for instance huge displays in sporting arenas. One of the novelties of LaHiRDs is that they afford viewing at both short and long distances. This fact also leads us to the classification of usage scenarios of such technology: one-user or multi-user scenarios. A LaHiRD can either provide one user with an abnormally large display-area for his own benefit, or it can provide a group of people to work on related- or unrelated tasks – simultaneously. "Watch the Document on the Wall!" provides a basic introduction to how treating something as a document rather than a collection of "information-fragments" can provide us with a different understanding of the needs of those who are "*documenting"* (using the information; creating new information; interacting with the information system): "users" of the system.

3.1.3. Findings

This Paper relates to research questions R(I).a, R(I).b and R(I).d. In the article we start out referring to the term "document" when posing the question of whether or not it is the same document when viewing it on a small screen on a PDA compared to viewing in on a wall-sized display – that is, viewing the same digital data-file (i.e. pdf) on different displays. Firstly, this question intuitively leads to a realization that there is definitely a change in perception regarding the "same" document; the physical size – and the image projected on the retina consequently changes. From this point we start discussing the displaying of data from a visualization standpoint, regarding the size of the display, distinguishing between transformation of the data and transformation of the visualization of data – in order to fit the (displaying of the –) "document" to a particular physical size. From this discussion it is also apparent that the size of the display also potentially affects interaction – as, if the (visualization of) the document contains more pixels than available in the display, one will have to do some interaction with the document in order to move the displayed portion of the document around as needed (panning), to see the rest of the document, or zooming – if the document/visualization is transformed (shrunk) to fit the smaller display. From my use of the term 'document', I argue that the large display area in a LaHiRD 'encourages', or 'affords' several people viewing the same document – hence making it also more 'public'. This leads us to the discussion of how documents also have a 'social' side to them – which eventually leads us to the almost inevitable question of definition: what is a 'document'? This question is not explicitly posed in the text, but a definition is nevertheless given – and this is the main contribution of the main author for this paper: the question of what constitutes a document and how this might help when reflecting upon the properties of this novel display technology. In many ways, I think this situation describes the collaboration between the Department of Computer Science and the School of Documentation in this context: In the same way that Radiotherapy Treatment Planning is used as a case for our purposes in this project, my project is used as a case study for document-researchers. In some sense we can say that the current project provides an example of the relation between basic research and applied research, where Document Studies as basic research (within the sciences of the humanities) is influenced, or draws on experiences from an applied field – and, as I will argue later on (in Chapter 5), provides us with concepts and theory that can aid our understanding (of systems) within the engineering process.

In light of previous research and the review-literature already mentioned I argue that two of the most prominent changes when going from small, relatively low-resolution displays to large, high-resolution displays is the visual angle that the display occupies (angle between our eyes and the edges of the screen), and the (potential) amount of simultaneously displayed information. We cite quite recent research that indicates that these issues can for instance affect recognition memory, peripheral awareness and the sense of immersion. We also provide, based on previous work by Swaminathan and Sato (Swaminathan and Sato, 1997), a taxonomy of potential different multi-monitor configurations constituting a large, display area and also provide feedback from the additional authors of the paper on experiences from the using the Display Wall on the argued advantages and disadvantages set forth by Swaminathan and Sato. This leads us to discuss different kinds of interaction problems that become apparent once the display reaches a certain size and resolution. These issues come as a result in the qualitative differences in LaHiRDs compared to traditional displays, that – even if they reach a certain size, the comparable resolution makes interaction quite similar – regardless of display size.

Also in the review of related research we found that different screen sizes seem to affect males and females differently, perceptually. Czerwinski, Tan, and Robertson (Czerwinski et al., 2002) found that the "gender gap" in 3D-world navigation (spatial tasks) diminishes and seem to almost disappear when users are given a wider field of view – meaning a broader display than what we are typically used to. Specifically, they set up two projection displays side by side and minimized the seam between them in order to have a continuous and coherent display that was twice as wide as an ordinary one. They made a virtual 3D-environment in which the participants engaged in way-finding tasks in a virtual world, a task in which men typically outperform females. They found significant effects of field of view and display size resulting on trial times. There was also a significant effect of gender in the small screen setup where males outperformed females, while in the large screen setup there was no observed difference and men and women performed equally. In a follow-up study Tan, Czerwinski, & Robertson (Tan et al., 2003a) found that with a large display setup of 100 degrees field of view and with the presence of optical flow cues, i.e., the effects of moving within the environment has on the change in image on the retina of immobile objects residing within environment, female performance improved to the point of evening out gender differences. They suggested that a wider field of view and optical flow cues could separately contribute to female performance enhancements. The two studies suggest that in tasks concerning spatial orientation, increasing display size may have a positive effect on female users. I will re-visit this research in chapter 4, where they, amongst other variables, motivated us in a particular direction with our research.

As for 'social and interactional' -aspects of display size, covering what the field of CSCW has contributed of related research, I cite mostly O'Hara and collaborating editors in (O'Hara et al., 2003). This collection of 16 papers does not cover the whole field of "public and situated" displays, but was at the time of the start of my work (2004) a landmark contribution in terms of describing the topic of research, especially the social and human factors, which at that time – and still, to a certain degree, has only been covered to a certain point. Carl Gutwind reviewed this volume in 2005 and commented that:

" (…) The problems I see in the book – that the sections are not strongly organized, most of the papers focus too little on social and interactional issues – are not fatal, and are a reflection of the current state of the field. Perhaps the most important contribution of the book is to highlight the gap between current systems-oriented research and the goal of understanding how public displays affect human interaction, and to provide some examples of how the next generation of display research should proceed." (Gutwin, 2005)

I take particular care in discussing the aspects of '*publicity*' and '*situatedness*', the latter in particular, as I find these issues particularly relevant and interesting to our research. Publicity is very relevant for people *sharing* information from their private computing devices, which is one of the uses that the technical research group (SHARE) has been working with, for instance when developing software to share (parts of-) a laptop display on the Display Wall. Situatedness is a major topic when talking about displays for collaborative activities; displays to i.e. coordinate work, temporally and spatially. One of the papers in the O'Hara et al. volume in particular discusses this from a very general point of view, the paper called "The Social Construction of Displays" (Crabtree et al., 2003). Crabtree and partners look at display as a verb, rather than a noun, focusing on the *act* of displaying something. I launch the consequential hypothesis of gain from LaHiRDs, compared to ordinary displays – based on our description and review of the technology: *More (additional) visually available information can aid/improve the cognitive (shared) decision-making process*. However, in light of Crabtree and partner's findings and advices, construction of displays should be done with care regarding *where* they are placed. Furthermore, we are advised to study already present displays; where are they placed, how are they situated and for what purposes are they constructed?

I describe the Radiation Therapy Planning (RTP) process and how design of a LaHiRD can potentially aid this process. I also touch upon the field of Radiology, as they are heavily involved in any process that regards medical imaging – being the service provider for all specialty clinics in this regard. I basically use a description of the RTP process (Fraass et al., 1998) to identify potential situation for placing the technology, and located at least one very promising candidate-problem in the marking of the critical organs targeted for radiation. The physicians will mark on every CT slice the critical organ(s), and I argue, in light of previous findings regarding productivity benefits of larger, higher-resolution displays, that the novel display technology might very well improve this process. However, the status of the RTP process is by no means static, and has probably many variations within hospitals already – depending on the equipment (technology) in use today. Developments in for instance 3D modelling and integration of such technology into this process can change this case in that regards. I do finally argue, that in light of research findings on large displays within CSCW, that care needs to be taken to study the workplace in which the technology is to be implemented well before engaging in construction and implementation of new technology. Regarding the research questions defined in chapter 1.2:

R(I).a What qualities of LaHiRDs could be most interesting in such a clinical context?

R(I).b What potential benefits (over existing technology) could one expect out of introducing technology as the display wall into a medical setting?

I have already mentioned above many of the qualities that LaHiRDs have. The more or less arbitrary size and potentially vast pixel-counts are the most prominent features that will differ from current display technology, relating to research question **R(I).b**. Even though projector technology offers quite good flexibility in regards to physical size of the display, the pixel-increase in for instance a Display Wall makes the potential for scaling of objects very different, also because pixellation is no longer an issue. The perhaps *most* significant change, compared to regular display technology, is the potential for increased amount of information content – or document complexity – that is possible with LaHiRDs. With increased display area – and increased 'information density', we have the potential to inform clinicians visually, in a way that is difficult - if at all attainable - with current systems. These issues brings us to the next research question, **R(I).d** *, In what clinical situations (in the above defined context), will the LaHiRD technology be considered most useful (by clinicians)?* As demonstrated by our prototype, the most prominent concern provoked is that of *information overload*. This issue will depend upon information layout – or interface design, of course, as well as the nature of the information displayed. As indicated in recent research regarding information visualization, our human perceptual limits might be beyond capabilities of current LaHiRDs (Yost et al., 2007, Clark, 2005), at least for some visualizations. However, considering both the qualities of the technology – especially the physical size (affordances), and the cost of it – it becomes quite clear that especially display walls and similar technology generally *affords* multiple users – or presenting information (*documenting)* for an audience. Hence, I argue – in relation to research question **R(I).d** that situations where small to medium groups cooperate in clinical settings are more appropriate for this technology than single-user scenarios. It may not be a particularly radical finding – but my reflections have also included single-user scenarios (such as the RTP process), where we have received a quite more ambivalent reactions to the potential impact of the novel display technology (see i.e. (Olsen et al., 2008b), p 537 – which I shall return to in the next chapter). The novel finding in this regard, is, hence, that it seems that from the feedback from expert clinicians (their relative acceptance towards this kind of project – and technology) that it is the 'group' mode – and, hence, *public* display mode that is attractive for the LaHiRDs in medical settings. Research question R(I).d will be answered in more detail in section 3.2.3.

The paper "Watch the Document on the Wall!" (Paper 2) provides a selective review on the topic of large, high-resolution displays, in light of a potential case for situating such technology within the hospital, namely the RTP process within oncology. We present the technology, its attributes and a selection of present and previous research within the topic of large and high-resolution displays. Also included is an initial discussion of the term and concept of a 'document' and how it could prove enlightening to analyse what health care workers would like of documents 'on the wall'; what would be contained within them?

3.2. Introducing the Display Wall to Clinicians: the Radiology Scenario

3.2.1. Introduction and rationale

There are several ways of investigating the properties of large, high-resolution displays and several methods to apply in order to learn something about their potential. However, in order to investigate their place in, for instance a clinical setting – or (more general), in a health care-related setting we have to apply methods that are valid in the 'real world'. Within the field of computer science the traditional way of doing experimental research is to apply the engineering methodology (Denning et al., 1989), p. 2 *('abstraction and design'*): defining a problem or hypothesis, designing a model and design an experiment in order to collect data, either in a lab-environment or in the 'natural' environment of the system and finally analyse. However, this research model is primarily suited for theoretical problems and hypotheses that can more or less easily be implemented into a suitable experiment. Typically, the experiment is implemented using engineering efforts and designing a model in a computer system in order to test it. Testing how systems affect the users and the environments that they (potentially) are to become a part of cannot be done without the involvement of the human actors that are supposed to *interact* with the system ('users'). The engineering efforts within computer architecture, parallel programming, visualization and several others has already brought us technology like the display wall and has tremendous success in developing ground-braking technology – technology that perhaps looks like nothing we already know, or something we never thought we would need. –Perhaps because we did not consider it possible – or that we never reflected on that the lack of something like that hampers our ability to solve certain kinds of problems. However, when new technology is present and is becoming commonly available, like the personal computer did in the 1970s and 80s, the deciding point on the level of impact of the new technology is always the degree to which it is taken into use by people – or society. A large, high-resolution display is not an infrastructure component, like computer networking, or grid-computing technology – it is an end-user technology. The display of information is at the user-end of the computer-, or information systems and is most commonly the communicating interface towards us. In the ACM report already mentioned (Denning et al., 1989), although it is over 20 years old now, and that several changes have already happened within this classification, 9 areas or sub-disciplines are defined within computer science. One of these is named, at that time, "human computer communication". Today this field is called human computer interaction, HCI, or interaction design or human information design, and this sub-discipline is itself containing many sub-areas of research. The definition from the Association for Computing Machinery (ACM) is the following:

"Human-computer interaction is a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them.[34]"

[34] http://old.sigchi.org/cdg/cdg2.html (accessed March 2012)

The key term in this definition is, at least for our purpose, "*interactive*". Interaction, as (Svanæs, 2000) notes, requires at least two parties – the human *interacting* with the computer. In the context of our display-wall project both the terms "human" and "computer" does not seem to cover all the aspects of this setting, as the large display, although it can be a one-user artefact, generally *affords* for several people to use it together. The *computer* is not only the computer anymore, but can include – as in this example 28 computers and a whole world of networked computers – along with other people using other computers elsewhere. The latter issue is generally investigated within the field of research labelled *"Computer Supported Cooperative Work"*, a closely related area of research to HCI, sometimes seen as contained within the scope of HCI. I will not go into this subject of discussion now, but it suffices to say that the display wall as a research topic is potentially a very complex one where many variables might play a crucial role – whether that variable is the technology, interaction with the wall, interaction between people interacting together or in cooperation using the wall, social or cultural aspect of this scenario, or other. With that many factors potentially present in an experimental setup the question of isolating the research topic might become quite a challenge. The physical construction of the display wall also makes it difficult to get into the natural environment of our scenario. The Wall is still rather expensive to set up, and it takes much physical space. The interaction capabilities offered are also rather limited. The current daily users of the technology are expert users and scientists, and the technological foundation is still rather immature for the technology to be introduced to the 'mass market'. All these factors make the design of use-case scenarios of the technology rather difficult. Basically we have a technology that we know has some very intriguing attributes and a real possibility of making an impact within the domain we are interested in: medical decision making. But – the technology is immature and potential uses of it are not clear to see – or at least they remain to be investigated.

Considering our wanting to explore the Display Wall in a medical context, it, hence, made sense looking for methodology from the field of Human Computer Interaction to aid my research question, **R(I).a** What qualities of LaHiRDs could be most interesting in such a clinical context? Prior to this I had to actively seek collaborating partners from the medical domain.

3.2.2. Approach

Of the research questions that are related to this work **R(I).a**, **R(I).c** *("To what degree will clinicians think this is useful technology?")* and **R(I).d** *("In what clinical situations (in the above defined context), will the LaHiRD technology be considered most useful (by clinicians)?")*, one research question might appear quite redundant: will clinicians think this technology is useful? From a technologist's view the answer is given: of course![i] However, clinical staff – expert medical professionals in particular – have a lot more considerations to take in order to assess the value of technology. Technology and engineering research has in the past been criticized for taking on for instance ethical questions regarding development of novel techniques and technology quite light-heartedly. The question of development-, or production-cost, compared to the relative gain is for instance quite omnipresent with such technology as LaHiRDs. It is in this context that I find the question of 'expert clinical approval' for this technology relevant. As a technologist, I have no way of assessing an 'objective' answer to this question, and, hence, I find the answer from our inquiries a relevant and important contribution. Another research question in this context is: In what clinical situations (in the above defined context), will the LaHiRD technology be considered most useful (by clinicians)? R(I).d. The answer to this question might be taken as 'qualified advice from expert medical professionals regarding display and information design. In the design of our prototype, I have tried to keep it as open-ended as possible, so that potential 'advise' may be less limited by our potential inadequacies regarding creativity and (visual-) design, in which none of the prototype designers have formal competence. Furthermore, there is also one inherent research question in the design of the prototype that was quite unconsciously introduced into it:

"how do the clinicians perceive the potential cascading of the information (image series) on the large display surface)"?

-In retrospect, this question was set forth by the technologists (researchers) working with the Display Wall - and quite unconsciously introduced into the design of the prototype. As an illustration of how this research question came about, I remember sentences like: *"imagine if medical staff could see all medical images simultaneously"*. This describes the general expectations for LaHiRD technology: more information simultaneously has to be better! As we will see in the Results section, the clinicians, as also shown in the transcript, answered this question quite unanimously.

Considering that we are dealing with a novel technology that few people have any (inter-)active experience with it made sense to start out with scenarios of use of it, and, hence, I decided to go for a scenario-informed building of a prototype in order to get some knowledge about the affordances of the technology as perceived by my target users: clinicians. Much of my approach to this endeavour is described in detail in the second paper: "A Large, High Resolution Tiled Display for Medical Use: Experiences from Prototyping of a Radiology Scenario" (Olsen et al., 2008b). What is not described in the paper is, among others, the process leading up to the choice of prototype, and the selection process of viable scenarios prior to this. As for the selection process, I more or less repeated the process of brainstorming in our research group (as mentioned in chapter 3.1.1) among the senior researchers (constituting, by now, a sort of 'heuristic reasoning' or '-brainstorming') and also among the junior researchers to select an appropriate and viable setting, or –problem domain for the scenario. Worth mentioning is that 'candidates' in this process are generally not solely chosen amongst scenarios (-that, in fact, constitute concrete wards or departments within the hospital) that are considered a 'perfect match' for the technology, but are also based on familiarity among the research group about the different locations and knowledge about potential research collaborators (within the hospital) and their respective research interests. This fact is probably not a novel 'research finding', nor very surprising or controversial. In any multi- or interdisciplinary research, you have to have at least two motivated parties from distinct fields of research, searching for the answer of a common question, or solution to a common problem[35].

Based on the previous findings and experience from the Oncology department and the fresh 'heuristic brainstorming', I located the 'centre of medical imaging', the Radiology department, as a promising "situatedness" for the LaHiRD technology. This choice of venue for our scenario was based on the fact that this department works primarily with large image datasets, as well as that the Radiology department on a regular basis meets with many of the other departments in collaboration, based on the findings from the image sets. I also found a motivated collaborative partner in the Radiology department. After presenting the novel technology at his office, the head of the department proved very confident that the increased pixel count, together with a potentially huge display area could well aid them in their work, better than the present technology. Generally in line with a scenario-based approach, I had the radiologist select a relevant patient case for a demo of the prototype. This way, I had already started making use of our collaboration, in that I allowed the medical expertise (the head of the Radiology department) to contribute to our scenario and prototype, while leaving the detailed design to us. 'Us' in this context was basically yours truly and a skilled technician with the display wall.

From this point I had to make a decision about how to implement the prototype. My choices were basically to change an already existing radiology interface to run 'on the wall', or to make something else from scratch. I have tried to describe our chosen prototype within the framework of Houde and Hill (Houde and Hill, 1997), and the choices I made at this time would affect the placement within the dimensions of look-and-feel and implementation. As described in the paper and previously in this thesis, the current display wall at the CS department is implemented using a cluster of Linux-nodes (Red Hat), and mostly using a modified version of the Virtual Network Computer (VNC) server. My efforts to find implementation solutions for the prototype revealed that the Linux implementation of the wall would limit our possibilities in regards to a demo for the Radiologists. If I were to choose for instance an open-source implementation of radiology interfaces[36], we would have to either (1) rewrite them to run on every cluster node or (2) (compile and-) run on the VNC server. The second alternative (VNC) was not really doable, as the VNC server did not support OpenGL calls (which virtually any medical image viewer or PACS system

[35] It seems that a part of the 'knowhow' within Medical Informatics as a science is how to go about initiating research from the one side or the other (Medicine/Healthcare or Informatics/CS). It has certainly been a part of my personal training to understand how this interdisciplinarity works. As a general comment to this discussion I want to note that when teaching Medical Informatics courses along the way, I have observed- and tried to mend the gaps between technology- and healthcare students. These two groups of students take different courses within the local master programme in Telemedicine and e-Health at University of Tromsø, but have one common course: Medical Informatics – in which I have been a part of the teaching staff. – Coming from different disciplines we tend to think a bit different about the 'same' problems, but a part of the work in introducing both healthcare- and technology students to Medical Informatics, as I see it, is both to learn to know and familiarize ourselves with each others' perspectives, and to accept that they are all important in order to drive the search for new knowledge forward. The common ground between our disciplines and understanding of -each others' is, as I see it, a necessity for the quality and vigour of the research and engineering of better clinical systems.

[36] Display walls running in a cluster configuration cannot run 'ordinary' software to display on the wall without modifying the code; hence, we had to focus on software that we were able to adapt to the platform (Linux-cluster)

require). We could try and re-implement the VNC server, but that would require a lot of resources, by the saying of the leading researcher behind the VNC-server implementation for the wall (the VNC server has already been modified to fit the large display area on the wall). Another problem with the VNC solution is that any application running on this server had available only the local server machine's resources (CPU/memory and GPU[37] of the single Dell machine described above), which would result in very poor performance on the (whole) wall, having 28 times the normal amount of pixels. We did experiment with image viewers like Osirix and 3D slicer in both Mac OS X and Linux respectively (using a vnc client and the vnc-server, respectively), and also Windows for 3D slicer (using Remote Desktop), but all alternatives would suffer from not being able to utilize all pixels on the wall (desktop resolution limitations inherent in the software), and very poor performance (sub 1 frame per second on the wall). We did consider solution (1), rewriting software, but I regarded the workload as being infeasible, considering that no existing interfaces for any systems would be implemented for a 22 megapixel display. Also, the preferred Open Source Software (OSS) found, Osirix, is only available for the Mac OS X and not quite easily ported to Linux, due to Osirix's tight use of- and integration with the graphical engine in OS X.

The solution that I ended up using was to 'borrow' the familiar interface from the PACS system used at the Radiology department (as a "frame" for the content that I chose to be in the demo), and to "stitch" relevant patient information (pictures/text) into interface examples that filled the 22 megapixel display wall. In order to display these gigantic images we used a parallel image viewer developed by another researcher within the SHARE research project[38]. This way, we could present large image sets with accompanying information (text, other image material, like pathology) in one interface, which seemed quite responsive with regards to loading images and panning and zooming on them. -One of the concepts that I wanted to test with the radiologists (and other potential clinicians), was the cascading of images – complete sets – all over the wall, and prototyping this particular interface made this quite manageable. After observing radiologists at UNN, I could tell that they are generally used to very responsive graphical interfaces (and are expert users of the software they have available), and so choosing the prototype with less interaction possibilities (aka large, static images) over a fully functional system made sense in order not to provoke negative attention to the technology that I feared would be the case using other software. We also utilized SW designed to playback video on the wall. The viewer was an extension of the VLC video decoder, which took as input several video files to play on different parts of the wall. In order to simulate dynamic content on the wall I made video-sequences of the image series (scrolling through the images) and used this as input into the VLC wall-player.

Another issue that I tended to in designing the demo for the radiologists was to try and 'lure' them into a 'clinical mode' during the demo. Presenting a novel technology for clinical specialists in this way, taking them out of their regular

[37] Graphics Processing Unit
[38] http://uit.no/ansatte/organisasjon/artikkel?p_document_id=178591&p_dimension_id=88138&p_menu=28713&p_lang=2

working place and into a computer science lab, I feared that we would get a 'commercial-like' setting – getting them to think that we were to 'sell' this novel technology. I use 'lure' with quotation marks, as it is meant in a positive way; based on my wanting to, first and foremost, answer the research questions: do they think this is useful technology? How will they perceive it as useful? How will they react to the cascading of information (images/image series)? To answer these questions it was necessary, I felt, to minimize the feeling of being at a promotional demo ('buying' a technology), and to maximize their 'clinical thinking' – in order to get as far as possible towards answering my questions. In order to try and achieve this, I took the image material for the patient that our collaborative partner, the head of the Radiology department at UNN, had chosen – and based on the observations that were made at UNN of these clinical conferences – I tried to make the presentation look like a presentation of a patient case. We presented all the image series that we had, in different ways, and added referral text, along with a diagnosis from the DICOM files where appropriate. During the demo, I also told the radiologists to treat it mostly like a patient case that they were to review.

As stated in Paper 2[39], the prototype was based on observations from both the previously mentioned Oncology Department at UNN, crude observations and an interview from the Pathology Department, *and* the observation of the Radiology meeting with neurologists. The primary documentation used at the observation sites were handwritten notes, which served as information sources for design of the scenario and the subsequent design of the prototype.

Finally, after the demo was videotaped and subsequently transcribed, the transcription was studied and analysed by three researchers (including myself) and our findings were confirmed by using one of the specialist participants from the radiology demo.

3.2.3. Results

The demo with the Radiologists, the head of clinical IT-systems, and a pathologist was videotaped and transcribed. The transcription is given in Appendix B (p. 10-127). If we start out with my defined research questions given, **R(I).c** *"To what degree will clinicians think this is useful technology?"* – the answer was: "certainly". The observations done prior to the prototype demo were also in line with the comments underway: we can show more patient data [on the LaHiRD]; while today there is no room for it (visually). A lot of the information, which may be shared visually using LaHiRD technology, is today shared orally. From the observation and interview at the Pathology department, I learned that someone would, for instance, read patient information (referral information and other) out loud; some info was read by default – while other information might be requested (by the audience) during clinical conferences. With a display wall, or similar technology, more information can be visually shared, and for instance viewing pathology samples through a microscope might be done in a very different way, seeming that the inherent level of detail might only depend on 'visual acuity' (Yost et al., 2007) – that is, the capabilities of the

[39] OLSEN, B. I., DHAKAL, S. B., ELDEVIK, O. P., HASVOLD, P. & HARTVIGSEN, G. (2008) A large, high resolution tiled display for medical use: experiences from prototyping of a radiology scenario. *Studies in health technology and informatics,* **136, 535-40.**

human eye (Clark, 2005). If we take into consideration digital cameras, which are attached to the microscopes and are able to capture a couple of tens of megapixels already – the potential for viewing detail-and-overview simultaneously is quite exciting.

Figure 4 Videocapture: one enlarged image from the image series

In Figure 4 *we can see clinicians viewing one out of 16 prepared "screenshots" that made up the demo. This interface example provides a CT image series with one enlarged slice.*

As for the second, added research question in this context, "*how do the clinicians perceive the potential cascading of the information (image series) on the large display surface)?"* the answer might be rather surprising. The sub-question, or additional question, of how the clinicians view the potential for image-cascading of image series is also related to the answers we got. At least two of the experts present at the demo felt 'uncomfortable' with as many as almost 100 images on the wall simultaneously (perhaps quite an understatement, if we look at the words they used: 'drowning in information') – and it seemed like the rest concurred with them. 'More', it seems, is not better in this context. It was also clear that as senior medical professionals, as they all were, the cascading was viewed as a kind of a 'regression' of the interface, compared to the stack-concept that is rather successfully used today, and which all radiologists seem familiar with. In our paper to the MIE2008 conference (Paper 2) I do list this as an important finding from our prototype. It should be added that this *is* a *first impression* by clinical experts. It is not at all certain that this view would endure after extensive *use* of the technology, or after modifications to the interface. Recently, other research-implementations of similar technology has started to emerge (Bakker, 2008), which seemingly contradicts our findings with respect to cascading of medical imaging datasets (i.e. p. 39). The specific uses of the technology and the report of their implementation of a tiled-display image viewer, however, do not contain specifics about the usage scenario, other than that a clinical expert (neuropsychologist) has participated in design and been consulted with respect to the outcomes of this prototype implementation. The context seems to be fMRI scans of certain subjects, but no pathological motivation is given for the use-case which the implementation is based on.

Moving on to the 'How' this technology might prove most useful, the comments provoked by our expert group seem to indicate that more of diverse information – information that might be needed already – and has no (visual) place in today's interfaces and display technology might be the way to go. This kind of information also accentuates potential interaction-issues, as more information could mean more shared control, or 'authoring' of the displayed content might be imminent. Today, it seems, only one person is in charge of 'authoring' the presentation, while with this novel technology, we might get several experts that author their own 'piece' of the document – concurrently. How this should be achieved in practice is virtually an open question – but several interaction techniques developed today affords multiple authors. Consider, for instance, the novel interaction techniques offered by the Nintendo Wii © - allowing multiple pointers and several modes of interaction. Ad hoc laser-pointers and similar, in addition to touch-interfaces has also been suggested and developed – also for our local Display Wall (using regular web-cameras). The choice of interaction will likely rely on the general nature of the work performed in any 'display environment', and is subject to carefully considered design choices.

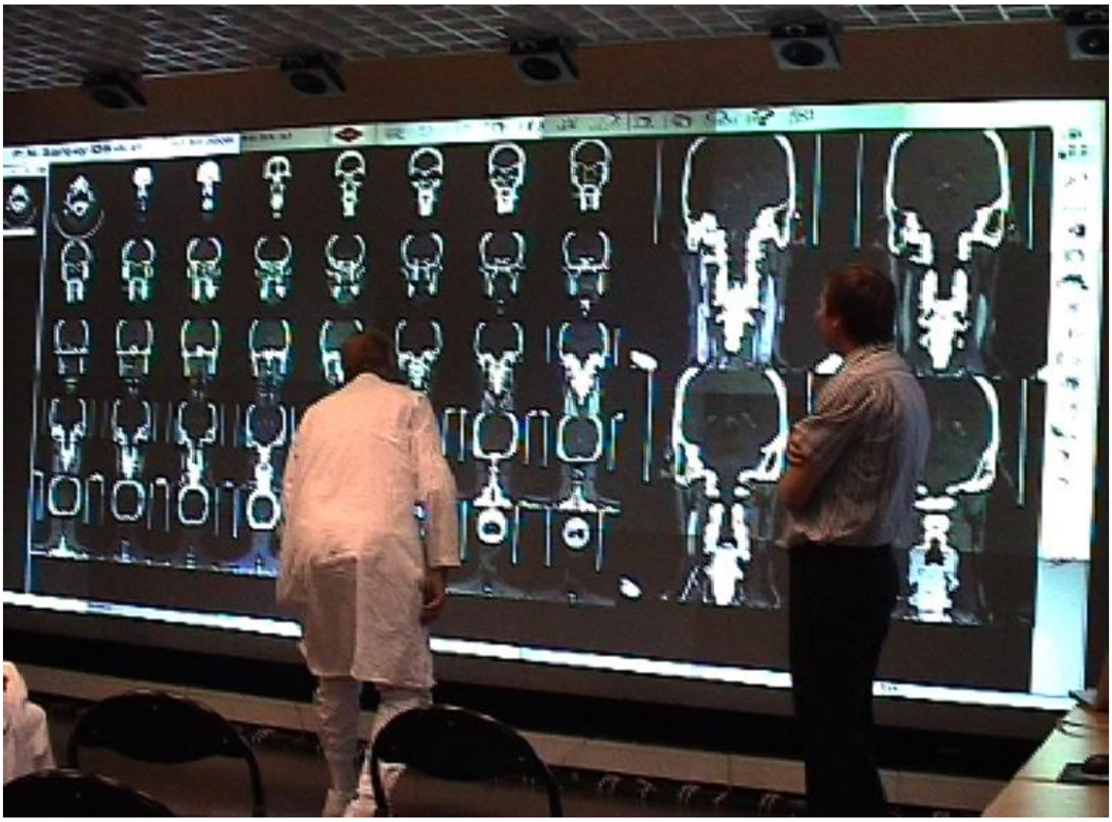

Figure 5 Videocapture: Radiologist approaching Wall to see details

In Figure 5 *we can see the head of the Radiology department at UNN walking up to an image so as to study the detail closer. This would not have been possible with an ordinary projector where he would lose detail when moving closer*.

What was basically suggested, as implied by the discussion above, by our expert clinicians was to 'partition' the display into distinct areas that could be controlled by the respective specialists at any conference. This suggestion is basically an extension of what is accomplished today in for instance the pathology conference room, where two projectors are used to show for instance x-ray images on one of them while the other is allocated the pathologic sample under the microscope – however, achieved with only one 'author' (the pathologist).

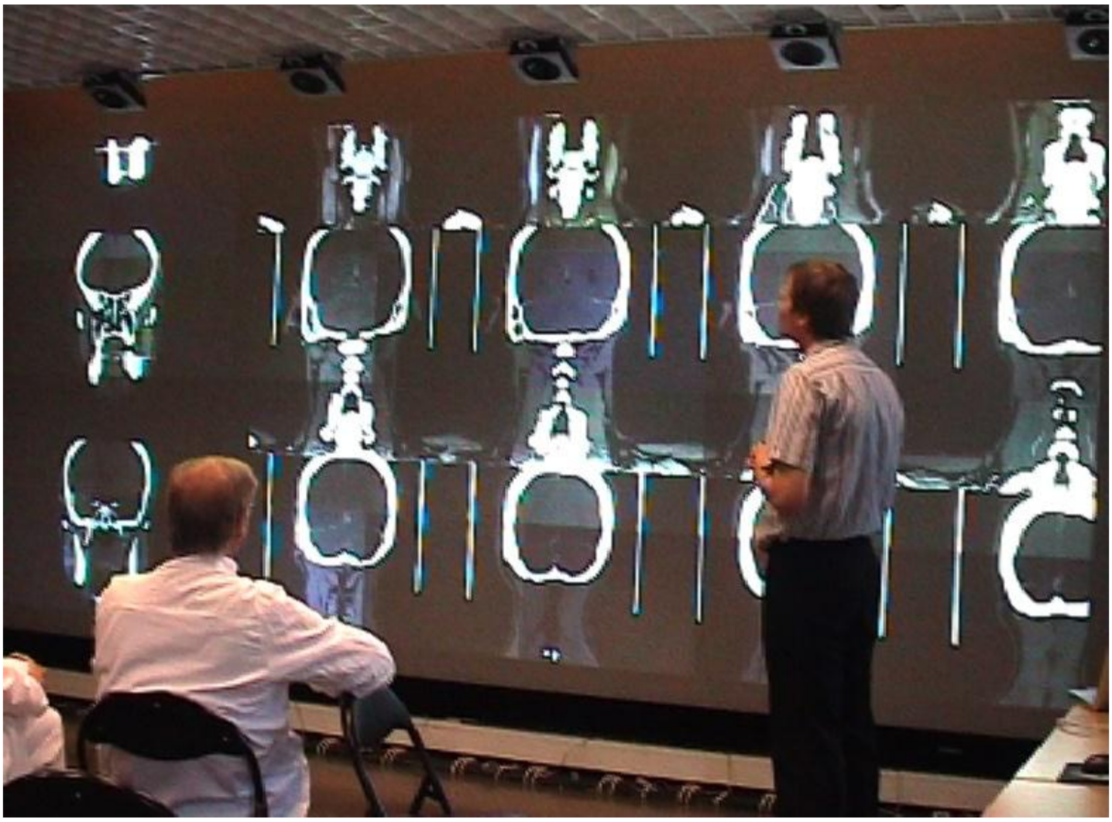

Figure 6 Videocapture: Software enlargement of images

Figure 6 is another snapshot from the demo where we in real-time zoomed in on parts of a CT image series panned along in. The audience were quite taken with how responsive the zooming and panning was in this example as this functionality utilized the parallel computing power in the cluster back-end of the Display Wall. As mentioned the performance of the Python-implemented parallel image viewer (PIV[40]) was one of the reasons I chose this kind of interface for our prototype and demo. A comment from the pathologist revealed both admiration of the performance and that he was not forgetting that this was a planned demo (it rather seems like he suspected some kind of 'cheating' going on):

"Is it as fast as this <in realtime> also?"

[40] Software developed by Daniel Stødle for the Display Wall at UiT

Other questions that were raised regarding the technology:

"... what Jon (Radiologist) is asking is whether or not we can <change filter> and view soft tissue details and bone details – so, would you be able to pick one series for bone-images or soft-tissue images"?

This question, it seems, is both related to what is possible with regards to real-time processing and whether or not the traditional options from a PACS environment is available with a display wall system (or if it is only static images as the ones they viewed).

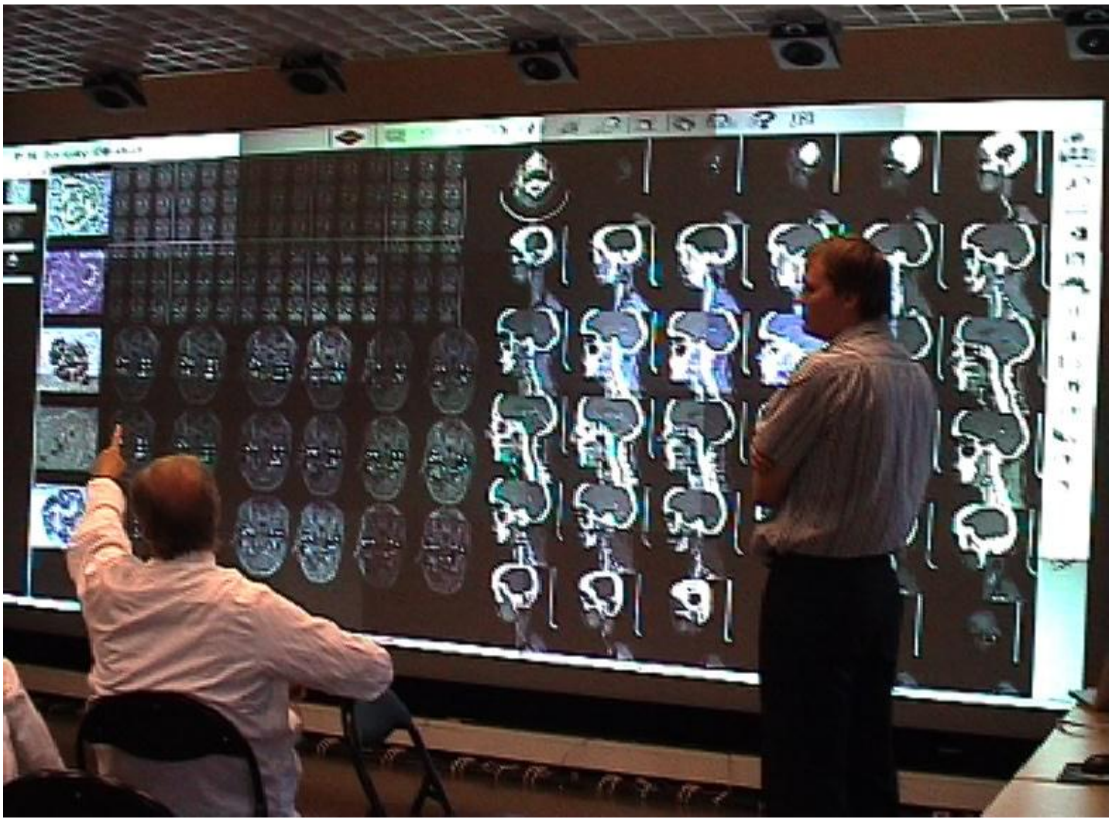

Figure 7 Videocapture: Many concurrent image modalities + pathology

In Figure 7 I added as many image modalities that we had available to the interface. Evident in this picture is that there is a lower limit for how small it is useful to make images for presentations, even though the inherent resolution in the wall supports it. It is almost impossible to make out details from the CTs in the upper left corner, next to the pathology slices (next to the column of pathology).[41]

It was also commented that the colour variations between projectors was disturbing for the kind of work that clinical radiologists do and the kinds of results they are communicating in conference-settings. These issues are being

[41] The complete video of the demo, along with a summary (video) that was presented at the MIE 2008 conference, is published at: http://phd.berntivar.com

dealt with today (which was also commented in the demo) (Majumder, 2008, Majumder et al., 2000).

3.3. Summary/Discussion

Our initial attempts to introduce the Display Wall into a medical setting resulted in a scenario of the technology in use for clinical radiology conferences and a subsequent demo of a prototype interface for this scenario. These conferences are usually performed when radiologists are sharing imaging findings with other (specialty-) clinics within the hospital. We did manage some initial results in introducing the technology to the clinicians - in a way I felt produced the most reliable feedback we were able to at this stage in the research. However, the empirical findings from the research design were also quite useful, in my opinion, as the current configuration/architecture of the display wall provides quite a significant obstacle for simple prototyping the specific purposes that we have had. These 'obstacles' are quite simply the cluster configuration and the use of Linux, in this case. With more resources available, this obstacle need not be crucial, as working with a distributed system such as the back-end cluster is also a great potential resource, if only you have the manpower (programmers) with the skill to utilize it.

The main weaknesses of this study as I see it, in retrospect, is the crudeness of the prototype. If we could have provided more hands-on experience for the clinical specialist we would likely have gotten much farther in terms of knowledge regarding affordances of the Display Wall and possibilities and limitations with such technology. Nevertheless, all in all the end result and demo that we were able to do, with basis in the experimental approach designing the prototype, were quite good – still. Videotaping provides excellent means to collect data in these situations and this alone would provide solid ground for development of subsequent designs for a radiology-conferencing solution using LaHiRD technology.

4. Display Size, Radiology and Human Visual Task Solving: Mental Rotation on a Display Wall

"... a primary goal of display design should be to map data into a visual form that is matched to our perceptual capabilities." (Ware, 2003)

In section 3.2 I describe how we tried to learn what potential 'target'- end-users of the LaHiRD technology would want from it – that is – what they would anticipate it would do better than what they have available today. It was particularly interesting to learn that what we originally thought would be a very interesting property of a Display Wall – to "hang" image series and spread them out, cascading them on the wall – could actually be counterproductive, and be interpreted as a regression – a step back from the now familiar medical image interface where scrolling through image series is preferred. However, LaHiRD technology has other important properties that are relevant to the medical domain, and one that I found interesting in light of the mentioned findings in the prototyping effort for radiology was the role of scale, or rather: the size of objects. In the group-collaboration mode (see section 3.1), the Display Wall would provide means to enlarge interesting objects from a set of data, almost regardless of inherent resolution of the image material, since the viewing-distance would in most cases be far enough away from the display not to make pixellation an issue. Of course, with objects other than static images like vector graphics of any sort, the issue of object size, or "scale" (which is the term I will prefer in the continuing) is even more interesting, since objects would not be distorted when moving closer to the display. However, the issue of image resolution could, and probably should be treated as an own subject for research in any investigation of large displays, especially from a cognitive point of view. I recap the research questions defined for this section:

R(II) Based on R(I) – in the context of clinical radiology conferences – are there specific relevant cognitive benefits from LaHiRD technology, or could there be exceptions to the belief that "larger is better" with regards to display size (i.e.: are there potential disadvantages with large displays)?

This question might be re-formulated to fit the novel context (in light of our previous findings) as:

What role (in perception) does size (of objects) play when designing interfaces for interactive LaHiRDs?

My interest from the work we had already done, and from previous recent research that has been done within the area of large-displays lead us to investigate objects size exclusively. Let us first take a look at research that has been done and what we do know about the topic of Scale.

4.1. Related research on the issue of Scale

First of all, when investigating the role of perception within design of LaHiRDs there are a couple of reviews and overview works available in contemporary CS-literature worth mentioning in this context. The first I would like to mention is

Mary Czerwinski's Large Display Research Overview (Czerwinski et al., 2006), as already mentioned in chapter 3.1. In this article, published in the proceedings of the annual CHI conference, she mentions some of the motivations behind the development of ever-larger displays, along with the research issues that are currently being investigated. Interestingly, her foci are primarily on two aspects of research problems, namely usability/interaction with large display and cognitive benefits from large displays compared to smaller. -In a separate work, Tao Ni, et.al. (Ni et al., 2006a) survey Technology, Techniques and Applications and also rate "the top ten challenges" for the community researching LaHiRDs. Ni et.al. name more practical and technological issues than what Czerwinski does – such as removing the seam between tiles, making the display reconfigurable, performance issues (cluster, high-performance computing issues) and scalability, but they also mention interaction/usability. -Finally, Ni et.al. conclude that "Perceptually valid ways of presenting information on large displays" and also "Empirical evidence for the benefits of large, high-resolution displays" are among the research issues of imminent importance. In the field of information visualization, Chen (Chen, 2005) identifies the basic understanding of perceptual- cognitive tasks as one of the top ten (he rates this as 2ndon the list) problems for the field of visualization in general. As seen from what I perceive as "relevance reports" from recent conference proceedings, there is a general need for more understanding of basic perceptual and cognitive tasks related to display size – a need that has been awakened by the recent, but long-sought increase in display size. The question to be answered is, hence: what has research found thus far?

In a related paper, Czerwinski, Tan, and Robertson (Czerwinski et al., 2002) found that the "gender gap" in 3D-world navigation (spatial tasks) diminishes and seem to almost disappear when users are given a wider field of view – meaning a broader display than what we are typically used to. Specifically, they set up two projection displays side by side and minimized the seam between them in order to have a continuous and coherent display that was twice as wide as an ordinary one. They made a virtual 3D-environment in which the participants engaged in way-finding tasks in a virtual world, a task in which men typically outperform females. They found significant effects of field of view and display size resulting on trial times. There was also a significant effect of gender in the small screen setup where males outperformed females, while in the large screen setup there was no observed difference and men and women performed equally.

In a follow-up study Tan, Czerwinski, & Robertson (Tan et al., 2003a) found that with a large display setup of 100 degrees field of view (normally around 30 degrees) and with the presence of optical flow cues, i.e., the effects of moving within the environment has on the change in image on the retina of immobile objects residing within environment, female performance improved to the point of evening out gender differences. They suggested that a wider field of view and optical flow cues could separately contribute to female performance enhancements.

Tan, Gergle, Scupelli, and Pausch (Tan et al., 2006) hypothesized that large displays result in immersing the users in the 3D-world, making them feel more "in" the world, and may bias them to adopt more efficient cognitive strategies when performing spatial tasks. Specifically, they hypothesized that a large screen biases users in adopting egocentric strategies for those tasks (i.e., "moving" their own person/head within the virtual world or "being there", as opposed to exocentric strategies – rotating the environment around them). In testing this hypothesis they also used the classical mental rotation test (ibid., p. 84). However, they found no sex differences in task accuracy or response time. Interestingly, in this study the relative size of the display was constant (i.e., only manipulating physical size as variable), so that the retinal size of the object was also a constant.

Based on the apparent needs of the research community for more understanding of user needs and human perceptual capabilities regarding display size I wanted to contribute to this understanding while also keeping a focus on our primary use of this technology: medicine – and radiology in particular. From our "browsing through the departments" at our local university hospital (see chapter 3.2) and through the influence of the research literature cited above it became clear to us that imaging in the hospital is very much about models of the human body and the organs. Medical professionals need to be very skilled at "translating" the images and information they receive concerning them (and the organism), putting it all into models that they compare to healthy ones. Especially within Radiology this is the case, where objects of the human body are studied often through abstract views of slices of the organs from different views; transverse, sagittal, coronal view, meaning horizontal-, vertical- and sideway- (profile-) view of the body. One of the "laboratory tasks" that resembles this task of viewing objects such as in the medical images to other models (potentially pathological vs. "healthy" objects) is called "mental rotation", and is one of the tasks that Tan and partners (Tan et al., 2006) used in their controlled experiments. However, they used in order to prove a lack of an effect – and argue that they successfully did prove the absence of effect of screen size on visual tasks when the strategy used in problem solving was exocentric.

Normally, these kinds of research findings would not encourage us to follow up with experiments of testing for effect in mental rotation. Nevertheless, there were a couple of issues that pushed us in the other direction. The first was, as described earlier, a realization that the matter of object size is an imminent design issue for interfaces to work on the Display Wall. Secondly, previous research involving mental rotation and object size had not taken into account field of view (FOV). Tan and partners (ibid.) tested objects of different physical size, but the distance to the display made object the same retinal size for the participants of their experiments. Thirdly, no one had, to my knowledge at that time, ever done spatial testing using mental rotation on a tiled display, which was my primary target for technology use in a medical context. Tan and colleagues used, for instance, single projectors. Finally, the research results that were present at that time did not seem too reliable, as chance performance for accuracy was reported in one study.

In sum, the call for understanding of perceptual effects of display size, the relevance of the mental rotation task and the lack of adequately relevant research results led us to undertake a controlled experiment using the display wall to test for an effect of display size. It also made sense to us to try and improve research design from previous research, and one of the things that struck us was that previous research within HCI apparently had not tested before for biases among the participants towards the task at hand, or simply testing for an effect of being a part of an experiment (Landsberger, 1958). The latter has become known as the 'Hawthorne effect', and both the term, and the concept in particular has been debated throughout the years. John G. Adair in (Adair, 1984) provides a quite thorough illumination of the 'methodological artefact', and criticizes previous and contemporary (at that time) research claiming to test for such an 'artefact'.

Originally, the research naming the term 'Hawthorne' bears it label from the "Hawthorne Works", Western Electric Company's factory plants outside Chicago and several studies conducted at that site in the period 1924-1932. The primary objective for these studies, one would have to suspect, was to uncover ideal working conditions for employees in order to raise or maximize production. The problem that one of the first studies (aka "Illumination studies", Adair, ibid. p. 336) was that despite quite profound changes in working conditions (i.e. bad lighting conditions), production did not suffer. However, the initial studies did not contribute as much to the 'Hawthorne effect' as later experiments, probably motivated by the former studies, where five female workers were taken out of their ordinary working conditions (assembling relays) into a special test room where relevant variables could be better controlled and evaluated. The experimenters changed several factors prior to investigation (i.e. method of determining wages) and underway (length of work day, whether company provided lunch, etc.). The problem that the researchers faced at this point was that production increased regardless of factors manipulated. When they decided to discontinue the project, it turned out that workers did not drop to pre-experimental productivity levels, but maintained levels from the experimentation. Adair (Adair, 1984), in his meta analysis categorized the research he found into three 'Hawthorne variables' controlled for: Attention; getting positive attention from being in a study, Awareness of experimental participation and 'novelty'. Controls for awareness, he reported, was that subjects were typically lead to believe that they were a part of an experimental group or program, while special attention control subjects were usually given a special placebo activity with no obvious effect on the experimental condition. In textbook literature (in social psychology) subsequent to the Hawthorne Studies, the effect was articulated as *"a threat to the validity of experimental outcomes in field experiments."* (Broches, 2008).

Our use of the Hawthorne concept is more related to expectations and conceptions about novel technology in general, but display technology in particular. From organizational science we know that conceptions about technology – and expectations are important factors when new technology is introduced into the workplace (Orlikowski, 1992), and also within software engineering (Sadler and Kitchenham, 1996b). Sadler and Kitchenham (ibid.) discuss the role and risk of a novelty effect in introducing new tools to software engineers, partitioning them into the *"learning curve effect"* and the *"Hawthorne effect"* (HE). It is interesting – and relevant – to see how they suggest treating the HE as a placebo effect is treated within medicine. -The HE is sometimes referred to as the Placebo of social research, and the methods to handle it suggested by Sadler and Kitchenham are more or less the same: blinding and double-blinding participants and "instructors" (those that lead or instruct in the evaluations).

4.2. Experiment 1: The Mental Rotation Task and Display Size

The task of mental rotation stems from an experiment conducted by Roger N. Shepard and Jacqueline Metzler, published in Science in 1971 (Shepard and Metzler, 1971). They had each of 8 subjects exposed to 1600 pairs of line drawings of three dimensional objects consisting of ten cubes attached face-to-face and with three right-angled elbows to form an arm-like structure (see Figure 8). Half of these figures were identical (congruent with respect to 3 dimensional shape) and half of them were different. The 1600 pairs were created from a set of 10 shapes in two sets, and every shape in each of the two sets had a mirrored shape in the other set. In this experiment, the objects were created on a computer and projected onto microfilm recorder. Furthermore, the drawings were created by rotating each of the 10 objects in 20 degrees increments from 0 to 180 degrees, creating 70 drawings in total. For the "same" pairs, two of the seven orientations of the object were selected and attached to a card for viewing by the participants. This original study by Shepard and Metzler also studied rotation around two different axes to see whether this had an effect on the rate of rotation. The 'different' pairs in their experiment were objects paired with a mirror image (isomer) of itself *and* a rotation. In sum, 800 of the 1600 pairs were 'same' and half of these were rotated in one plane while the other half (400) were rotated around a different axis ("*picture plane*" and *"depth"*, respectively). The interesting results of the Shepard and Metzler study was an almost perfect linear relation between the rate of rotation (reaction time), that is – the time it took participants to judge whether the two same objects which had been rotated in space, and the amount of rotation between the objects. –The more rotated one object was compared to the other, the longer it took participants to make an assessment of similarity between the objects. As mentioned, the study also examined rotation plane as a factor, but this did not seem to have a significant effect. This finding, together with debriefing reports from the participants after the experiments where subject reported to have tried and rotate the objects in their mind to try and fit into each other, made the researchers (Shepard and Metzler) conclude that what most participants had done was to encode an internal version from the 2D line-drawings of the objects into 3D objects in memory so as to be able to rotate them around any axis with equal ease (ibid.).

Since all participants reported that they had, in order to do the comparison between the objects, to "imagine one object as rotated into the same orientation as the other" – hence "mental rotation", the theory is that mental rotation is a motor skill that humans have, to mentally manipulate objects in space and the Shepard and Metzler experiment is regarded as evidence of a presence of such, and the results have been reproduced for over thirty years, in quite a substantial amount of research.

Based on previous positive findings of larger sized displays on female performance and the novelty-factor may influence performance in a controlled experiment (aka a 'Hawthorne effect'), our hypotheses were as follows:

H1: The size of the display (object size) will affect females' performance regarding mental rotation compared to male performance on a small display

H2: The expectation of one display being superior (novelty) to the other will affect performance in mental rotation

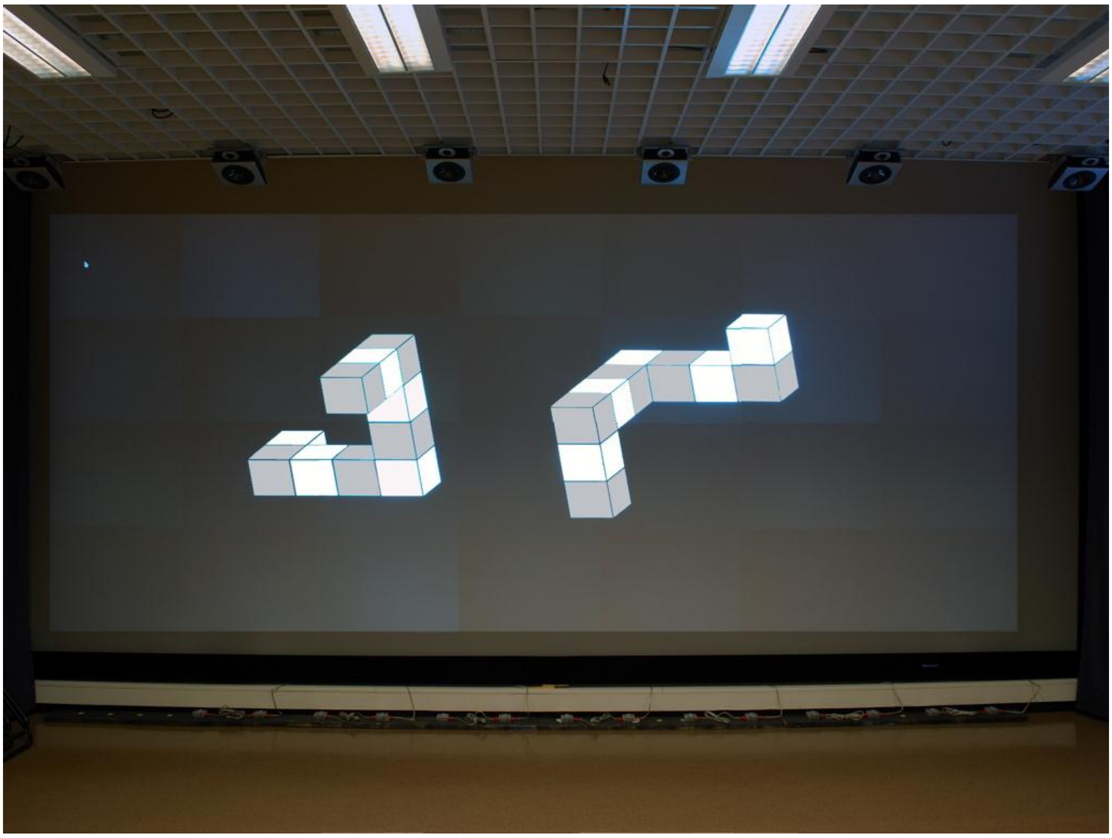

Figure 8 Mental Rotation stimuli on the Display Wall

4.2.1. Experimental Setup

The experimental setup is described in detail in (Olsen et al., 2009c). Figure 9 shows a schematic setup of distances from displays and corresponding visual angles occupied by the displays. Worth mentioning in addition to this description is the process leading to the final experimental setup.

When taking the Display Wall into use in a controlled experiment such as the one we report, we had a couple of choices of how to implement the presenting of stimuli and recording of responses and response-times. As described in our paper, we used existing software called Superlab © for presenting the stimuli. In addition to this solution, which was possible only because of software developed at the CS-department to transfer the local- (laptop-) desktop onto the Display Wall, we tried an open-source remote-desktop solution (Virtual Network Computer – VNC) and Microsoft's Remote Desktop. Both the mentioned alternatives failed because the software does not support desktop resolutions in the size of the wall (7168*3072). Furthermore, as we wanted to keep both aspect-ratio (4:3) and resolution mostly constant (we did not explicitly want to make resolution a factor in the experimental setup), the current choice of technology (labelled NAD-server and NAD-client) was the only way we would take advantage of the (almost) full size of the Wall in the experiment. Worth

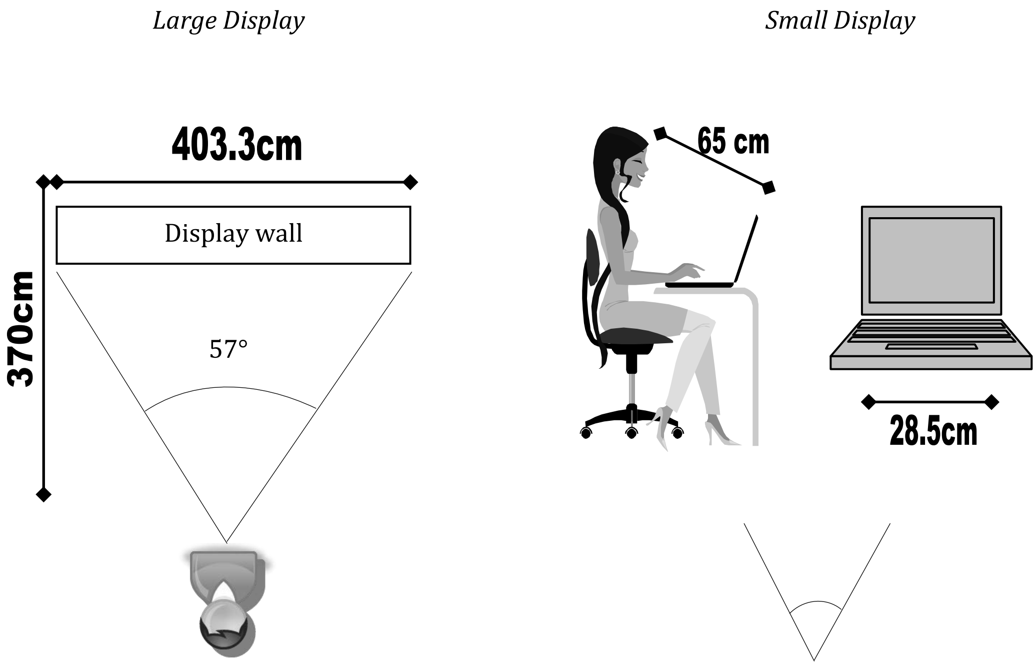

Figure 9 Experimental Setup with distance to displays and corresponding visual angles

mentioning is also the potential for implementing the mental rotation-task and –experiment on the back-end cluster of the Display Wall would be a viable option. However, we would in the latter case also be risking that what we implemented would not be a valid version of a MR-experiment (we would also need to validate the experiment) – not to mention the implementation-overhead this would cost this research project. The latter issue is not to be taken lightly, in my experience, as building software for the display wall (parallel software to be run on the cluster) is both technically difficult and very resource-demanding. In the course of a PhD-project including only one person's work, like the current, we would risk spending much time on something not leading to any immediate results. Hence, both the availability of the NAD software for the Display Wall, and the thoroughly tested Superlab © MR-program, used on several occasions by our collaborators from cognitive psychology, made the choice for us rather easy. All this being said – in future research-endeavors including MR, we would want to investigate the potential impact of resolution as well – meaning that a complete re-implementation of the MR experiment would have to be undertaken.

4.2.2. Our Findings

We found no apparent effect of screen size or expectation in regards to accuracy. Since we chose within-subjects design it is also important to note that Order (which screen was tested first for each subject, basically testing for a learning effect) did not play a significant role and was excluded from the

Table 3 Experiment 1: ANOVA table for RTs

ANOVA Table for RTs

	DF	Sum of Squares	Mean Square	F-Value	P-Value	Lambda	Power
Hypothesis	1	34299642,214	34299642,214	,293	,5917	,293	,081
Sex	1	42535321,682	42535321,682	,363	,5505	,363	,088
Hypothesis * Sex	1	2505287,146	2505287,146	,021	,8845	,021	,052
Subject(Group)	36	4215075859,686	117085440,547				
Screen	1	281153561,425	281153561,425	10,405	,0027	10,405	,898
Screen * Hypothesis	1	1831863,112	1831863,112	,068	,7961	,068	,057
Screen * Sex	1	36113638,889	36113638,889	1,337	,2553	1,337	,192
Screen * Hypothesis * Sex	1	112049253,379	112049253,379	4,147	,0491	4,147	,497
Screen * Subject(Group)	36	972711003,394	27019750,094				
Angle	6	833498522,967	138916420,494	80,013	<,0001	480,077	1,000
Angle * Hypothesis	6	20779190,172	3463198,362	1,995	,0676	11,968	,721
Angle * Sex	6	12528032,552	2088005,425	1,203	,3060	7,216	,462
Angle * Hypothesis * Sex	6	4833909,669	805651,612	,464	,8345	2,784	,185
Angle * Subject(Group)	216	375013953,048	1736175,709				
Screen * Angle	6	2274426,682	379071,114	,415	,8689	2,488	,169
Screen * Angle * Hypothesis	6	7623514,360	1270585,727	1,390	,2199	8,338	,530
Screen * Angle * Sex	6	11210650,050	1868441,675	2,044	,0612	12,261	,734
Screen * Angle * Hypothesis * Sex	6	4357524,010	726254,002	,794	,5753	4,766	,306
Screen * Angle * Subject(Group)	216	197491075,629	914310,535				

analysis. Most of the important findings are also given and discussed in our third paper. In Table 3, I present the ANOVA table for the RTs. Significant main effects of Screen (size), $F(1,1)=10.4$, $p<0.03$ and Angle, $F(1,6)=80.01$, $p<0.0001$ were found. The main effect of Angle is also plotted for the two display conditions in Figure 10. This effect of Angle basically validates the experiment with regards to the original Shepard-Metzler finding of the positive linear relationship with increasing angular disparity between the same shape objects and response times. This indicates that more time is used to mentally rotate objects farther in order to do the comparison between the objects.

The main finding of a significant effect of Screen size is also apparent from Figure 10; since mental rotation of objects was significantly slower in the large display condition. However, we know that the transfer of the stimuli from the laptop display to the Display Wall induced a variable delay, which is inherent in these mean timings[ii] of response time (RT). We were not able to measure this delay exactly in this experiment, but the delay basically consisted of network-latency and transfer over a 100mbit TCP/IP connection, plus a variable delay of up scaling the image (to fit the larger tiled-display) in the VNC-server software. The time used for up scaling was measured to vary from ca. 400ms to ca. 1100ms (measure in software on the VNC server), while the network overhead was ca. 100ms. Our inability to control or measure this delay made within-subject effects with screen size unreliable in this experiment.

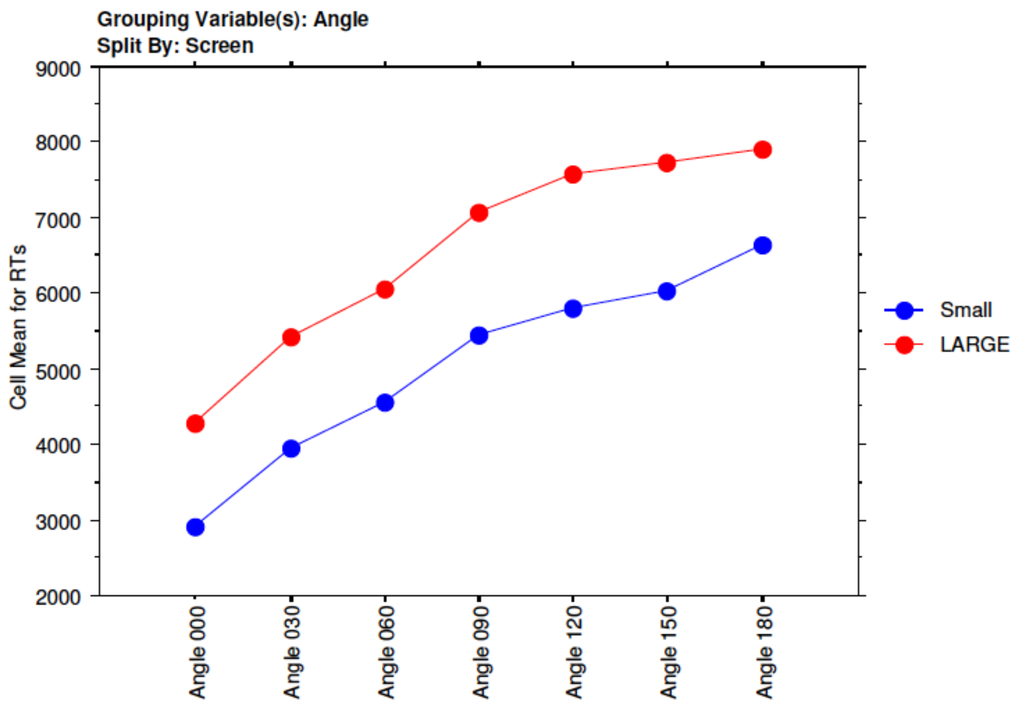

Figure 10 Experiment 1: mean RTs for angular conditions grouped by display size

Apparent from Table 3 we also found one interactive effect (three-way), *Screen*Hypothesis*Sex* was significant on a 5% significance level. This effect implied that in the different display conditions, expectations about superior display affected the sexes differently. This interaction is illustrated in Figure 11. Apparent from this plot is that mental rotation performance (rate) was negatively affected by the large screen condition for all but one group of participants: Females who expected to do better in the large display condition seemed to perform quite equally in this condition than in the small screen condition. If we also factor-in a delay in the large-display condition of ca 800ms (minimum 500ms and max 1200ms) it seems that this group of female participants performed slightly better in the large display condition (lower RTs than in the small screen condition).

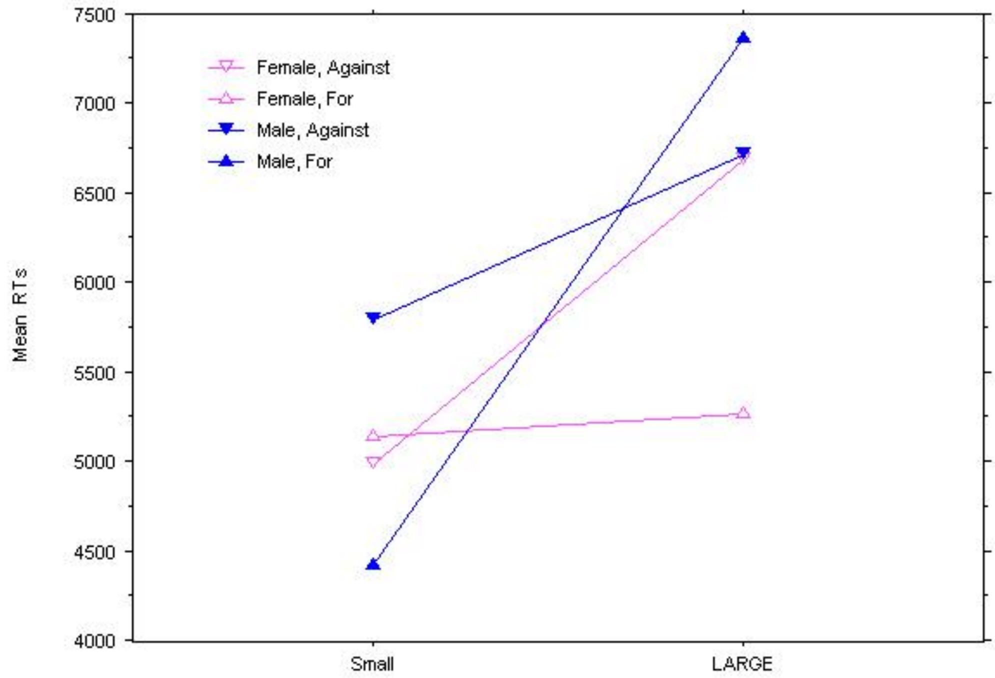

Figure 11 Mean RTs for the two display conditions, split by sex and the hypothesis that the participants were shown. This plot illustrates the Sex*Screen*Hypothesis interaction.

Finally, if we glance at Figure 12 we can see that mean RTs for increasing angular conditions in the two display conditions (shown split by gender) clearly reveal that the genders differ in their performance in the two display conditions, despite the lack of significance of in the ANOVA ($p>0.25$) for the sex*display condition.

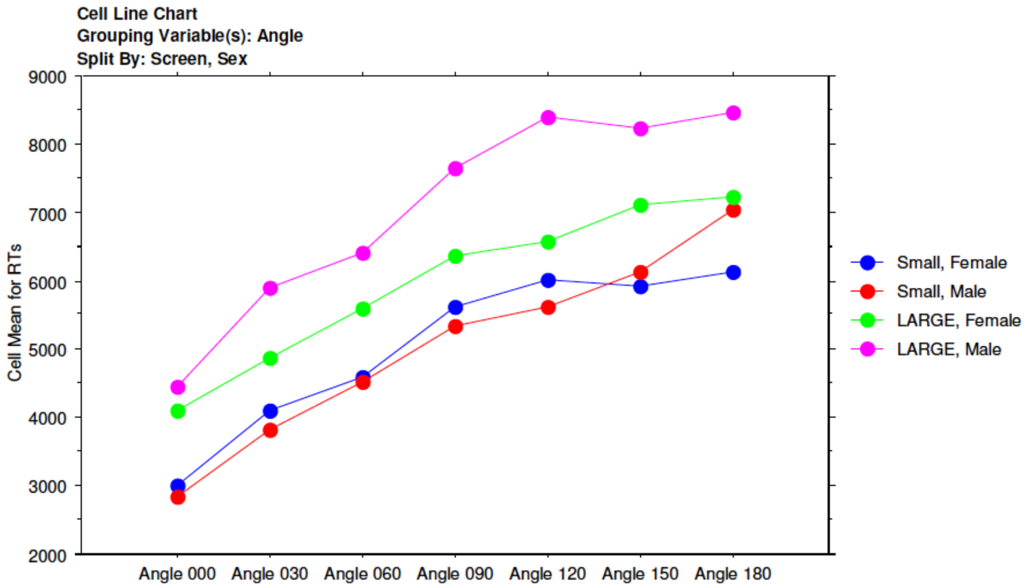

Figure 12 Experiment 1: mean RTs for angular conditions grouped by display size and split by sex

Looking at the top two lines (GREEN and PINK), displaying mean RTs for increasing angular conditions for both sexes, it appears that males (PINK line) perform slower than females (GREEN line) in all angular conditions of the large display condition. In the Small screen condition (BLUE and RED lines), the sexes seem to have quite equal performance and the slopes of the 'functions' appear rather equal.

In order to directly evaluate if the large display condition featured a performance advantage for females over males, I computed mean RTs for the two display conditions for both sexes and also computed 95% confidence intervals (CI) for the observed mean RTs. The CI was found to be 523ms (using the formula of (Loftus and Masson, 1994) for within-subjects design), and women were indeed 603 ms faster on average in the large screen condition than men (Women: mean RT= 5975; SD= 2736; Men: mean RT= 6578; SD= 3828) – exceeding the confidence interval. These results are illustrated in Figure 13. We also note that there is no difference between sexes in the small screen condition.

Based on the finding that only females expecting to do better in the large display condition performed better we suspected that this group might be trading accuracy for performance. In order to assess this, we performed a simple regression with accuracy as the regressor and RTs as the independent variable. We found no evidence for the presence of a speed-accuracy trade-off in the whole group (N=40), since R2 = .04; F(1,38)= 1.4, p= 0.24. Moreover, the slope's coefficient was negative (-45.7), suggesting that RTs tended to be shorter with increasingly accurate performance. When we repeated the same regression analysis on the group of women expecting the display wall to improve performance, there was no evidence for a speed-accuracy trade-off in this specific group either, since the slope's coefficient was larger and still negative (-

189.7) and the correlation was now significant: R2 = .42; F(1,7)= 5.1, p= .05.

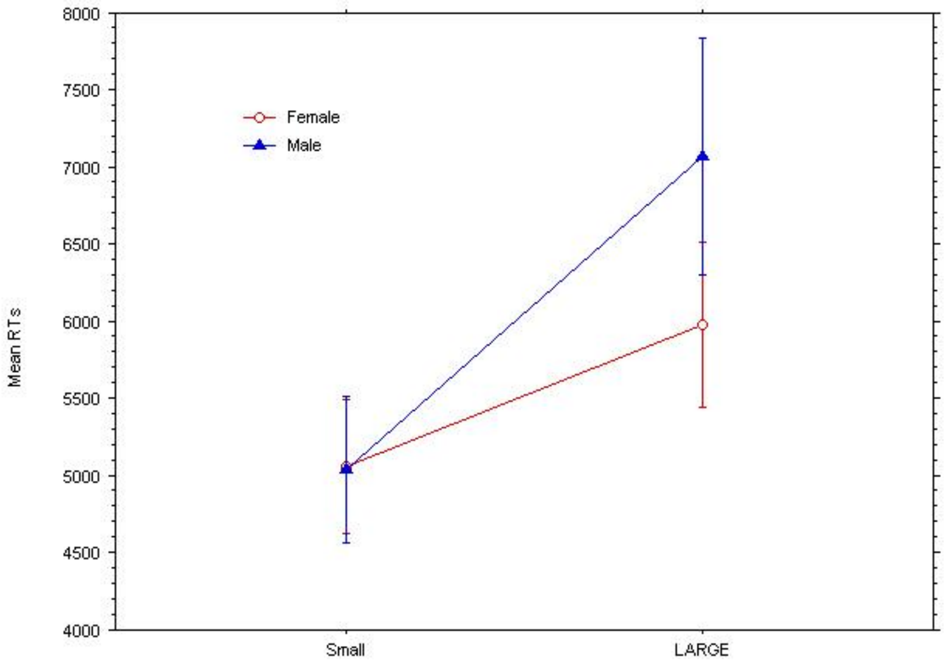

Figure 13 Mean RTs for both sexes in the two display conditions with 95% CIs illustrated by the vertical bars

I also collected Preference data in the debriefing from the experimental trials. These data also confirmed the results above since females seemed to prefer the large screen (61%), while males reported to prefer the smaller screen (65%). Table 4 shows these figures in a cross-table with hypothesis, *"For"* being the hypothesis stating that larger display should yield superior performance, *"Against"* claiming the smaller display to be superior with regards to the mental rotation task.

Table 4 Preference data regarding display size from Experiment 1

sex * preference * hypothesis_exposed Crosstabulation

Count

hypothesis_exposed			preference: large screen	preference: small screen	Total
Against	sex	f	5	3	8
		m	4	6	10
	Total		9	9	18
For	sex	f	6	4	10
		m	3	7	10
	Total		9	11	20

Thus, the preference data lead us to believe that participants may have been influenced by the hypothesis, but a Chi-square analysis contradicted this, as $\chi 2 = 0.012$ for females and $\chi 2 = 0.220$ for males, when testing for dependency between hypothesis and screen preference.

4.2.3. Discussion

Regarding hypothesis H1 and H2 we may already draw some preliminary conclusions[42].

By definition, we *may* choose to reject the null hypothesis $H1_0$, since, according to Figure 13, we observe that male and female average performance fall outside of each other's CIs in the large display condition, but not in the small display condition. Regarding H2, we cannot readily reject the null hypothesis since 'Expectation' (labelled *"Hypothesis"* in the table) is not significantly affecting variance as demonstrated in the ANOVA in Table 3 (p=0.59) – that is; there is no *main effect* of this variable. Expectation is, however, present in a three-way interactional effect Screen*Hypothesis*Sex, also apparent in Table 3 (p=0.49). The plot in Figure 11 illustrates this effect. We will revisit these results in the second experiment and a novel plot made for comparison between the 'Expectation' variable in the two experiments will illustrate this even better (see Figure 18).

In Paper 3 we have reported the results from Experiment 1 where we discuss the finding of a female performance-advantage on a large, tiled display yielding a wider-than-normal field of view. We had observed a female superiority in the mental rotation task, contrary to traditional findings of male superiority in this task. However, as the results from the ANOVA revealed, this superiority mainly expressed itself in an interaction with expectation for performing better with a large display compared to a small display. Female superiority observed in a mental rotation task when objects are at a certain size are quite remarkable results, but given the 'entanglement' with the 'Expectation' variable (being aware of the 'research hypothesis' – and/or the novelty-effect of the tiled display, we were left wondering if it is only in the presence of a positive expectation that females outperform males on a large display.

[42] H1 stated that female performance compared to male performance should be affected by display size, while H2 stated that *Expectation* regarding which display condition should yield superior performance should affect mental rotation performance.

4.3. Experiment 2: Mental Rotation and Display Size – no Expectation

In order to try and 'disentangle' the effects of expectation from display size I decided to replicate the first experimental setup, without any explicit attempt at inducing expectations regarding the experimental variable (display size).

4.3.1. Experimental Setup

The setup for the second experiment was virtually a replication of the first experiment – with a few of exceptions. We did use more or less the same equipment (same Display Wall and an equivalent Dell Laptop computer) and the same physical setup. The same distance from the displays was set up and, of course, the same venue (lab) with the same table and chairs. Lighting was also kept constant between the two experiments.

The first change from Experiment 1 was the removal of the hypothesis for the experiment (expectation stimulus). Given that the results were 'entangled' in the first experiment (gender interacted with expectation) we had to remove one factor in order to disentangle them. In this way we hope to learn if the size of the display alone can affect female performance, or if it is only in the presence of an expectation about this novel technology this effect can be observed.

I also tried to improve the design of the experiment, based on participant comments from the first experiment. The most frequent complaint or comment was that the experiment was too lengthy, making us fear that mental fatigue affected their performance. In retrospect, this was one of our initial concerns with the within-subject design of the display size variable. Our solution was to remove two angular stimuli in the setup (angles 0 and 180), effectively removing 2/7 of the trials. The details of the experimental setup are given in Paper 6. Note: I also managed to 'control' the delay inherent in the large display condition using a high-speed camera to measure the delay induced by network and processing overhead in the VNC server.

4.3.2. Findings

I present below some of the results that did not fit into the main article about this experiment. Some of the main results and figures are also replicated from Paper 6.

Effect		F	Hypothesis df	Sig.	Partial Eta Squared	Observed Powerb
ScreenSize	Pillai's Trace	2.512a	1.000	.119	.045	.343
	Wilks' Lambda	2.512a	1.000	.119	.045	.343
	Hotelling's Trace	2.512a	1.000	.119	.045	.343
	Roy's Largest Root	2.512a	1.000	.119	.045	.343
ScreenSize * Sex	Pillai's Trace	5.883a	1.000	.019	.100	.663
	Wilks' Lambda	5.883a	1.000	.019	.100	.663
	Hotelling's Trace	5.883a	1.000	.019	.100	.663
	Roy's Largest Root	5.883a	1.000	.019	.100	.663
ScreenSize *	Pillai's Trace	9.893a	1.000	.003	.157	.870

Display_size_expect_best_performance	Wilks' Lambda	9.893a	1.000	.003	.157	.870
	Hotelling's Trace	9.893a	1.000	.003	.157	.870
	Roy's Largest Root	9.893a	1.000	.003	.157	.870
ScreenSize * Sex * Display_size_expect_best_performance	Pillai's Trace	.484a	1.000	.490	.009	.105
	Wilks' Lambda	.484a	1.000	.490	.009	.105
	Hotelling's Trace	.484a	1.000	.490	.009	.105
	Roy's Largest Root	.484a	1.000	.490	.009	.105
Angle	Pillai's Trace	36.281a	4.000	.000	.744	1.000
	Wilks' Lambda	36.281a	4.000	.000	.744	1.000
	Hotelling's Trace	36.281a	4.000	.000	.744	1.000
	Roy's Largest Root	36.281a	4.000	.000	.744	1.000
Angle * Sex	Pillai's Trace	1.456a	4.000	.230	.104	.419
	Wilks' Lambda	1.456a	4.000	.230	.104	.419
	Hotelling's Trace	1.456a	4.000	.230	.104	.419
	Roy's Largest Root	1.456a	4.000	.230	.104	.419
Angle * Display_size_expect_best_performance	Pillai's Trace	2.890a	4.000	.031	.188	.741
	Wilks' Lambda	2.890a	4.000	.031	.188	.741
	Hotelling's Trace	2.890a	4.000	.031	.188	.741
	Roy's Largest Root	2.890a	4.000	.031	.188	.741
Angle * Sex * Display_size_expect_best_performance	Pillai's Trace	.913a	4.000	.464	.068	.269
	Wilks' Lambda	.913a	4.000	.464	.068	.269
	Hotelling's Trace	.913a	4.000	.464	.068	.269
	Roy's Largest Root	.913a	4.000	.464	.068	.269
ScreenSize * Angle	Pillai's Trace	.671a	4.000	.616	.051	.203
	Wilks' Lambda	.671a	4.000	.616	.051	.203
	Hotelling's Trace	.671a	4.000	.616	.051	.203
	Roy's Largest Root	.671a	4.000	.616	.051	.203
ScreenSize * Angle * Sex	Pillai's Trace	1.778a	4.000	.148	.125	.504
	Wilks' Lambda	1.778a	4.000	.148	.125	.504
	Hotelling's Trace	1.778a	4.000	.148	.125	.504
	Roy's Largest Root	1.778a	4.000	.148	.125	.504
ScreenSize * Angle * Display_size_expect_best_performance	Pillai's Trace	.835a	4.000	.510	.063	.247
	Wilks' Lambda	.835a	4.000	.510	.063	.247
	Hotelling's Trace	.835a	4.000	.510	.063	.247

	Roy's Largest Root	.835a	4.000	.510	.063	.247
ScreenSize * Angle * Sex * Display_size_expect_best_performance	Pillai's Trace	1.383a	4.000	.253	.100	.399
	Wilks' Lambda	1.383a	4.000	.253	.100	.399
	Hotelling's Trace	1.383a	4.000	.253	.100	.399
	Roy's Largest Root	1.383a	4.000	.253	.100	.399

a. Exact statistic

b. Computed using alpha = .05

Table 5 displays the ANOVA produced with SPSS 16, using Angle (5 conditions) and Display Size (2 conditions) as within subject factors and SEX as between subjects factor. Another between-subjects factor that I have included in this analysis is a variable collected in the debriefing questionnaire that all participants answered after completing testing in both display size conditions (see chapter 9.4 for the complete questionnaire), labelled "Display_size_expect_best_performance". In this variable I asked the participants what display size they thought that would improve their performance with regards to speed and accuracy: Small or Large? Hence, this variable was our best approximation to estimating 'expectations' in the second experiment without actually influencing expectations. Since this variable was recorded after completing the MR task it is likely that it reflects a feeling of which display size condition was less strenuous when performing the task.

Table 5 Anova table for Mental Rotation Experiment 2 (Multivariate Analysis)

Effect		F	Hypothesis df	Sig.	Partial Eta Squared	Observed Power[b]
ScreenSize	Pillai's Trace	2.512[a]	1.000	.119	.045	.343
	Wilks' Lambda	2.512[a]	1.000	.119	.045	.343
	Hotelling's Trace	2.512[a]	1.000	.119	.045	.343
	Roy's Largest Root	2.512[a]	1.000	.119	.045	.343
ScreenSize * Sex	Pillai's Trace	5.883[a]	1.000	.019	.100	.663
	Wilks' Lambda	5.883[a]	1.000	.019	.100	.663
	Hotelling's Trace	5.883[a]	1.000	.019	.100	.663
	Roy's Largest Root	5.883[a]	1.000	.019	.100	.663
ScreenSize * Display_size_expect_best_performance	Pillai's Trace	9.893[a]	1.000	.003	.157	.870
	Wilks' Lambda	9.893[a]	1.000	.003	.157	.870
	Hotelling's Trace	9.893[a]	1.000	.003	.157	.870
	Roy's Largest Root	9.893[a]	1.000	.003	.157	.870
ScreenSize * Sex * Display_size_expect_best_performance	Pillai's Trace	.484[a]	1.000	.490	.009	.105
	Wilks' Lambda	.484[a]	1.000	.490	.009	.105
	Hotelling's Trace	.484[a]	1.000	.490	.009	.105

	Roy's Largest Root	.484[a]	1.000	.490	.009	.105
Angle	Pillai's Trace	36.281[a]	4.000	.000	.744	1.000
	Wilks' Lambda	36.281[a]	4.000	.000	.744	1.000
	Hotelling's Trace	36.281[a]	4.000	.000	.744	1.000
	Roy's Largest Root	36.281[a]	4.000	.000	.744	1.000
Angle * Sex	Pillai's Trace	1.456[a]	4.000	.230	.104	.419
	Wilks' Lambda	1.456[a]	4.000	.230	.104	.419
	Hotelling's Trace	1.456[a]	4.000	.230	.104	.419
	Roy's Largest Root	1.456[a]	4.000	.230	.104	.419
Angle * Display_size_expect_best_performance	Pillai's Trace	2.890[a]	4.000	.031	.188	.741
	Wilks' Lambda	2.890[a]	4.000	.031	.188	.741
	Hotelling's Trace	2.890[a]	4.000	.031	.188	.741
	Roy's Largest Root	2.890[a]	4.000	.031	.188	.741
Angle * Sex * Display_size_expect_best_performance	Pillai's Trace	.913[a]	4.000	.464	.068	.269
	Wilks' Lambda	.913[a]	4.000	.464	.068	.269
	Hotelling's Trace	.913[a]	4.000	.464	.068	.269
	Roy's Largest Root	.913[a]	4.000	.464	.068	.269
ScreenSize * Angle	Pillai's Trace	.671[a]	4.000	.616	.051	.203
	Wilks' Lambda	.671[a]	4.000	.616	.051	.203
	Hotelling's Trace	.671[a]	4.000	.616	.051	.203
	Roy's Largest Root	.671[a]	4.000	.616	.051	.203
ScreenSize * Angle * Sex	Pillai's Trace	1.778[a]	4.000	.148	.125	.504
	Wilks' Lambda	1.778[a]	4.000	.148	.125	.504
	Hotelling's Trace	1.778[a]	4.000	.148	.125	.504
	Roy's Largest Root	1.778[a]	4.000	.148	.125	.504
ScreenSize * Angle * Display_size_expect_best_performance	Pillai's Trace	.835[a]	4.000	.510	.063	.247
	Wilks' Lambda	.835[a]	4.000	.510	.063	.247
	Hotelling's Trace	.835[a]	4.000	.510	.063	.247
	Roy's Largest Root	.835[a]	4.000	.510	.063	.247
ScreenSize * Angle * Sex * Display_size_expect_best_performance	Pillai's Trace	1.383[a]	4.000	.253	.100	.399
	Wilks' Lambda	1.383[a]	4.000	.253	.100	.399
	Hotelling's Trace	1.383[a]	4.000	.253	.100	.399
	Roy's Largest Root	1.383[a]	4.000	.253	.100	.399

a. Exact statistic

b. Computed using alpha = .05

We observed a main effect of Angle, $F(1,4) = 36.28$, $p<0.001$ and the expected interactional effect of Sex with ScreenSize $F = 5.88$, $p = 0.019$. We also observed interactional effects of ScreenSize * Display_size_expect_best_performance $F(1,1) = 9.89$, $p = 0.003$ and Angle * Display_size_expect_best_performance, $F(1,4) = 2.89$, $p = 0.031$. We also note that in the analysis of between-subjects factor, Display_size_expect_best_performance was observed as a significant main effect $F(1,1) = 12.64$, $p= 0.001$. In Figure 14 we can observe the positive linear relationship between angle of rotation and RTs as suggested by the main effect of Angle. It is also evident from this graph that this effect is present for both sexes in both display size conditions. This implies that we have again replicated the finding from the original Shepard-Metzler study (1971)– as we did in Experiment 1. If we compare the plots in Figure 14 with the corresponding plot from Experiment 1, Figure 12 we can clearly see similarities. In Figure 12 as in

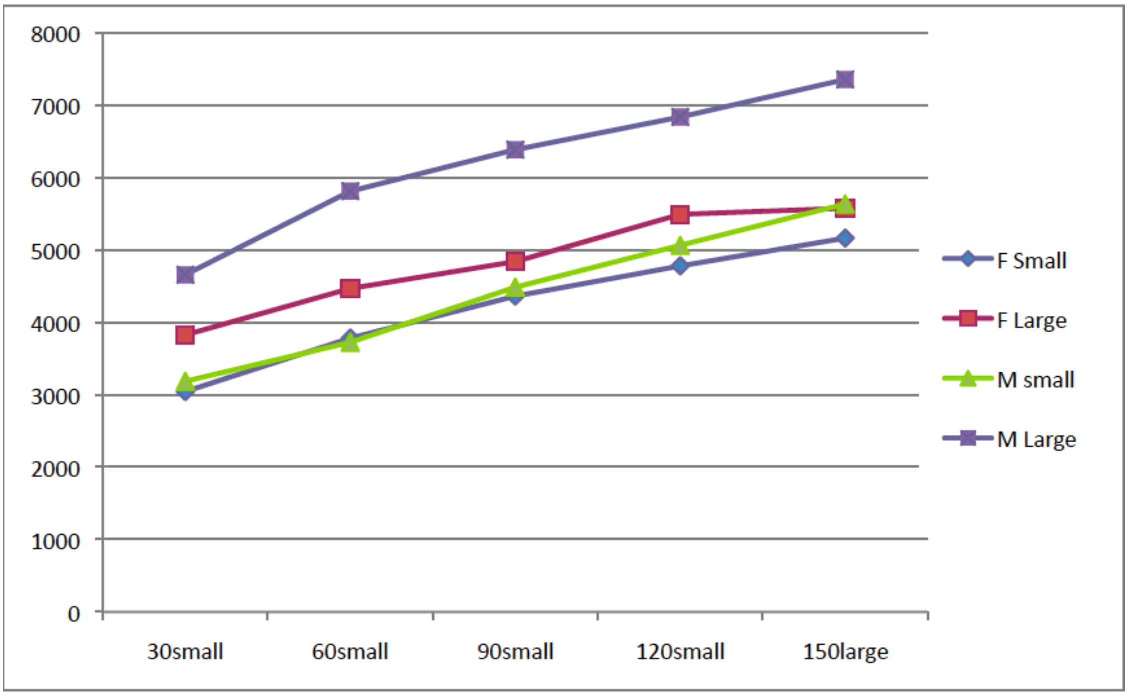

Figure 14 Experiment 2: mean RTs for angular conditions grouped by display size, split by sex

Figure 14 the bottom two line lines constitute mean RTs for men and women in the small display condition. The two sexes do not differ significantly in the small display condition. The top two lines in both figures illustrate male performance (purple and pink line in Figure 14 and Figure 12, respectively), while the female performance in the large display condition was located at significantly lower RTs in the slope beneath male performance (red and green line in Figure 14 and Figure 12, respectively).

What is quite evident from Figure 15 is the interactional effect of Sex with ScreenSize. Note that I have subtracted the mean delay induced by the large screen condition (*848* ms) in this plot. We can see that female performance is by all means equal in both display condition (*4050* ms and in the Large Screen Condition *4057* ms in the Small Screen condition) with regards to the mental rotation task, while males have a significant increase in their mean RTs in the large display condition (from *4208* ms in the Small Screen Condition to *5347* ms in the Large Screen condition).

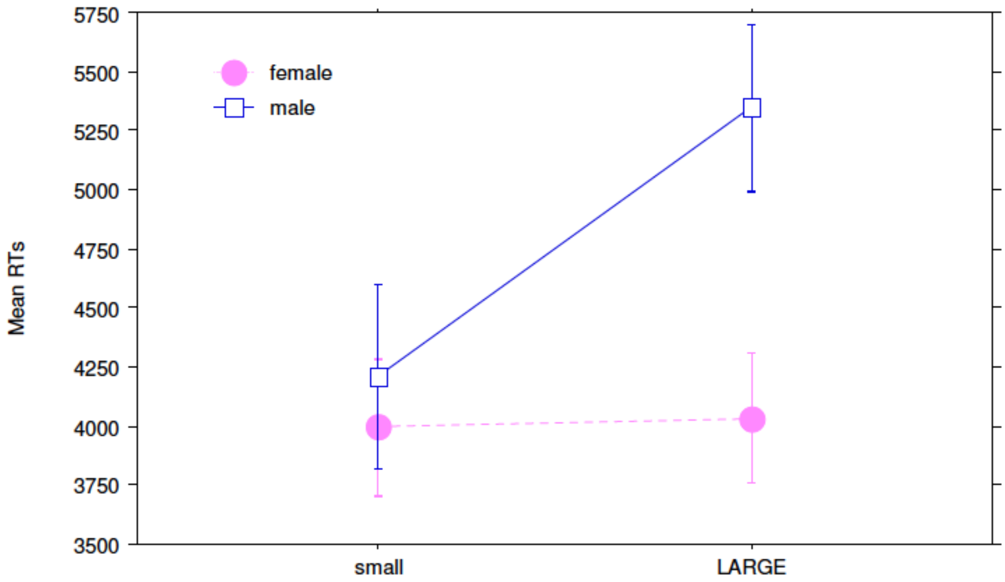

Figure 15 Experiment 2: Plot of mean RTs for males and females in the two display conditions

As for the effect of the **Display_size_expect_best_performance** variable, this is plotted in Figure 16. Evident from this plot is that those expecting better performance on the smaller display perform significantly better (shorter RTs) than those expecting the large display condition to yield superior performance (ca. *4000* ms compared to ca. *5250* ms). It is important to note that these means in Figure 15 and Figure 16 reflect overall performance – in both display conditions, split by sex in the former.

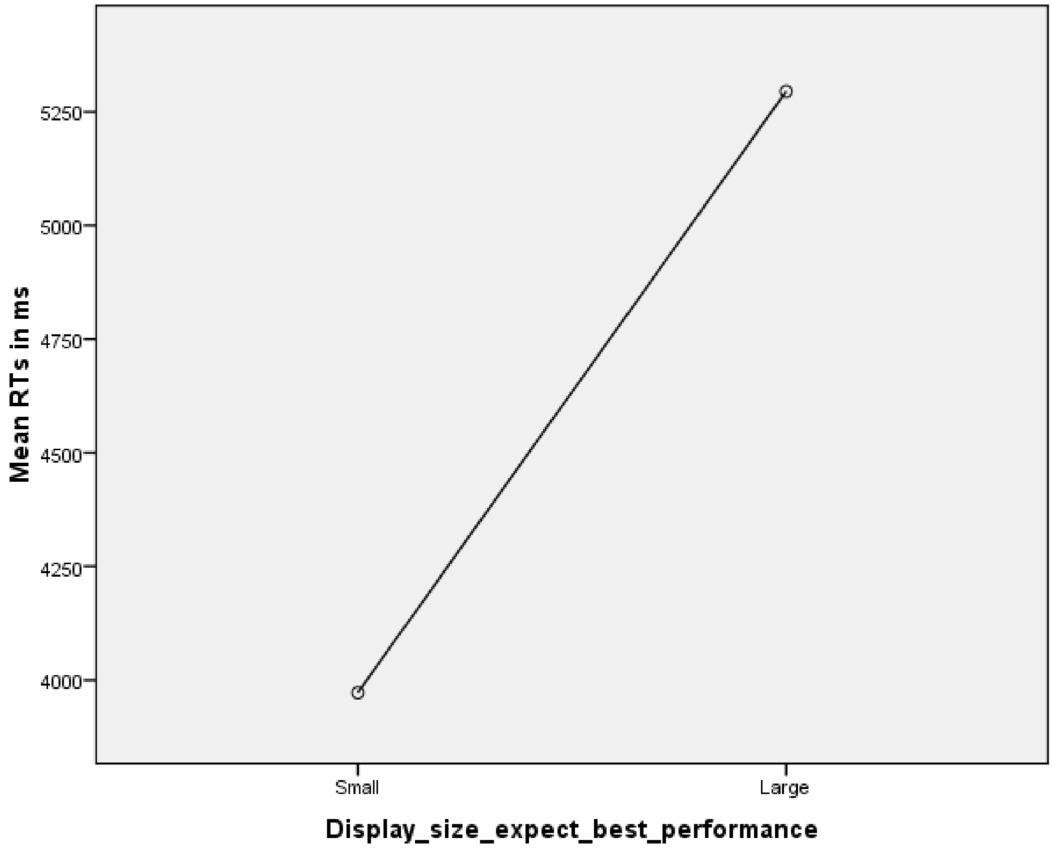

Figure 16 Mean RTs for the groups of participants expecting either small or large display superior performance.

The *Display_size_expect_best_performance variable*Angle* interaction plotted in Figure 17 illustrates how this difference in performance persists over all angular conditions and seems to indicate a rather steeper slope for the Large Display condition (green line).

In Paper 4[43], we attempt to discuss and in brief conclude the results of Experiment 2, compared to the results from Experiment 1 that we presented in Paper 3[44]. This paper mainly focuses on the rationale for Experiment 2, as motivated from our first experiment and what the latter results mean in the context of the prior experiment. Hence, our intention was to communicate that the Display Wall did not create a venue *better* for the females (compared to a 'normal sized' display, but rather that males seem to be significantly 'slowed down'

[43] OLSEN, B. I., LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. (2011). Spatial Tasks on a Large, High-Resolution, Tiled Display: A Male Inferiority in Performance with a Mental Rotation Task. In *Engineering Psychology and Cognitive Ergonomics. D. Harris, Springer Berlin / Heidelberg.* ***6781: 63-71***

[44] OLSEN, B. I., LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. (2009) Spatial Tasks on a Large, High-Resolution Tiled Display: Females Mentally Rotate Large Objects Faster Than Men. In *"Engineering Psychology and Cognitive Ergonomics. D. Harris, Springer Berlin / Heidelberg.* ***5639: 233-242.***

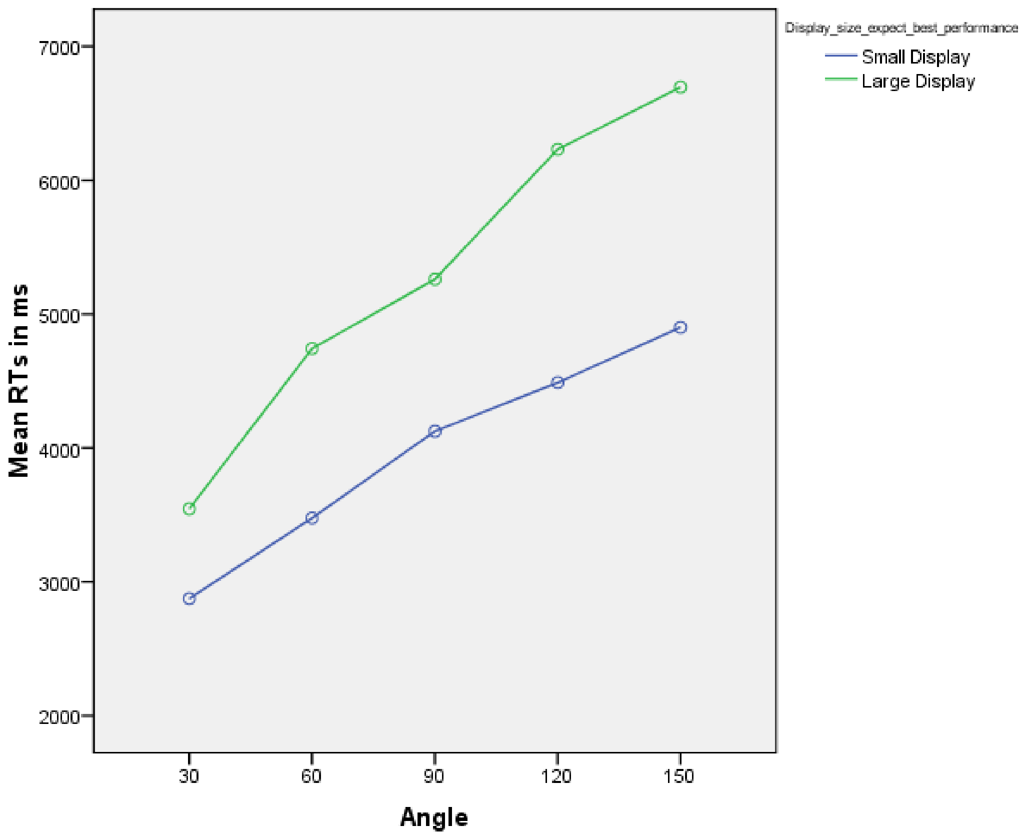

Figure 17 Mean RTs for the angular conditions, split by the Display_size_expect_best_performance variable

4.3.3. Discussion (Experiment 2)

In light of the results from Experiment 1, we were left wondering if it was only the expectation of performing better in the mental rotation task on a large display that made females outperform males, contrary to the typical male superiority in this spatial task. Although, it is unclear why females, in particular, should be sensitive to such an expectation effect for a new technology, the previous design did not allow us to fully assess the effects of expectation, since there were no conditions in which no expectation was specifically induced. Therefore, in the following replication experiment (2), we left out the explicit manipulation of expectation. Remarkably, we did find again a female superiority on the large display. It is impressive to see how similar the findings in Experiment 2 were to those in Experiment 1, as it should be evident from comparing Figure 14 to Figure 12. We may thus conclude that we have successfully confirmed a finding of female superiority since such a behaviour was consistently observed over two separate studies. Within Paper 6, we provide specific suggestions for why such an effect should be observed. In brief, we surmise that it is likely that differences in the problem solving strategies preferentially used by each sex may be the reason for the male drop in performance on a large display, compared to a small display. This may be due to the 'perceptual nature' of the holistic processing method (the male preferred strategy) and the sequence of events that are inherent. These may be negatively affected by a larger object size (i.e. resulting in more eye-movement and/or shift of focus), while a more piecemeal problem solving method, which is more characteristic for females (Bethell-Fox, 1988, Casey, 1996, Eme and Marquer, 1999, Pezaris and Casey, 1991), would already display such a 'built in' strategy. In this manner, female performance would remain unaffected by display size, while male performance experiences a significant degradation, resulting in higher RTs for a large display.

4.3.4. Expectation, Mental Rotation and Gender

In Paper 5, with the long title: "*Remember to Control for the (un)expected while Designing Controlled Experiments in HCI: The case of Sex Differences in the Spatial Ability of Mental Rotation and Display Size*" I have tried to elucidate our findings regarding *expectation*, (our variant of the "Hawthorne effect") and how this affected our results. Our primary finding in this regard is that we, as researchers and 'experimenters' were to some extent 'misled' by the results in Experiment 1, believing that the only group affected by expectation was the group of women expecting to do better in the Display Wall condition. However, in light of the results of Experiment 2, we can conclude that females *are* superior to males on a large display with wider field of view; hence a better conclusion regarding the effect observed in the first experiment would be that females expecting to do worse in the large display condition were negatively affected by the hypothesis that smaller displays were superior. I also re-visit the effect of the 'Expectation' variable (*"For"* and *"Against"*) with a novel plot given in Figure 18. These results are also evident from Figure 11, but with this layout it is easier to

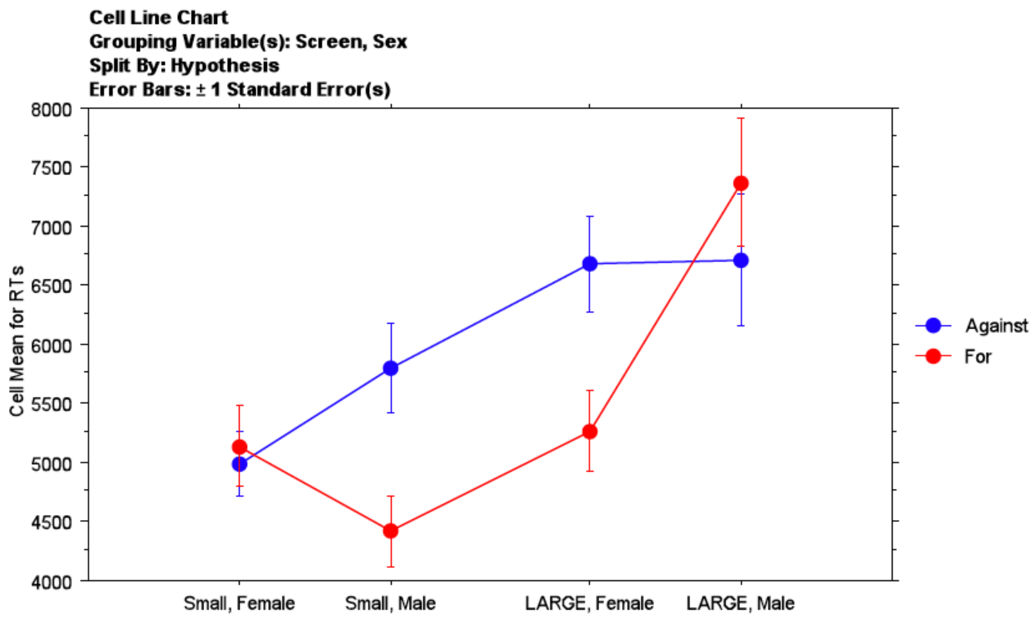

Figure 18 Plots of the "Hypothesis" effect on RTs; mean RTs given for both sexes in the two display condition with separate lines for what hypothesis they were exposed to

spot that, in fact, the only group and display size-condition of participants unaffected by the 'Expectation' factor were females' performance on a small display. Glancing at male performance we observe that those expecting Small

Screen superiority (*"Against"*, that is – hypothesis 'against' large-display superiority, Blue line in plots) performed notably worse (higher-RTs) than those expecting Large display superiority. However, in the Large Display condition (rightmost means in the plot) we observe a reverse tendency; that is, expectations of a large display superiority make them perform worse than those expecting smaller displays to be better. This may well be an observation of a fear of not confirming an expectation, similar to 'stereotype threat', combined with instructions of task difficulty (i.e. that the task at hand is more or less difficult in one or the other condition)(Moè, 2009). Stereotype threat is *"being at risk of confirming, as self-characteristic, a negative stereotype about one's group"* (Steele and Aronson, 1995). Moé, in her studies (ibid.) found that females' performance were only affected by expectations regarding their self, but in our case it seems in the novel condition (large display), which they had no prior experience with or expectations of, they were affected and performed worse when an inferior condition was expected.

4.1. General Discussion regarding Mental Rotation and Display Size

In reports of previous, related research, Suzuki and Nakata (Suzuki and Nakata, 1988) investigated whether the size of objects (retinal size) can affect RTs. A small group of participants (N= 6; 2 females) viewed either small, medium, or large object stimuli, where the retinal objective sizes, measured between the midpoints of the objects, ranged from 2.9 degrees to 5.7 degrees to 11.5 degrees. They found that angular differences in figures had a clear effect on RTs, as did the differences in retinal size. In accordance with Tan and colleagues (Tan et al., 2006), they found no effect of constant retinal size of objects (i.e. manipulating both the size of the display and distance from it in order to keep retinal size constant). Furthermore, Suzuki and Nakata found that RTs increased with the smaller sized objects, compared to the medium and large sized objects, arguing that this might be explained that the objects might have to be mentally 'scaled up' (going through a *"size-normalization process"*) before rotation on the smaller object.

Shwartz (Shwartz, 1979) examined whether the size of an object and its complexity affect rotation rates. Shwartz had 20 subjects (no mention of their sex) make a comparison between two-dimensional objects, which were shown briefly and in succession on the screen, the first stimulus being also followed by an orientation cue in the direction of which the subject were to visualize the object being rotated. When the second stimulus was given, the subject was to make a same/different judgment about the two objects. Shwartz found that increasing size of the objects resulted in increased rotation time. He also found that larger objects required increasingly more time to rotate farther. Note that Shwartz used two-dimensional objects while Suzuki and Nakata used images of block similar to those we have used. Shwartz (Shwartz, 1979), in his experimental setup, presented small stimuli which *"[...] fell inside a circle with a radius of 2° of visual angle, and outside a circle of .5°"*, large objects twice the size. This means that Shwartz had small object up to 4° angle and large up to 8°. However, since his setup was with objects presented in sequence - and not in parallel - as we have done, the visual angle could be regarded as twice these figures (8 and 16 degrees, respectively) if no space were added between them. Angle (as opposed to screen size or total sizes of objects) between objects is the measure used by Suzuki and Nakata. Comparing with their setup we see that our small screen provides the same angle as Suzuki and Nakata's largest retinal size (11.8° vs. 11.5°). This means that the smallest retinal sizes in their experiment, where they found the effect, was actually almost ¼th the size of the smallest objects we have used. In other words: Suzuki and Nakata found that very small objects required longer time to rotate, while Shwartz found that relatively larger objects required longer time to rotate. Our findings are in support to those of Shwartz. One could speculate at this point – that very small objects and very large objects require extra effort to manipulate mentally, while there could be an 'optimal size' for objects with regards to mental manipulation of images objects. Furthermore, taking our current findings into consideration, these reference sizes (small, 'optimal' and large) might be different for males and females

Although we predicted on the basis of a few previous studies that women's performance would improve with large visual displays, we did not have any specific hypothesis at the outset for why this should be the case. One possibility is, as suggested by Tan and colleagues (Tan et al., 2006), that large displays result in immersing the users in the 3D-world, making them feel more 'in' the world or 'being there'; thus, women may benefit more than men from immersing into the workspace environment. However, Tan and colleagues' argued that their results showed that only *egocentric* visual tasks (rotating oneself in the virtual environment) should be affected by screen size, while our results suggest that *exocentric* tasks are also affected by the size of the display. We have hypothesized in Paper 3 that women may be more adept in expanding their functional field of view.

However, in Paper 6[45] we discuss how the strategic approach for solving the MR task may differ between participants and affect our results. In common literature these strategies are typically divided into two and labelled 'holistic' vs. 'analytic/verbal' (or more piecemeal) strategies. Holistic strategy is denoted when subjects observe and encode in visual working memory a complete version of both objects and subsequently perform mental rotation on one compared to the other until they match (or not). The analytic/verbal strategy is denoted any other method of comparing the two objects, for instance counting the blocks or comparing pieces or particular features of the stimuli to each other before they make the call. In Paper 6 (ibid.) we make the argument that the analytic/verbal strategy, which is the preferred for females, may be less affected by object size compared to the holistic strategy. The holistic strategy is also found to be more efficient than the analytic/verbal, which is argued to be one account for the sex difference in mental rotation (Jordan et al., 2002, Moè, 2009).

As for the 'implications for design' it is too early to draw any design-advise from our results. The apparent degradation in performance (efficacy) for one group of users (whether that is just males – or more specific: people tending to use holistic mental rotation strategies) *is significant.*

[45] OLSEN, B.I., LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. Size Does Matter: Females Mentally Rotate Large Objects Faster Than Men (2012, SUBMITTED To Scandinavian Journal of Psychology)

4.1.1. The Gender Controversy

One could scrutinize the study of effects of gender in general, especially on tasks such as mental rotation that are associated with further 'controversial' issues such as intelligence. It is clearly an issue that research that focuses on the issue of gender gets more than its fair share of attention, especially by the media, but perhaps also in scientific research. My motivation of studying effects of display size on the spatial task of mental rotation originated in the case and scenario of a Radiology application, where the role of examining 3-dimensional objects within the human body seen via two-dimensional displays, as it is typically done within medicine in general, should be obvious. In a recent study of meta-analysis of publications within psychology focused on gender differences, Hyde (Hyde, 2005) discusses this issue and launches her gender similarities hypothesis. She postulates that men and women – boys and girls are similar in most ways, apart from a few. Hyde uses effect sizes as a measure and collects these from a broad field of different human abilities, from, for instance, reading to mathematics – to behavioural – to physical abilities, summarized in different meta-analysis. Her findings are in support of her similarities hypothesis – that mostly we are the same. The magnitudes of effect sizes found are mostly small, some moderate and very few are large or very large - *" ... 78% of gender differences are small or close to zero."* (ibid., p582). However, Hyde does find the exceptions that were expected: physical abilities, such as throwing velocity and – distance, along with some measures of sexuality, to mention a couple. Spatial abilities is one of the areas that Hyde does not emphasize as one where differences are large enough – in sum. Nevertheless, within the particular spatial task of mental rotation, the gender differences tend to have a large effect size, as also found in the 1985 meta-analysis that Hyde cite ((Linn and Petersen, 1985)). For the particular kind of mental rotation task developed by Vandenberg and Kuse (Vandenberg and Kuse, 1978), this effect size reaches that of the other abilities that are mentioned by Hyde (see (Masters and Sanders, 1993)). Finally, Daniel and Susan Voyer together with M.P. Bryden conclude in their thorough meta analysis, criticizing Linn and Petersen's work from 1985 conclude that "*Thus, those conducting future research should concentrate on specific spatial tasks and give special consideration to the Mental Rotations Test in order to determine the factors underlying sex differences in spatial performance.*" (Voyer et al., 1995). This conclusion is drawn by Voyer et.al after conducting a new meta analysis and finding a sex difference in the mental rotation task representing a mean difference in 0.94 standard deviation units between means of men and women (ibid. p. 265). Hence, I argue, an effect of display size on the task of mental rotation that differs between the genders *has* implications on design of interfaces for the large display surface.

4.1.2. Summary of the Mental Rotation Experiment

In our previous accounts, trying to elucidate how increased display size and resolution might affect the work of clinical radiologists, especially in team-based work and –contexts we found that 1) Object size is important, especially since cascading images in the extra display area did not seem to be an improvement of the process and 2) graphical illustrations (2D) of 3 dimensional objects and comparisons between such objects is a frequently solved task for radiologists.

Based on accounts of female advantages of larger displays with wider field of view, and that the – to the abovementioned everyday tasks for radiologists relevant task of mental rotation – has not been investigated with regards to field of view, I decided to pursue the question of how object size might relate to the MR task and how this might differ between the genders.

Over two experiments we have consistently found evidence for a female advantage and even superiority when object size reaches that of 27° of visual angle between objects in the traditional MR task devised by Shepard and Metzler. This finding is rather surprising from a basic research point of view, given the typical male superiority observed in this spatial task. From an applied point of view, at this stage, we may only note that changing visual size of object may have an unwanted effect for some users. In this case we would likely see males dislike having certain objects enlarged beyond a certain threshold. From previous accounts of effect of object size on the MR task, we may surmise that too small visual representations of object could also cause discomfort and that there is such a thing as 'comfort size' for 2D representation of 3D objects (see (Suzuki and Nakata, 1988) for small objects study).

As for my research question and proposed hypothesis, H1 and H2 I may, in light of both experiments conducted, and specifically in light of the ANOVA related to Experiment 2, conclude that $H1_0$ may be rejected with a 95% significance level. That is to say that a large display will affect female performance compared to male performance. However, in the analysis of our results where I have also factored-out a small delay induced by our large screen condition, we learn that it is *actually* male performance that is being affected *negatively* by larger objects.

Regarding the acceptance or rejection of $H2_0$, this is a more complex case, where 'Expectation' was only observed as a significant effect in a three-way interaction in Experiment 1. However, as we point out in Paper 5, and which is also evident from Figure 18, expectation *did* affect mental rotation rate in Experiment 1, and it did so rather differently between the genders. In light of the results from Experiment 2 we can also with more conviction conclude that 'expectation' and knowledge about experimental variables does affect MR performance, which has also been shown by other researchers in other contexts (Moè, 2009, Moè and Pazzaglia, 2006). In Experiment 2 we can also see that another 'Expectation' is significant on a 95% significance level (the expectation of which screen size participants felt they performed better on), but these data were collected post task completion, and, hence, did not – per definition – affect mental rotation rate.

Critique of the mental rotation experiments. Most likely, the main problem in our study of effects of display size on mental rotation is the inherent delay in update of the large display, which caused some 'disturbance' in our results – making within subjects comparisons in Experiment 1 difficult. Even though we have timed the delay in Experiment 2 and managed to factor-out it from analysis it is still possible that it could affect the results. However, such a delay does only constitute an extra (and enforced) "pause" between stimuli. In our experimental design we did not have restrictions on time-use; the task was self-paced. This means that participants could pause at their own will. This fact rather excludes the delay from any likely involvement in our results. The choice of within-subjects design in the experiment could also be scrutinized, but one of the important critiques of this design was amended in that we checked for effects of Order in the experiments (which display condition was tested first), which did not seem to have an effect on the resultant MR performance. In Experiment 1 we had perhaps rather small groups (N=40), compared to the number of factors (Display Size, Sex, Expectation), which may have compromised our results. However, the rather clean replication of the Large Display effect on gender in Experiment 2 suggests quite homogenous population in both experiments. The lack of effect of Sex on small displays in both experiments gives support for a rather particular population that we have sampled from – one with little inherent sex differences in performance on mental rotation. In fact, we took great care in Experiment 2 to increase the homogeneity in our sample so as to only recruit students, mainly from two basic fields of study (Science and Psychology).

5. A novel analysis-framework for systems to operate within a socio-technical context

This chapter is centred on answering research question R(III) of my work, and quite severely differs from the first part, conceptually and in methodology. Because of this, a certain need arises to explain the background for the work – and the motivation to pursue it as a research question. This work, however, is closely related to the work-description mentioned in the Introduction chapter (1), p 1-21. It somehow seems appropriate to apologize for, -or at least warn, potential readers of this work about the rather biographical nature of the introductory text below, but this approach is chosen to illuminate the background for this work sufficiently. In some ways one could regard it as a "biography of a scientific object", as L. Daston puts it in the title of her book (Daston, 2000), and my intention is to illuminate how the work with the document concept as a tool or method of design (-analysis) has evolved.

5.1. An introduction to the "Document Perspective"

The history of this part of my work in many ways dates back to a seminar in 2002, at "Sydspissen Seminarsenter" in Tromsø, where I for the first time met with the 'document concept'. At that time, the topic of the seminar was electronic health records (EHRs), which was – at that time, and still presently is – regarded as a very complex topic (or an issue of complexity), and 'solutions' such as standardization were presented. One of the speakers (whom I later learned to know as professor Niels Windfeld Lund) talked about the concept of documentation as means to deal with complexity, and – frankly – it struck me as a rather complex theory, but still very intriguing, as it more or less seemed to involve the very 'nature of information'. This 'nature of information' has also proved to be one of the most problematic issues within medicine, where for instance vocabularies vary between subjects and between geographical sites (worldwide) and where new concepts and additions to vocabularies are almost an everyday event, along with an ever-progressing knowledge-base. Even so, this seminar and the concepts and issues presented were not immediately relevant for my current work at that time.

One year after this seminar, in the spring of 2003, I got a job as a lab-technician at the Department of Documentation Studies, helping students studying this subject with amongst other things their thesis. As an engineering student in Computer Science my work was mostly dealing with the technical infrastructure in the lab, but in helping the student in their work I got acquainted with their projects and the methods that they used. Even though the objects of study that these students had chosen were ranging from knit things, to paintings and other works of art; the sort of things I knew little about at that time – and all the way to more technical stuff like computer games, I was quite taken with how well they managed to study for instance the process of creating such 'documents' or how the documents were perceived – either by themselves or by 'most people'. I thought to myself that these documents (or meta-documents) that the students were producing are actually describing system requirements – in some way. At this venue, I also got to discuss the theoretical foundations of Documentation Studies with the faculty staff, which were very stimulating talks for me (I cannot talk for the mentioned staff in this context, but it seemed that my knowledge paradigms seemed rather overlapping – and *complementary*, somehow).

This rather brief work experience leads me to read some of the background material and theory behind the students' work. Subsequently, I accepted an offer to work more closely with students that fall as an advisor for first year students in their philosophical introduction to the field of documentation. This way, I both got to familiarize myself with documentation as a field of study, its ontological roots, and practically – through the students' work – which basically consisted of a theoretical introduction to analysing a chosen document and to discuss this analysis in a philosophical context. This work, I feel, confirmed my initial thoughts of requirements descriptions – as students mostly described the prerequisites for the documents that they analysed, and the process of creating them.

The start of the currently described work was still almost one year into the future at this point in time, and so the 'material'; the theory and the 'empirical results' (the students' work) still had some time to mature for my part. At this time, of course, I did not reflect upon whether or not I would return to academia at all – seeming that I had just acquired a degree in computer science, and was ready to start engineering system. Almost one year passed until I would start my work as a junior-researcher (-to be) and got to continue these reflections[iii].

5.2. A document perspective (-a brief introduction)

Returning to our current research focus, the Display Wall and LaHiRD technology offers a new magnitude to the amount of visually available information – as many more 'channels' of information can be displayed simultaneously and combined in many more ways. *Complexity* becomes an issue for information design and interaction design (Swaminathan and Sato, 1997). Furthermore, a device such as the Display Wall in medical use in the context that we are interested in, namely *group work and collaboration* also brings 'social issues' to the table. Social systems and information systems to support social processes are complex systems (Kaplan and Seebeck, 2001) – which research efforts within Computer Supported Cooperative Work and Groupware systems over the last 15-20 years have illuminated (Ngwenyama and Lyytinen, 1997). Group work is a complex social activity. Designing successful systems to support humans in collaboration *is* a very complex task. Doing research on a technology such as the display wall, and trying to design information systems for it implies working with a complex technical infrastructure (Jensen, 2006). –It implies building complex distributed and/or parallel-software for a complex domain such as medicine, and also integrating complex theories from the social sciences when building a multi-user technology for collaboration between multiple agents on the large display. Furthermore, the inherent expectation of more informed medical decision-making depends on the correct information being available at the right time and place. The issue of (medical-) information systems *integration* is a hot topic at present – and one that apparently is rather distant from being universally accomplished anytime soon, even though the most important components for achieving this are already existing in current standards (like HL7 and ICD 10 for messaging and classification of diseases, respectively).

The task[iv] seemed quite challenging and the timing for the display wall in this regard as a research topic appeared to be a bit 'premature'[46], both as the display wall technology was evolving quite rapidly in hardware as well as software components, and as the study of the human-, and social aspects of technology in particular are also evolving rapidly, especially theoretically. Perhaps even more challenging was the integration of complex analysis methods into systems design and engineering, which yet seems to have some maturation to do (Crabtree, 2004, Kazman et al., 2003).

This leads us directly to the problem area that I have chosen to investigate – and it also comes as quite a natural consequence of both my focus on the human (-factors) side of the technology, and from the described continuing collaboration with the Document School at the University of Tromsø. 'Document theory' and 'documentation-studies' is both a new concept and a very old one. As stated in Paper 9:

" 'Documentation' predates and was replaced with the terms 'information science' and 'information retrieval' (Buckland and Liu, 1995). In fact, what today is named the American Society for Information Science was coined American Documentation Institute when it was established in 1937 (ibid., p 1)".

My main research question has been:

R(III) In the context of R(I) and large displays as venues for common work tasks: what role can Document Studies (DS) play in the context of sociotechnical systems design and -analysis?

Sub questions addressed, to varying degrees, are:

R(III).a What is 'a document', in a medical- and engineering context?

R(III).b How can document-theory and document-analysis in particular contribute to the design of socio-technical systems, in particular a display wall in a hospital - or such systems in general?

R(III).c In regards to question III.b) - how do we go about "using" document theory in this regard? What kind of processes need to be undertaken and what frameworks need to be applied to the (design-) problem?

As for question R(III).a, this is only an indirect sub-question of R(III), as a result of my findings from questions b. and c. – which I will show below. I will start with trying to answer the first of these questions with the fourth paper included in this thesis. It also needs to be stated that the resulting work described in this chapter has been addressed from a more "humanistic" approach than as structured 'IMRAD[47]-format' that we are familiar with from the science paradigm of research reports. This implies that our papers are formatted with as much a 'discourse' in mind as much as drawing a conclusion based on problem statements and results; I humbly ask readers to keep this in mind when proceeding to read this chapter and accompanying papers.

[46] -If such a thing as a 'premature research topic' exists!
[47] Introduction – Methods – Results – And – Discussion

5.3. Medical Documents

At the start of my project, the contemporary discussion within the 'science of Documentation'[48] was basically focusing on the ontology of a 'document' – and the search for a definition (Frohman, 2009). General contributions at this time either provided discourses regarding ontology/ontological roots, definitional discourses, or empirical studies of documents (i.e. in society). As with any scientific endeavour, I guess, there was a general 'existential discussion' whether 'documentation' deserves a place as an object of study – or as a field of study – as a scientific discipline in its own right (from my brief experience from a small handful of disciplines, this discussion – at some level – seems omnipresent for many field of study)[v]. In line with the contemporary research at this time – and also to provide the research group at the Computer Science with familiarity with the document concept – I decided to try and contribute to the basic understanding of 'documents'. Hence, we wrote a chapter for the 10 years anniversary book of the Department of Documentation studies, trying to increase our understanding of 'documents' – medical documents in particular. This part (5.3) of chapter 5 basically describes this work, in essence provided in Paper 7 (Olsen et al., 2007).

5.3.1. Approach

I have used a literature review within Medical informatics to ground a definition of medical- and clinical documents. To illustrate changes in perception of what may constitute medical- or clinical documents, in the transition from paper based medical (patient-) records – and knowledge bases, I have used, at that time, presently active research efforts within our medical informatics- and telemedicine (MI&T) research group, to illustrate future directions for these documents (medical-/clinical documents). I reflect upon the use of the word 'document' within healthcare, providing a brief selection of contemporary uses of the word. Our discussion of the term document is in this text very related to our initial research agenda of electronic health records – which provides a framework for the discourse on medical documents (documentation) and complexity.

As this work was meant to be a contribution to the documentation research-society, I have tried to structure and formulate our paper in accordance with the norm within the sciences of the humanities (that is: as mentioned, it diverges to some extent from the IMRAD model, which is frequently used within the natural-sciences). Each of the respective researchers in the author list has authored one part of this paper related to documents inherent in their current research activity. I subsequently edited this material, as the main author, in order to fit all contributions into a coherent essay. The 'sample documents', hence, are Medical Images, Documents for collaborative activity, 'statistical' documents – as used within public health (-informatics) and – finally – sensor based documents.

The literature review, as well as the actuality-reports from the respective fields of medical informatics from each of the contributors, serves as a basis for a

[48] I will also refer the discipline as Document Studies, as is its current institutional name at University of Tromsø

reflection upon what constitutes a medical document – and how the 'digitality' better suits future needs from these kinds of related documents.

5.3.2. Results

The main results from the search of a definition for 'medical documents' are actually several definitions and relations between them, as well as example-usages of the terms. I have basically made a distinction between 'clinical documents' and 'medical documents', as the one refers to documents relating to patient care, while 'medical' relates more to epistemological issues – relating to knowledge within the science of medicine. The mentioning of 'documents' within medicine (medical informatics) is also closely related to 'records', which – in medicine (and within information retrieval, it seems), is regarded as a more general term, where documents can be contained within records. This is fairly in line with the definition from the Clinical Document Architecture definition (CDA – of HL7[49]) (Dolin et al., 2006), stating that a document is a 'complete information object', that can exist independently. I argue that the 'completeness' of the 'document' is a challenge, seeming that the 'medical-' or 'clinical' document concerns the most complicated organism on earth (the human body) – and that the social-/societal context of any such document is extremely variable. The question of how to achieve this 'universal context' for any document, as it is suggested in contemporary literature, is standardization.

As for the second part of my research question: what is a medical document from an engineering standpoint, this is basically answered by document standards – for structure and for terminology. HL7s Clinical Document Architecture (CDA) provides an example of such a document standard – for clinical documents. This standard is meant to be a facilitator for the exchange of patient information (documentation) across institutions – and potentially national borders.

5.3.3. Discussion

Our book chapter in *"A document (re)turn"* (Skare et al., 2007) provides a discussion and definitions of medical and clinical documents as well as a discourse on how the transition into digital documents changes the concept of 'documents' within medicine. We give examples from research topics and – projects within our current research group to further illustrate what current and future medical documents are – and should/may contain. In light of the current status and focus of contemporary research within Document Studies this chapter describes the nature of our collaborative work up until then, while also contributing to the current research agenda of Document Studies. This work also gave me a chance to increase my understanding and to broaden our horizon as a research group on the basic research topic for our collaborative partners at the School of Document Studies.

I believe that this reported and documented work was a necessity for our interdisciplinary work that followed – and which is reported in the next chapter. Without this common understanding of each other's work-domains we might not have been able to produce the results that came subsequently to this. As a general note to interdisciplinary work, such as this, I think that one may have to

[49] Health Level 7, a non-profit organization that produces healthcare standards for medicine www.hl7.org, retrieved Aug 2009

budget for possibly quite a long 'maturation period' in any such collaborative research project, in order to reach the necessary understanding and respect for each other's scientific foundations, knowledge of these – and skills in applying them. For me personally, this period took several years, however – not with constant work all along (as explained above, this process was slowly started in 2002/03 and has been part-time underway). In doing multidisciplinary work (or wanting to do so), one might compare the approaches with for instance that of ethno methodological grounded research, where one tries to approach a target-group to study their work methods (Goguen, 1994). One has to accrue certain knowledge about the group's (and individuals') thinking and motivation for going about their work – in the way that they do – at the place that they do it, before an understanding of this (worth documenting) 'appears'. In the case of our collaborative work with document researchers, this understanding has been vital – as the knowledge needed for my work to reach a 'productive stage' was not apparent – or 'composed' for my use of it before this project. As mentioned above, the status for document research at the time I started this project was at a quite different place than what we could consider immediately fruitful from an 'applied perspective'. Hence was the internal understanding of the concepts and theories – along with the current research agenda for the field a study of necessity, in my view.

5.3.4. Leaving the traditional understanding of 'a document' in an engineering context – arriving at the twenty-first century

In Paper 8 (Olsen et al., 2010), I take the notion of a document one step further and introduce a novel 'document' as a future digital ecosystem. The title *"Leaving twentieth century understanding of documents – from book to eBook to digital ecosystem"* reflects this intention of not only a definitional discourse, but an attempt at changing our understanding of what we mean by talking about something as a document – and how future trends in the merger of reader/writer (author/authors) necessitates novel conceptual frameworks in order to grasp the complexity of the future eBook. We present a scenario of the future eBook and discuss how technology and digitality changes the concept of a book. We argue that the eBook *is* a digital ecosystem:

"According to the definition of Boley and Chang (Boley and Chang, 2007), it would need to fulfill four requirements; Interaction and engagement among the species, Balance – attention is directed where needed; Domain clustered and loosely coupled and, finally, it should be self-organized with regards to individuals and their ability to take action as necessary in any situation. The eBook today affords some interaction between the species, although the main author will contribute most of the written material. Bookstores, like Amazon, will to some degree allow consumers to contribute in the form of reviews. Balance is not so easy to identify for the eBook. There is always a team involved in creating a book, with the number of participants and their respective contributions being dependant on the type of book in question. However, eBooks today have still a long way to go before they are evolving even after publication. Domain clustering and loose coupling is to some degree true when Web 2.0 technology is included in the eBook concept, and for some types of books this is quite established. If we regard Wikis, or at least subsections, or articles within Wikipedia as such books, this is certainly true (Biuk-Aghai et al.)."

The eBook, as a digital ecosystem, and a social system based on complex technical systems, need novel frameworks to be analyzed, and to be modeled. We argue that document theory may provide such a framework.

5.4. An Ontology of documents and a document model for Use in Systems Analysis and –Engineering

The main result of my work with research question R(III) and sub-questions is contained within Paper 9 (Olsen et al., 2012). This chapter is dedicated a summary of this work and the contributions of this paper to the research questions.

5.4.1. Background and Motivation

As this project came from trying to elucidate how LaHiRDs could benefit a clinical setting, my initial approach was exploratory and experimental. However, seeming that the technology that we work with – discovered through my early work – has significant potential benefits for groups of users, it also made sense to try and take into use methodology for such systems – groupware, or what has been coined Computer Supported Cooperative Work-systems (CSCW-systems). The first phase of my project, hence, included search for appropriate methodology and tools in order to find such appropriate for this task.

CSCW has in the past been very much concerned with analysis of work, and studies of collaborative activities – and how technology supports these; or – rather – fails to support such activities (Grudin, 1988). It has been a concern amongst researchers within this field that CSCW has been too focused on critique of systems, while researchers really should be interested in improving systems (Crabtree, 2004, Coiera, 2007). The call has been made to go from design critique to design practice, essentially making the main question: how can different types of analysis of work practice (i.e. like ethnography) inform design (Button and Dourish, 1996)? Paul Dourish is still, one decade after the referenced "call", critiquing the use of ethnography within HCI – arguing that it is problematic that the expected outcome of any ethnographic inquiry regarding technology use should provide "implications for design" (Dourish, 2006). Dourish argues that this does not honor the theoretical rigor of the method and *" … may, indeed, fail to capture the value of ethnographic investigations."* From another angle, Enrico Coiera has raised a concerned voice that, even though analysis of sociotechnical systems[vi] (STSs) has provided us with knowledge about these issues, and powerful methods to study them, these studies (especially within Medical Informatics) have a tendency of focusing primarily on critiquing how technology fails to accommodate the complex nature of human – human interaction, pointing out the limitations of technology, rather than suggesting improvements to it (Coiera, 2007).

In the search for valid methods in order to inform design, and to do research regarding a novel technology in a particular setting, I was rather puzzled that I could not find many relevant techniques in order to inform the design of such systems. I had – and still have – no doubt that methods and tools applicable exist, but there was no easy way to locate and access these[50]. I have done observational studies within the hospital in order to locate interesting venues for placing the technology, but it seemed quite difficult to identify a particular technique that could inform and guide my explorative research. This finding – coming from a

[50] Since the start of this project a couple of really good reference works have been produced, *like CARROLL, J. M. (ed.) 2003. HCI Models, Theories and Frameworks: Toward A Multidisciplinary Science, New York, NY: Morgan Kaufman.* and http://www.interaction-design.org/ *(accessed Feb 2012)*

junior researcher within HCI (using this as the umbrella term for the set of methodology) – is perhaps not surprising for more experienced researchers reading this, as this is arguably one of the "weaknesses" of a, by now, very diversified field of study, totaling a great number of different aspects for analysis and methods to study technology. It seems that there are a great number of different tools and methods to use in order to study the interdependency of people and social systems with technical systems, but they all provide insight into specific parts of the system, and there does not seem to exist any guidelines of where to start – or how to select what methods to apply. Furthermore, many of the methods that exist are specifically aimed at studying technology already in use – meaning that all of these may have limited value when trying to assess exactly what novel technology and artifacts may imply or improve in a particular setting. For the current project the problem appears to be that experimentation is not easy to argument for – and feasible within a time- and error-critical problem domain, such as healthcare. It becomes a rather classic hen- and egg problem where benefits from a technology have to be proven before its application – or the experimentation – but without experimentation we will not know the benefits. This is not a novel problem within Medical Informatics, I am sure. However, the lack of overall structure for analysis of sociotechnical systems in general *is* a problem that I find relevant – and which became a focus for my work with the concept of documentation and its applicability for systems design. This context of a missing holistic approach to sociotechnical systems analysis provides a framework and background for research question *R(III).b How can document-theory and document-analysis in particular contribute to the design of socio-technical systems, in particular a display wall in a hospital - or such systems in general?*

5.4.2. Document Analysis as A Sociotechnical Framework

In the preceding chapter I described a feeling of the timing being a bit premature for direct applications for Document Theory. This sensation (or even gut-feeling) was based upon the contemporary scientific discourse within Documentation Studies – and, as I would discover, was dominant *outside* the local situation at the University of Tromsø – where I had experienced applications of this theory to real world objects. Hence, it was not before I dug deeper into the matter of 'documents' and 'documentation', and engaged in the contemporary scientific discussion that this unease presented itself.

In the works that I presented at the DOCAM'05[51] and the COOP'06[52] conference I had a focus on the document concept as a tool for analysis of the non-functional requirement of systems[53] (cf. (Pressman, 2000) for a description of non-functional requirements – and the process of requirements elicitation in general) – and that a description of the process of documentation (in light of these issues of perception and social attributes of documents) could prove very informing within systems design – particularly for the requirements elicitation and –

[51] http://thedocumentacademy.org/resources/2005/abstracts/berntivar.pdf (Accessed Feb 2012)

[52] http://www.zacklad.org/pages/Pages%20inferieures/archives%20conferences%20coop/Coop%202006/coop2006/tech-web-n2.utt.fr/coop/index2f30.html?rub=c4p (Accessed Feb 2012) Note: this was a short paper contribution for this conference and, hence, was not in the conference proceedings (only full papers published).

[53] -or the perceptual and social issues of systems

engineering part of the development process. I based these arguments on my personal experiences as a systems engineer (by training) of the work done by students at the School of Documentation at University of Tromsø – empirical work as it turned out – but never studied as such, or published anywhere; although there are a couple of exceptions, like (Follestad, 2004). Published works within Documentation Studies, like Skare's discourse of a particular document in the book "What remains", by Christa Wolf (Skare, 2003) exemplifies a document-approach to analysis. Skare has in this work used a literature approach to studying and analyzing documents. Marc Kosciejew provided a sociological approach to document analysis in his paper for the 2006 DOCAM conference (Kosciejew, 2006), where he describes and analyzes the documentary practices of South-African authorities during the Apartheid reign. He views a set of documents or practices involving them and analyzes these documents within the frameworks of for instance Michel Foucault and Bruno Latour (Foucault, 1977, Latour, 1987). From yet another angle of document analysis, Vårheim has at the DOCAM'06 conference (Vårheim, 2006) employed an institutional approach to document studies, and discusses in his work issues of 'public trust' in libraries.

As can be observed from the brief selection of types of issues discussed, and general contributions from the document research community has had a tendency to be of either an ontological nature, or from a phenomenological angle. My interest in the 'document' or 'documentation' –concept, as stated, has originated from a systems-perspective. The basic question has been: what can document theory and new models do for the design of systems? The current state of research for Document Studies, at the time I started this work did not provide me with all the components and tools that I needed in order to assess the value of the concepts and theories to the engineering of systems, systems to include LaHiRD technology in particular – and so, a part of my work, hence, became to collect the (theoretical-) resources needed and to try and join them into such a tool.

The culmination of the this work, addressing research questions R(III).b and R(III).c is to a large degree contained within paper Paper 9 (Olsen et al., 2012). Some of this work and results is also provided in APPENDIX C: appendices to 'A document approach' (chapter 5).

5.4.3. Approach

The approach, or method to reach my findings regarding what document theory can contribute to the process of systems design, or the way to apply it, is not easily described as a step-by-step process. It has been a rather long and winding road, as it has included familiarizing me with both the document theory, but also the currently known methods to address systems design from a sociotechnical point of view.

In retrospect it can be argued that the work has been organized in something close to an iterative fashion, where increasing insight into document theory and sociotechnical and systems design methods from Human Computer Interaction has affected and provided input into the iterations. Figure 19 shows a schematic view of this process. The gradual maturation in understanding of document theory and concept *and* HCI-theories (and CSCW) has developed into both understanding of how apply the concepts, and relations between the theoretical underpinnings of HCI and this model.

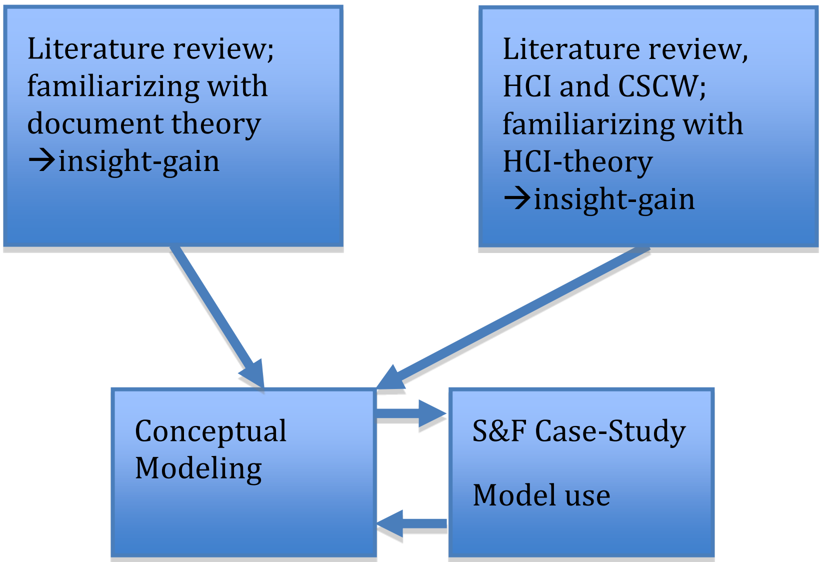

Figure 19 Conceptual View of the Research Process on Documentation as a Conceptual Tool

5.4.4. A "case study": Store and Forward Psychology (S&F Psych.)

As the model in Figure 19 illustrates, at some point, the document model was tried on a "real world" problem – more specifically during my research stay at UC Davis[54]. I was privileged to take part in a research project within telepsychiatry - a validation project of a novel telemedicine service model called store-and-forward telepsychiatry. The usage of the document model on this issue seemed rational at the time, since our model had reached a stage where it seemed viable for practical use, but S&F project was also used as somewhat of a case study 'by chance'. The timing of the research stay coincided with a phase of the project where it would have been natural to apply the document approach and model on my project with the Radiology department at UNN. However, when the opportunity to stay with the Health Informatics Department at UC Davis came along it was too good an opportunity to turn down. The documentation of the theoretical work with the document model was still a long way from done, and so it was decided that I would work with this issue while in California – while also tending to any projects that I could join at UC Davis.

At UC Davis[55], I was most generously allowed to pursue the work with the document model and I decided to try and apply this model for a system analysis of a novel telemedicine service based on the novel S&F-model. As Figure 19 implies, the application of the document model to the S&F telemedicine service

[54] http://www.ucdmc.ucdavis.edu/informatics/
[55] My research stay at UC Davis lasted one calendar year from Aug 2007 to July 2008

model meant that this analysis would serve as a sort of case-study of an analysis, as well as input into the still ongoing modeling process.

5.4.5. Summary of the S&F Telepsychiatry case

The Store and Forward Telepsychiatry project, as presented in the document analysis provided in Appendix C, was analyzed according to the presently available document model at the time of my arrival in this project (Aug-Sept 2007). However, as described in Figure 19, this project and the analysis of it was also (recursively) input into the development of the document model as well. Hence, the document analysis provided in this thesis is also 'reflective' towards the document model as well – providing not only details about the system being analyzed, but also comments and input to the 'modeling process'.

It is, however, quite possible to grasp both the concept of the S&F Telepsychiatry system as well as some of the details of the system from looking at the analysis. In the analysis the analyst has divided the system into two distinct documents; MD-doc and Psych-doc, where former precedes the latter in the timeline of document production. This is also illustrated in Figure 26. The document analysis is not to be regarded as a research-finding per se (which is why it is in an Appendix), but it does illustrate a potential form of the DA, with regards to its potential as an artifact in the analysis- or design process of engineering a sociotechnical system. The primary role for the DA in the context of this dissertation is input into the resulting document model and its description given in Paper 9 (Olsen et al., 2012).

5.4.6. Alpha testing of DA

As mentioned in Paper 9 (ibid.), p.120, I did a very limited and informal test of the Document Analysis (DA) with students in the Medical Informatics course at UiT. Two groups of four students were instructed to do a document analysis as a part of the Requirements Engineering part of a development project for a rudimental telemedicine application. Beforehand, they had developed scenarios of uses for the system as a background for the DA. Because of time-constraints I could not do a formal investigation of the uses of the DA in their development process. The time-constraints also made completion of the DA impossible and so these results were inconclusive. I did, however, manage unstructured interviews (or rather-focus groups) with the two groups separately and collected some "pilot-feedback" for the DA.

5.4.7. Results

In Paper 9, *"Document theory for the design of socio-technical systems: A document model as ontology of human expression"*, I describe a model or taxonomy of the constituents of documents that can serve as a template for analysis of documentation systems. In regards to research question **R(III)**, regarding what role Document Studies can play in the design of sociotechnical systems, I have found that document analysis, in the form that we have presented it, provides a very holistic approach to systems analysis. The document model in its broadness and complementarity presents Document Studies as a form of meta-science, where I argue that the details of document analysis is dependent on tools and methods that are inherent in other fields of study. This is to say that the document model may bring structure to a systems analysis on a higher-level, especially in a sociotechnical context

To the detailed question of what document theory can *contribute* to the design of sociotechnical systems such as a display wall in health care settings, the answers – at this point – is difficult to answer with certainty. My analysis was done on a novel telemedicine system, which is quite different from my initial scenario of a display wall for use in clinical radiology conferences. The common factor in both systems is that they represent novel document systems that do not exist today. S&F Telepsychiatry is by all means also a sociotechnical system, in that it includes advanced technology in a novel social system of delivery of psychiatric services.

As discussed in Paper 9 (Olsen et al., 2012), the use of document analysis thus far – where it is residing in the home of the social sciences and the humanities – is limited to existing documents – in many cases 'historical' documents, or structural analysis. Engineers build novel artifacts. We may re-use concepts and material, but the norm is to *engineer* things that have not been before. Hence, these analysis of existing documents are not our primary interest. Therefore, I argue, the document analysis that has the most promise, at least for systems with a great deal of *novelty* (like LaHiRD implementations in a hospital, or other technical inventions), is *Experimental Document Analysis* (EDA). This kind of analysis would use the document model in order to analyze 'imaginary' or predicted documents in order to provide input into the design process. This EDA could well utilize document analysis of other documents (e.g. older systems, or paper-based systems – non-digital systems) in order to bootstrap the EDA.

The concrete contribution of the document model that we have presented is a *holistic* model, which – despite the potential for detailed analysis – is quite apprehendable with relatively few components and a quite 'commonly known' syntax and concepts[56].

To research question III.c, regarding the 'use' of document analysis, we have created, as far as contemporary document theory goes, a complete document model, at some level applicable to systems analysis. We have developed this model based on reasoning from literature in both documentation and human computer interaction. The model has been created and used at the same time in our joint project with the Store and Forward Telepsychiatry project and the result is a crude document analysis with an 'explanatory nature' towards the model used for its creation. My hope is that this model may provide grounds for more detailed analysis of other sociotechnical systems and a basis for more research, perhaps focused on a mapping between a document model (a template for analysis) and more detailed methods for analysis. In regards to a development process (like some form of inclusion in a *requirements document*), the DA probably has a long way to go. At present, 'Human Factors' (in the form of 'Usability' or 'Ergonomics') has still some way to go in order to be sufficiently included in development models and processes (Jerome and Kazman, 2006, Bygstad et al., 2008). Inclusion of a DA in such models is probably at best 2nd

[56] Especially if we compare it to Computer Semiotics and similar efforts from a humanistic point of reference.

priority at this time, but the conceptual document model – in a broad sence – I think is of quite importance in order to grasp and communicate other aspects than the 'technical' in systems development.

In an attempt to summarize research *findings* from my work with the document concept, I regard it as a *meta-concept* and a *meta-theory* in the context of analysis of sociotechnical systems and human computer interaction. The document model cannot likely replace any old forms of analysis, but can quite well function as a taxonomy of analysis (on a practical – or *applied*) level or an ontology for sociotechnical systems. Document analysis should contain necessary detail to explain documents as *human expressions* (Olsen et al., 2012) and the *process* of creating (or "instantiating") these documents. Hence, the meta-concept is quite readily my answer to R(III).b: how can it contribute. As for R(III).c, how to go about using the concept and theory our presented model is one answer: 'instantiate' this model; create an analysis and insert this into the development process, subsequent, of course, to educating stakeholders with regards to the model as an ontology for the systems.

We introduce the (E*xperimental) Document Analysis* (EDA) as a boundary object, and most boundary objects are primarily considered such subsequent to an identification (in an analysis of collaboration between different 'social worlds') and the introduction of artificial boundary objects has been argued against (Bowker and Star, 1999) and discussed i.e. in (Eriksson, 2008). Eriksson, prior to this discussion, recalls the different characteristics that Bowker and Star list as inherent in boundary objects: applicable in several communities; fulfill requirements of information from each community; have a constant identity across communities; being tailorable to the needs of a community; ambiguous and constant – and that they can be either concrete or abstract. Eriksson argues that artificial boundary objects should be able to function as such as long as they comply with these requirements. We argue that a (E)DA should be able to comply with these requirements both because the objects of analysis should be easily identifiable by any stakeholder in a project (belonging to any relevant community), as any 'doceme' should come from either (f)actual circumstances in a already present system of documents (in existing systems), or from accurate descriptions of 'new' circumstances that the stakeholders should agree upon with the document analyst(s) and the designers (if different) – in the case or a novel system. Furthermore, all stakeholders are potentially input sources to this analysis – or active contributors to it – ideally.

Lastly, relating to R(III).c, the alpha-test of the DA mentioned in chapter 5.4.6 provided some comments and input, even though this (E)DA was not concluded. The crude findings from the feedback of the interviews (with the groups) were that the (document) model was fairly easy to comprehend. The scenarios provided a good background to do the more detailed analysis of potential documents. However, the complementary aspects – cognitive and social – of the documents provided quite a challenge for the students (by their own admission). Having only scenarios on which to build analysis was not sufficient to make any meaningful assumptions of these aspects of the document. As a reflection on role of the EDA as a mediating artifact within this context, we believe that this analysis would have to be done in cooperation by several of the stakeholders and the producers of the documents, each using their special competences to contribute. The analysis of the social and cognitive properties of a document might well have to be left to specialists within these fields. This should not come as any surprise, as we have not argued that a document perspective can replace these methods. An experimental document analyst's role would hence be to supervise this process and audit the EDA and the process of creating it whenever needed.

5.4.8. Discussion/Summary

In essence, and in brief, we can say that traditional systems engineering is a reductionist's approach to the design problem, breaking down problems into manageable (information-) pieces, data structures and data – the "atoms" of information. As computer- and information systems became publically available in the early 1970s it, hence, became inherently important to break *information*, the contents that were to be manipulated by the computing devices, down into a manageable form – a numeric form. This was a necessity at the time in order to build the tools and methods that we more or less take for granted today, like the creation of a human-readable and writeable language and interpreters between machine- and human language. In the beginning there were only numerical instructions to communicate with the machines. Later, the Assembly language and compilers to translate into machine language were developed. Subsequently, ever more user-friendly programming languages and –concepts has made the (design-) interaction between computing and communication systems ever simpler – even though we still probably have a long road to walk before we can write common language or even draw (which we already can – to some degree, using standardized drawing-objects) to the computer in order to program it. In other words, our need to break *documents* down into 'computable atoms' of 'raw information' or pieces of information has distanced information-systems from the 'natural habitat' and culture that they are to operate within.

It is by now rather well known that traditional systems engineering has faults with regards to human factors, how people relate to the information systems created (Grudin, 1988, Ellis et al., 1991, Ackerman, 2000). This topic has been tried dealt with throughout several subfields of Human Computer Interaction (such as CSCW), and is work in progress in terms of including concepts and research findings from HCI into systems development (Bygstad et al., 2008, Hussain et al., 2009). I contend that the document model may serve as a 'unifying' concept in this process, given its 'holisticity' and simplicity and its potential as a meta-concept for both traditional systems engineering and human-factors analysis. Both have their rightful place in the document model.

Within any field of engineering the question of *trade-offs* is essential. Within software engineering the question of resource expenditure - cost, and payoff is omnipresent. What does a requirement cost to implement in terms of time and resources? How much will it cost to uncover a requirement? What is the risk (potential cost) of not eliciting, testing and implementing a requirement – or a group or kind of requirement? One of the reasons why I argue that this particular document model is appropriate for systems analysis is because of its conceptual breadth (i.e. holistic) *and* because of its flexibility in the amount- and level of analysis that is possible. A superficial or shallow analysis that does not go into depth on any docemes will provide a crude and conceptual model of the documentation system that allows designers and engineers, in cooperation with 'clients' and users (actors and agents) to analyse any part of the document at more detail. This way, one can estimate at least the cost of analysing any part, both in time and other resources, while also weighing that particular part of the documentation system towards the environment where the system is to work. That is – if the system is to be introduced into a particularly "social environment" (i.e. high interaction between people), you can choose to analyse this part of the document(s) in more detail while reducing efforts in other dimensions of the document.

'Satisficing' is a word that Herbert A. Simon explains (Simon, 1988) he introduced in order to differentiate satisfactory solutions from optimal solutions, where optimal solutions may not be feasible to locate. He reflects upon how the area of Design is about choosing solutions that can be attributed this adjective: satisficing. In the context of document analysis, satisficing is obviously a relevant term and concept, as the analysis can be done from a multitude of perspectives (through the 'eyes of the analyst') and to an almost infinite level of detail. The problem might become how to select the 'satisfiable' criteria, rather than analysing the system from all possible angles, but this is a common design-issue, especially for systems-design. It is still an issue that needs attention regarding this document model (future work).

As a final remark in this regard, any applied science is likely to influence the basic science it 'facilitates' (Shortliffe et al., 2001). My endeavour to extract the fundamentals of documentation theory into an analysis tool for (sociotechnical-) systems-design, could prove to influence or accelerate the development of a document theory in that regards. A document theory that not only suffices to capture the essence of documents in a context for the sciences of the humanities , but is also *usable* for analysis and the design process of *documentation systems.*

6. Concluding remarks

Even though this project started out with a work-description including subject fields of CSCW and Medical Informatics, I would rate this work as mainly to pertain to general HCI (as the umbrella term including both human-computer interaction and social issues of information systems). Yes – some of the work has elements of Medical Informatics, some of the work lies within traditional HCI (perceptual qualities of LaHiRDs), some within CSCW (a novel framework for sociotechnical systems analysis) and some of this work lies within the basic Document Studies. I will in this chapter clarify where I think the individual contributions of my work belong.

6.1. Contributions to new knowledge – Medical Informatics

Contributions to the medical informatics domain, as I see it, are two-fold. First, I have found that the novel display technology may have qualitative benefits over currently used technology. The clinical specialists that we have worked with envision that LaHiRD technology may provide additional important information visually that is currently unavailable (or only available orally) due to the limitations in size and resolution of contemporary displays. My results are not unequivocal positive conclusions that higher-resolution and the potential for arbitrary sized displays should replace older ones, but that the potential in LaHiRD technology is quite exciting. The results, I think, strongly signal that more research and prototyping are necessary in order to investigate the potential for the technology.

Secondly, a specific finding of our prototyping is that image-series cascading and the viewing of more image slices simultaneously may *not* be regarded as a benefit from the LaHiRDs by clinical specialists in Radiology. This finding may be said to apply to radiology in particular only, but as radiologists are the diagnostic specialists regarding medical imaging, this finding should be generalizable to any issue relating to medical imaging (i.e. that this 'effect' should apply to non-radiologists as well, if we presume that they use the same the same cognitive approach to diagnostic reasoning on medical images). -In any case, my research suggests that the cascading of images should not be on the shortlist of interface-suggestions when such are prototyped for LaHiRD technology. Priority should be given to present diverse information in the extra display area and extra pixels.

6.2. Contributions - Human Cognition and interface- and display-design

My findings indicate that object size affects the spatial task of mental rotation differently between the genders. Females seem to mentally rotate large objects faster than men – because large objects seem to degrade mental rotation rates for males. The effect presented itself on a 220 inches (ca. 27° visual angle between object in the traditional Shepard-Metzler stimuli) tiled display when we compared performance to that on a 14.1 inches (ca. 12° visual angle between objects) laptop display. The effect was observed consistently in 2 separate studies. In the latter study we confirmed a female advantage of over 20% in mean response times with the Display Wall, compared to male performance. In effect, this result points to a 20% decrease in male performance (or affecting a particular strategy for solving this task) (as reported in Paper 4). These results need to be confirmed with other studies, but we report a significant performance degradation that for object sizes about twice the 'normal'. This could have ergonomic consequences that should be amended in interface design. This kind of issue should manifest itself in the use of interfaces, perhaps comparable to font-sizes. We cannot, however, at this stage confidently report implications for design, but rather conclude that we have found basic differences in the effect that display size has on the particular task of mental rotation and that, as such, these may have implications for design. This finding is also contributions to basic research of cognitive psychology and cognition and may provide some input into understanding the basic human ability of mental rotation.

I have also found that expectations among the participants towards the experiment variables can affect their performance. My contribution in this regard calls for sensitivity in research design for controlled experiments where one should take care to try and control for an expectancy effect and unravel potential awareness among the participants towards the experiment variables. I think this is especially relevant for behavioural studies of technology, where the 'novelty' factor is particularly pertinent. These are not novel findings per se (the Hawthorne effect has long been known to exist within the social sciences, however debated), but it has not, to our knowledge, been very usual within HCI to test for such an effect for other than qualitative studies.

6.3. Contributions - Documentation Studies

The study of medical documents, from the perspective of medical informatics is basically a finding within documentation studies. I have described the nature of medical documents and their transition from analogue (paper) to digital patient records, or more generally within health information systems. In order to describe my contribution in this regard I have to reflect upon the relationship between basic research and applied research. Basic research is generally described as a search for 'comprehensive knowledge' about some subject – without specific uses or applications in mind[57]. Applied research, on the other hand is efforts to gain new knowledge too, but with specific applications in mind – a practical objective of some sort. Applied research is also viewed as the application of basic research findings to specific problems. In an Interdisciplinary-, as well as Multi-disciplinary work such as this, it is interesting to see how Edward H. Shortliffe has, in his illustration of Medical Informatics (Shortliffe et al., 2001) as a basic research described this relationship between basic and applied research. He argues that Medical Informatics or Biomedical Informatics is the basic research domain in which the search for new methods and theories are the primary focus. The basic research area of Medical Informatics has several application domains, in which the theories and methods are applied in order solve specific problems. These application areas are, in turn, motivating researchers within the basic science of Medical Informatics in their work:

"(…) medical informatics researchers derive their inspirations from one of the application areas, identifying fundamental methodological issues that need to be addressed and testing them in prototypes or, for more mature methods, in actual

[57] For example definitions, see for instance: http://www.buildingbiotechnology.com/glossary.php, or http://www.arc.gov.au/general/glossary.htm, both accessed Aug 2009

systems that are used in clinical or biomedical research settings (…)". (Shortliffe et al., 2001), p.30.

If we generalize this schema, within this context, Medical (or Health-) Informatics becomes the application domain where Documentation Studies draws its inspiration – as basic research. My inquiries into what constitutes medical documents is input into the discourse of what constitutes a document, in general, and into the process of defining the concept of documentation. In 'return' from being an inspiration for the basic science of Document Studies, we have gotten a conceptual model for documents, which I have tried to work into an analytic tool for analysis of sociotechnical systems (Chapter 5). Very simplified, my work fits within this model of basic vs applied research – only used in a more general context.

6.4. Contributions, Computer Science and HCI

From a systems-perspective, the document model that I introduce seems to encompass both a technical perspective, as well as human and social values that are constantly argued of critical importance within the HCI community. The model and analysis method is far from done in its present form; it needs further development and it has still to be tested "in vivo". From its current form it is not clear whether this model could be a "formal" part of a development process, or may suffice as a mental model of a system that can be elucidated and communicated throughout the requirements process.

6.5. Future work

As the work presented in the current thesis is on different aspects of large display design for medical purposes, it is perhaps most useful to partition potential future work according to the different topics investigated. I have divided the work into three different paths and will try to describe prospective research and potential work ahead for each of them.

6.5.1. Display Design for Radiology and Clinical Conferences

Even though I have done some prototyping work in this project, the introduction of LaHiRD technology into clinical domains remains rather distant. In order to implement technology such as a display wall in a radiology department or other departments in a hospital I would likely have to do extensive qualitative studies of technology in use in these locations today before requirements for novel systems are recorded. As the technology is still quite expensive in terms of investment costs, as well as immature technology likely introduces some overhead when taking it into use, *situatedness* seems to be quite important in the first round: where, in healthcare, should one prioritize implementing such technology (first). The first implementation would also likely have quite important signal effects in that potential successes or failures will likely influence future expansion and facilitation.

I have included in the collection of papers an extra paper that regards future work for clinical conferences (Paper 10). This work was presented at a workshop at the INTERACT 2009 conference in Uppsala, Sweden. We have also written a grant application, based on this paper, for funding of a prototype system at the local university-hospital (UNN).

6.5.2. The Cognitive Aspects of Display-Scale

I will focus on future work for the task of mental rotation and object size. We discovered that females mentally rotate large objects faster than men. Or – rather, that males seemed to slow their performance when object size increases. The perhaps first apparent task that remains in this regard is to test if this effect is present also on the Vandenberg and Kuse (VK) test, comparing four objects to a target object, a task that has shown more robust gender differences than the original Shepard and Metzler (SM) stimuli – comparing one object to another. Due to the increased number of object visible on the display in the in the VK stimuli, these object will have to be displayed on an even larger display than what we have use in order to have similar sized object, and this should also have some effect on the amount of eye-movement necessary. However, this issue is also present on normal-sized displays – where objects presented in VK-style must naturally have a smaller size than what is the case in the SM-stimuli.

A replication of our study findings would also have great value. Especially since our population proved to have rather small gender differences in the mental rotation task overall (and that this is rather unusual, even across different cultures (Peters et al., 2006)). This could well be an effect of recruiting quite a lot of our participants from the hard natural sciences (physics, chemistry, computer science).

The second issue that is apparent from our setup, that may influence the results, is the inherent 848 ms average delay that is introduced by the experiment design (equipment-use and method to display objects in the large display condition). The question remaining is whether or not this onset delay from key-press to stimulus presentation is affecting the genders differently and contributing to the effect observed. Both the mentioned issues above could possibly be investigated in one replication of our experiment, using the VK experiment and eliminating the onset delay, possibly also manipulating the latter as a variable as well.

The issue of significant interactional effect of object size with gender on the task of mental rotation could also be investigated qualitatively and quantitatively among healthcare specialists, radiologists in particular, in daily tasks that are similar to the MRT.

Mental Rotation and Expectation. The results from our first experiment demonstrate that expectation towards an effect of novel technology (or novel situation) may well affect the results of laboratory experiments. This is not a novel finding per se, but it is rather remarkable that it is here demonstrated without any apparent speed-accuracy tradeoff. It is quite possible that this effect, when visible in a cognitive motor task such as mental rotation, can occur in other, situations as well – and not only in laboratory tasks. In this context we are left with a couple of relevant questions for future work: how do we assess validity of experiments that do not test for biases among participants, such as towards a novel situation like introduction of new technology (or the variables that represent the novel situation)? What applied-implications may effects of expectations have on introducing novel technology in work-situations: Is it possible to use (positive) expectations in order to ensure 'success' of novel technology, or at least reduce chance of failure?

6.5.3. Document Analysis for Sociotechnical Systems

Future work on the DA. The document model as 'assembled' in this project should be treated as both a basis for a discussion regarding holistic design-processes in HCI and as a crude template for future systems analysis to be used in design –or research of sociotechnical systems. Potential future work for the document model and "–approach" is both of theoretical and applied nature.

Theoretically, the document model needs to be discussed in a broad sense: is this a valid model of a sociotechnical system, and if not – why – and how can it be 'amended' (if possible)? Is the Document Model a research tool with applicability strictly within the sciences of the humanities, or is it useful for the applied sciences as well?

From an applied point of view the model should be tried on real design-cases and tested (as a communicating artifact) in such contexts. This implies educating stakeholders prior to such an experiment as well as developing the model into a usable 'analysis template' for engineering purposes. Time-constraints made these issues not within the scope of the currently reported work, but even the crude analysis enclosed in chapter 11 is a possible object for a process. The downside of this project, in this context, was that it was a research-project, which was about a novel telemedicine service that is probably not subject to development in several years still. In light of this issue, it is quite imminent that any future project involving the DA is within an "in vivo" development process, where it is also possible to measure any impact it might have (or fail to have). In this way, the DA is subject to normal research-protocols within information systems research (c.f. e.g. (Kitchenham, 1996a, Kitchenham, 1996b), (Sadler and Kitchenham, 1996a), (Kitchenham and Jones, 1997)).

In order to make document analysis a fruitful *design tool*, for the analysis of sociotechnical systems, I feel that there is a necessity for a mapping between the different parts of the document model and possible analysis methods from HCI, CSCW and traditional systems engineering. At first glance this might seem like quite an undertaking, but the different parts of the document model quite neatly describes which analysis methods might be appropriate. The difficult task would probably be to find reasonable incentives for starting specific analysis, but these issues are already there (in any project you have to choose which parts of the system to focus on and why – and how to analyze the related issues).

Something that I think has not gotten enough attention in my work with the document model and -*analysis*, in particular, is the distinction between a process description (describing the process of document creation) and product description (a description of the final product). This distinction is important and the document model should encompass both. However, the document analysis provided in this dissertation is perhaps more focused on the latter (product) than the former. It is, however, - the way I see it – a tension between the two in terms of what to focus on in the final document analysis (as a meta-document). Perhaps it is necessary to distinguish between the two in the analysis and provide a complete section for process description with links to the document-parts. This is also potential future work.

There is also a tension within the context of an analysis of a document between what *has been*, what *is* and what *will be*. This issue regards what kinds of analysis that are appropriate for any given system to be built. If a structured system is already in-place and is meant to be partly or completely replaced by a novel system (-independent of whether this change includes going from analogue to digital systems), an analysis of the already existing system is probably the best point of departure. If the current system is tightly integrated with prevailing culture, and where e.g. some informal "patches" has been made to this system (like post-its), these issues will likely need to be uncovered in order to successfully introduce change (which any new system does). On the other hand: if the new system introduces completely novel documentary practices there is probably a very different need for analysis. In documentation studies, the issue of "time stamping" (or tense) for a document analysis (for which point in time is the analysis "valid") is dealt with on a superior level, where one distinguishes between "historical-", "structural-" or "experimental-" document analysis. This is also an issue that should be made somehow explicit in the document model.

7. List of papers

The following papers are included in this thesis.

Paper 1. LUND, N.W., OLSEN, B., ANSHUS, O., LARSEN, T., BJØRNDALEN, J. & HARTVIGSEN, G. (2007) "Watch the Document on the Wall!" An Analytical Model for Health Care Documents on Large Displays. IN GOOS, G., HARTMANIS, J. & LEEUWEN, J. V. (Eds.) Lecture Notes in Computer Science, proceedings from Web Information Systems Engineering – WISE 2007 Workshops. **Volume 4832/2007, 395-406**

Paper 2. OLSEN, B. I., DHAKAL, S. B., ELDEVIK, O. P., HASVOLD, P. & HARTVIGSEN, G. (2008) A large, high resolution tiled display for medical use: experiences from prototyping of a radiology scenario. *Studies in health technology and informatics,* **136, 535-40.**

Paper 3. OLSEN, B. I., LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. (2009) Spatial Tasks on a Large, High-Resolution Tiled Display: Females Mentally Rotate Large Objects Faster Than Men. In *"Engineering Psychology and Cognitive Ergonomics. D. Harris, Springer Berlin / Heidelberg.* ***5639: 233-242.***

Paper 4. OLSEN, B. I., LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. (2011). Spatial Tasks on a Large, High-Resolution, Tiled Display: A Male Inferiority in Performance with a Mental Rotation Task. In *Engineering Psychology and Cognitive Ergonomics. D. Harris, Springer Berlin / Heidelberg.* ***6781: 63-71***

Paper 5. OLSEN, B.I, LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. (2012 - IN SUBMISSION) Remember to Control for the (un)expected while Designing Controlled Experiments in HCI: The case of Sex Differences in the Spatial Ability of Mental Rotation and Display Size

Paper 6. OLSEN, B.I., LAENG, B., KRISTIANSEN, K.-A. & HARTVIGSEN, G. Size Does Matter: Females Mentally Rotate Large Objects Faster Than Men (2012, SUBMITTED To Scandinavian Journal of Psychology)

Paper 7. OLSEN, B. I., LUND, N. W., BELLIKA, J. G., ÅRSAND, E., HASVOLD, P., ELLINGSEN, G., HORSCH, A. & HARTVIGSEN, G. (2007) Documents in medicine: From paper documents to quality-healthcare? IN SKARE, R., LUND, N. W. & VÅRHEIM, A. (Eds.) A Document (Re)turn. Frankfurt am Main, Peter Lang., **pp. 95-116**

Paper 8. OLSEN, B.I., HARTVIGSEN, G, LUND, N.W. (2010) Leaving twentieth-century understanding of documents. From book to eBook to digital ecosystem. 2010 4th IEEE International Conference on Digital Ecosystems and Technologies (DEST), Dubai, United Arab Emirates, **pp. 600 – 605**

Paper 9. OLSEN, B.I., LUND, N.W., ELLINGSEN, G. & HARTVIGSEN, G (2012) Document theory for the design of socio-technical systems: A document model as ontology of human expression, Journal of Documentation, **Vol. 68 Iss: 1, pp.100 - 126**

7.1. Additional Papers

I include one "additional" paper, basically describing future work for the medical informatics domain.

Paper 10. OLSEN, B. I., KRISTIANSEN, K-A., ELDEVIK, O. P. & HARTVIGSEN, G.

(2009) Large, high-resolution displays for co-located collaboration within healthcare: information proliferation for medical decision-making. Presented at INTERACT2009 Workshop: Team meetings within clinical domains – exploring the use of routines and technical support for communication. Uppsala, Sweden.

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Appendices

9. APPENDIX A: Documents used in the Mental Rotation (MR) experiment

Enclosed within this section are documents that are related to the MR experiment.

9.1. Hypothesis stating that small displays are better for MR

Below we present the information that was given to participants explaining that they should expect that the small display should provide superior performance over the large display. The text reads “You are participating in an experiment regarding rotation and comparison of three-dimensional (3D) objects and the relationship between how well people perform this task and the size of the screen. Recent research shows that people perform this task better when using small screens. In this experiment we want to test whether this hypothesis holds truth. We also measure the distance between the pupils of the participants to see whether this makes any difference.”

The figure that follows the text illustrates how mean response-times are shorter with a small display compared to a large.

Mental Rotasjon Eksperiment

Du er deltaker i et forsøk som omhandler rotasjon og sammenligning av tredimensjonale (3D) objekter og sammenhengen mellom hvor flinke vi er til å gjøre dette og størrelse på skjermen som viser objektene.

Ny forskning viser at vi mennesker blir bedre til å utføre denne oppgaven ved å bruke små skjermer. I dette eksperimentet vil vi undersøke om denne hypotesen stemmer eller ikke.

Vi måler også avstanden mellom pupillene for å videre undersøke om denne har en sammenheng med resultatene.

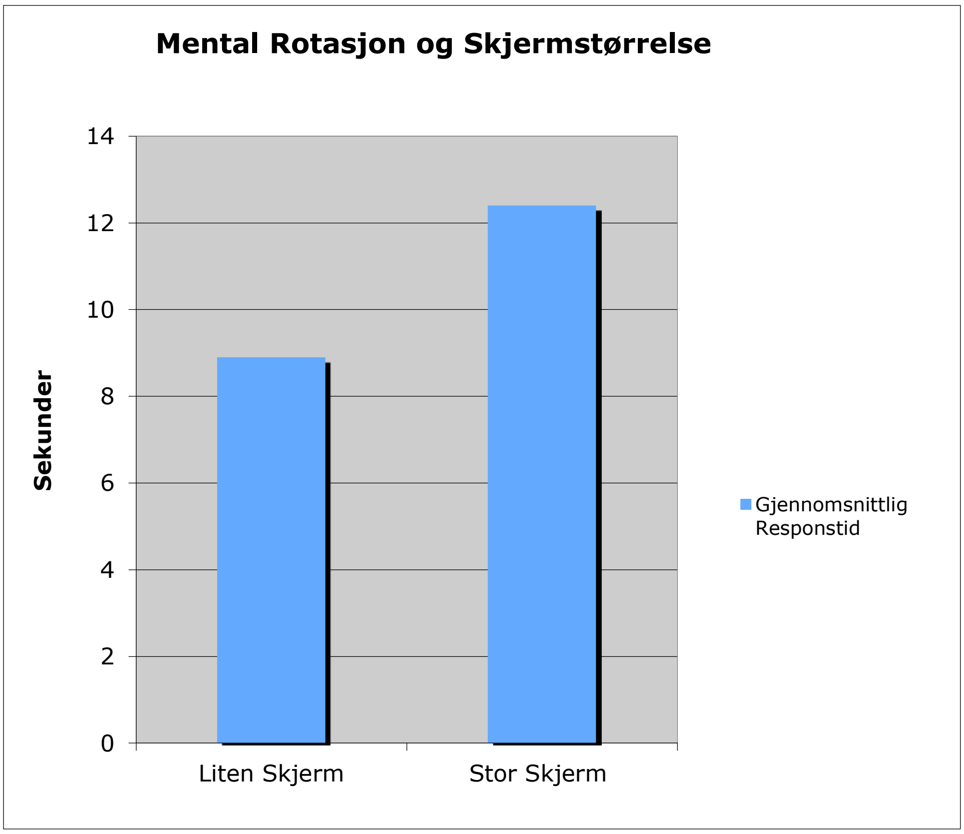

Figure 20 Mental Rotation hypothesis: positive towards small displays

9.2. Hypothesis stating that large displays are better for MR

Hypothesis stating that large displays are better for MR

Below follows the opposite hypothesis presented to the participants – that large displays give better performance than smaller. The text reads "You are participating in an experiment regarding rotation and comparison of three-dimensional (3D) objects and the relationship between how well people perform this task and the size of the screen. Recent research shows that people perform this task better when using large screens. In this experiment we want to test whether this hypothesis holds truth. We also measure the distance between the pupils of the participants to see whether this makes any difference."

The figure that follows illustrates how response-time shrinks with larger displays.

Mental Rotasjon Eksperiment

Du er deltaker i et forsøk som omhandler rotasjon og sammenligning av tredimensjonale (3D) objekter og sammenhengen mellom hvor flinke vi er til å gjøre dette og størrelse på skjermen som viser objektene.

Ny forskning viser at vi mennesker blir bedre til å utføre denne oppgaven ved å bruke store skjermer. I dette eksperimentet vil vi undersøke om denne hypotesen stemmer eller ikke.

Vi måler også avstanden mellom pupillene for å videre undersøke om denne har en sammenheng med resultatene.

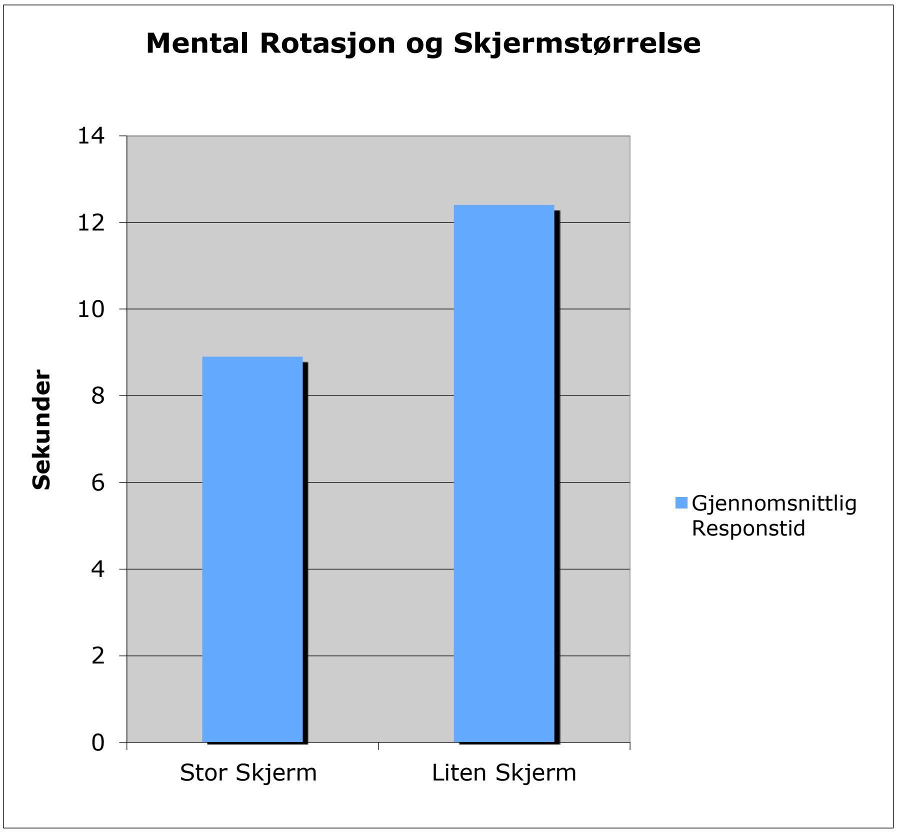

Figure 21 Mental Rotation hypothesis: positive towards large displays

9.3. Questionnaire for Experiment 1 (In Norwegian – English speakers were interviewed)

Mental rotasjon og skjerm størrelse deltaker nr:____

Kjønn: mann Kvinne

Alder: år

Pupilleavstand: mm

Utdanning: 9 årig Vidreg Høyskole: Universitet:

Bransje/yrke:

Spilt dataspill siden:

9.4. Qustionnaire for Experiment 2 (English version)

Mental rotation and screen size.

Round 2
Deltaker nr:

Gender :

Age :

Pupil distance (eyes):

Education : Elementary High-school College/University

Profession/classes :

1. Do you play computer games?

   a. Yes
   b. No

2. If yes: do you play computer games that involve orienting/moving in 3-dimensional spaces (airplane simulators, World of Warcraft, etc.) – or other 3-D games?

   a. Games like World of Warcraft (moving in space)
   b. Games like Tetris (moving/turning/manipulating objects in space)
   c. Other types of games (examples)
      i. _______________
      ii. _______________
      iii. _______________

3. Do you, in everyday life, perform tasks that remind you of the task you did in this experiment?

   a. Daily

b. Weekly
c. Rarely
d. Never

4. Which screen do you think you perform the best on when it comes to number of right rotations and least time use on?

   a. Small
   b. Large

5. Which screen was more comfortable to do the task on?

   a. Large
   b. Small

6. If you would do the same experiment all over again, which screen would you prefer?

   a. Large
   b. Small

7. If you had to cooperate with someone in other mental rotation tasks, which screen would you prefer then?

   a. Small screen
   b. Large screen

8. Did you notice that the Large Screen is "Tiled"

   a. Yes
   b. No

9. If you noticed: did this interfere, for instance when you were solving the tasks in the experiment?

   a. Yes
   b. No

10. Du you normally use glasses or do you have any vision-impairments, which are not corrected with glasses or contact lenses (answer yes only if you have not used glasses or contact lenses during the experiment)?

    a. Yes
    b. No

10. APPENDIX B: Appendices to the Radiology Demo

10.1. The Transcript from the Radiology Prototype Demo

Below is the transcript from the videotaping of the demo of our prototyped radiology interface for the Display Wall. The original language is, of course Norwegian, and this is a translated version. The video is available at url (in both summarized and complete versions):

http://phd.berntivar.com (Visited Feb 2012)

Bernt Ivar Olsen (BIO – me, the presenter of the demo)

Professor Odd Petter Eldevik (PE, Head of Radiologi UNN),

John Hald (JH, Radiumhospitalet),

Jan Størmer (JS, head of IT-systems UNN, former head of Radiology dept. UNN),

Vidar Isaksen (VI, Pathologist)

Bruno Laeng (professor of psychology (cognitive) at University of Tromsø

Sanjay Babu Dhakal (assistent, technician for the demo),

Kari-Ann Kristiansen (psychology student),

Jan Fredrik Frantzen (public relations consultant National Center for Telemedicine)

(all mentioned in black are did not contribute so as to be mentioned in the transcript)

-------------------- START --------------------

BIO: First, I must greet you all from Professor Otto Anshus, who took the initiative to build the wall. He was quite upset to hear the timing of this demo, because he is on vacation right now. Unfortunately, so is the rest of his research group as well. They are the people whose research efforts make us able to do this demo today. They have worked extensively with the software that drives the wall – enabling us to show you what we have for you today. Along the way you may interrupt and speak as much as you want. You may also walk up to the screen if you wish. “Sanjay”? (BIO would like to have the first slide up)

PICTURE 1

BIO: This here is probably a familiar interface, I would assume (?). It is simply what you're used to today, as I understood it. Petter has given me a CD of images from a patient. I have taken this picture and enlarged it on the display wall. You can readily see that it is about the same as a regular projector does for you now. “Sanjay”? (Next picture)

PICTURE 2

BIO: Actually a lot of the same, but I have taken two different series of images and merged them into the same interface. Now I might ask you if there is something immediately that looks different or if there is something that strikes you ...

PE: The first picture was stretched out, of course, but that's just fine and fine resolution ... Here you can crawl into the cerebellum...
BIO: ... But basically, it is the same as you have today...

PE: Yes - I see...

BIO: (Nods to Sanjay: next picture)

PICTURE 3

BIO: On to the next picture we have made it even more complicated (to Sanjay: yes)... we've cut the number of pictures. What you see here is that .. this is .. 90 interface-frames that are put together ... you cannot achieve this with a standard projector - this resolution ... so what you will get here is...

PE: So it's the same resolution of a picture that we will have four - and four pictures ... (?)

BIO: Yes. ... So you just want to get many more images.
PE: Yes.

PICTURE 4

BIO: And here we have made a variation on the same principle ... only that we have made selection of an image - and enlarged it. (For Sanjay) Next image.

PICTURE 5

BIO: This is the same, only two different series of pictures. (Slight pause where the BIO waits for feedback from the audience ...) So I do not know what ...

PE: It's interesting what you have here. You could almost have .. if you had the screen so you could the ... otherwise scroll the through, not true, but here it is the .. opportunity to go back and find out where it is a violation and where it is .... so it's interesting.

VI: Can you, for example, have an X-ray there and then you have something else over there (pointing to different sections of the wall interface)....

BIO: Yes. Here, the only limit is your imagination. I may reveal events ahead of us a little bit and say that here (in these images/interfaces); we have no text in conjunction with the patient imaging data. First we will only show some possible layouts of image types, set up in different ways and we will then finally we will try to review a patient case afterwards (with textual information). Sanjay (next photo).

PICTURE 6

BIO: A bit of the same. You can make selection of images at your own will ... (Not exactly what is being said but difficult to hear)

JH: This is the way we used to looked at the pictures ... We had these light boxes .. and then all the pictures up appeared...

PE: Yes ... when used X-ray film, and they hung up with “alternators” and a projector on the wall ... and so we covered the whole .. so we had .. what was it? Four films? Five films in one and ... together ten films... but it was so so small that only the ones sitting in front could see them, so we had to take down one of the films and enlarge it.. and projecting it.. This was the big break (PE looks to JH) ... that we only got one picture to look at .. that the person leading the demonstration took one of the films down - and you got it on a projector-screen like this one.

BIO: So, in a way, you had this (kind of a setup)...

PE: Yes - we had ... it was impossible to see - it was only the people in the first row who could see, then, and if someone spotted something (PE gets up and goes up to the wall to demonstrate) then traveled up and go forward .... "Oh .. yes!" (he pretends that he has found something in the picture when he walked closer). It was just the bosses who sat in the front row who could see... so all the people sitting behind, trying to learn some things .. only the cheekiest who would .. huh.

JH: Is it possible to change some of the pictures and see ... (He is gesturing that he wants to zoom in and out).

BIO: (Nods affirmative and addressed Sanjay) Sanjay! Could you try two zoom, please. But - do it on this image! (Sanjay thinks he should switch to the next image, but BIO says we want to zoom the image 6, like JH sought).
... (Small pause while we wait for the image to be loaded again, Sanjay must change back to image 6).

BIO: Now we have, so to speak, cheated a bit on the way here ... Try two zoom on it (to Sanjay. Sajay zoomed in picture 6 and parts of the image fills the entire wall, while others fall out of "vision." So - you can pan along the image that you want ... the effect is exactly the same as what we have done now - we have enlarged a photo .. you will eventually lose resolution in the image

PE: But if it is now located inside ... What Jon is asking about is whether we can change the density of the image and bring up .. soft tissue and bone detail details .. you can pick a series and then making the bone images or soft tissue images .. ?

BIO: Of course. In a final system you will be able to do it. What we have done now is to take one image at a time, so with these pictures here, you could not do it, but of course - with a real PACS system you could.

PE: So if we got the PACS images up so we could see ...

BIO: (confirm this)

VI: Is it just as fast in real life as this? (Here we may misunderstand each other a bit – BIO does not know if he's thinking of zooming and what he has seen the demo, or if he is talking about rendering that we just talked about).

BIO: It's actually a rather peculiar question, because, in principle, it should be able to go even faster (now BIO is referring to rendering of models based on PACS images), simply because you have so many computers working in parallel, in the back (of the wall), so that a PACS station does is that he render these images, that he takes the out and choose to either bone structures or other things - real time, while sitting and watching - and when you have so much more computing power available like this, it can actually go much faster. But - like ... It is a challenge with the system in the way it is made now ... that .. it will go very slowly on this implementation

VI: Yeah .. because it is composed of so many ...

BIO. ... Simply because the software is not currently designed to display on such large and high-resolution displays - either software or hardware. We need to ... “massage” it a bit to get it to work on the wall as it is now (I wonder if they actually understand that it is the PACS station I'm talking about here).

.. Short pause ...

BIO: (Nods to Sanjay that he should go to the next photo).

PE: It's amazing. I must say.

PICTURE 7

BIO: It's actually one of the things we believe in the continuation ... that we actually make a radiology interface to the wall ... Sanjay is a master's student in telemedicine and should therefore have a master's thesis in the spring and when we consider letting him try to get it. - And then we could see it in practice.

PE: We can see a grid in the background some tiles are brighter and some darker areas ... it is something that is inherent with the wall or is it something that you will be able to get rid of ... you see that it is (PE proceed to the wall and shows how a projector showing a light black color, while an other one dark) ... a light there .. and a darker there.

BIO: Yes. It we can do something about that. Basically, the wall is made of 28 projectors

PE: Yes - that was exactly what I ...

BIO: That is why you can see ...

PE: With these images outside these screens … (I assume he means that the pictures all look like one coherent picture - and not 28 pictures put together)

BIO: What do you mean? No - no. They stretch across all the screens. They operate as one screen. But - you will be able to do something with it (ie the bezels and differences in lighting between projectors - which looks a bit disturbing). This wall was made with "commodity-parts", that is available to the general public - anyone can really build such a screen, or to buy the parts for it .. so that the projectors behind here is not state of the art .. they are bought 4-5 years ago .. so there is clearly much that can be done. So - the answer to your question is: yes! We can do something about it ...

PE: I see.

PICTURE 8 (pathology images are loaded ...)

BIO: Yes ...

PE: It was good we got into some pathology ... What was that for any pathology again .. you recorded it (talking to BIO)?

BIO: (looking at VI)

VI: Islet cells

PE: Islet cells .. Thus, pancreatic-cells

BIO: But they did not belong to the patient? ...

PE: No.

BIO: There was no pathology belonging to this patient.

VI: (We) get a little too close (he thought the pictures were too big ...)

BIO: We have put together a little more (pathology - pictures) ... to get the same effect for the pathology (as for MRI and CT. (to Sanjay) Next.

PICTURE 9

VI: (Says something about the light on all the images. I think he's talking about the distinctions between the projector was clearly on the pathology images)

BIO: Here we have tried to collect some pictures of the patient ... A bit of everything (pauses a bit)

PE: Yes.

BIO: This is what we call a "mockup" in computer science. We've just made and put together pictures that we thought it suited to ...

PE: Yes. Exactly. Certainly.

BIO: So this is where you can do in any way which is appropriate.

PE: ... So you have a strip of pathology there and then you ... one-two-three series .. two that are MR-angio and one that is CT or reformatted images.

BIO: Yes. (Nods to Sanjay to go to the next photo). So I think we start on a review of the patient. Here we have also tried to enter text in the image. Here you see that the color shades are different (text box is white, so lysforskjellene between projectors is good).

IMAGE 10 (first with text too)

PE: But it goes that smooth out?

BIO: Yes. I do not know how closely you want to .. go to the patient

JH: (points out a typo in the text)

BIO: Those we did not do anything with (typos)

PE: Yes. There you go. It's always embarrassing to bring up their own mistakes... (Joke about the error writing) ... "Approved by Dr. Eldevik", right? (He looks at JH) (continues to joke a little about typos)

BIO: (For Sanjay). Next. Yes ... It soon becomes much text ... (Trying to break a bit or to allow those interested to read the text. There are two text boxes with two series of pictures on the wall). It makes you maybe comment on myself, what is useful (to include here)

PE: It's not such a bad idea to have text, I often see when we sit to demonstrate .. it will depends on the attitude and approach of the person who gives the presentation, but some start - before they show a single image, to read out loud what the referring physician has written: "44 year old woman ... ".. and some times .. the referring physician did what we asked them to do for years, they have taken our word for it - and they have given us a full report on the condition of the patient .. then it takes the four minutes to read up ..

BIO: (Laughs)

PE: And those who sit to look at this is really trained, so they go to the last three lines to read.. so a lot of text may not be as distracting as one might think .. most (specialists) knows how to pick out exactly what they want.

BIO: We have not done anything special to try to format either, so ...

JS: In an information (science) context, perhaps the biggest challenge is to find solutions that no matter what kind of "crap" that is stored, so you always present what is the essence (the important information).. because it becomes more and more "crap" ... Also, when one wants to do things seriously, to have the relevant information (?) You want to draw out what is uniformly / interesting (?) - And present it in a way that allows the entire audience to quickly focus only on it .. right? This is the wonderful "information challenge" here .. It scares me a bit here, is that - it is too much. For a single person - so you do not manage to absorb .. and you are anxious because you think you're missing something.

VI: But if one takes it here .. mammography history as an example, then it's three things that are used: one is X-rays, the other is what's in the DIPS (patient records) and the third is the pathology ... Is it so that one person must control everything, or can one control the X-ray images, one controls the records and the third controls the pathology – it must be that way, otherwise it ...

BIO: Of course, yes! And - it's one of the things that they found very soon, when they began to create such big screens, it is very unlike a normal screen and standard PC, so it is ideal for several people working simultaneously on the wall. It was a huge challenge because no one had thought of it that you might need multiple keyboards and multiple mice on the same PC .. and soon they realized that mouse and keyboard is quite difficult to use on a large screen .. so if we have time for it towards the end we can look at some of the work some researchers have worked on here (regarding interaction with the wall). There are a number of cameras down here .. and they have worked with is a sort of touch interface, so you can actually go up to the wall and work on the screen, so if you want to have a person who works on one side ... and one on the other there are ways to do it .. or you can let them control it by using the PDA .. so the answer is really: yes, of course, you could allow serveral people.. (to control the screen at once)

JS: It's a good point, that if it is an interdisciplinary meeting and in a way .. represents .. each can have their information piece on each sector and can ... (I Think he was referring to the division of the screen and that each "group" (interdisciplinary) should have control of their section of the screen) and really work at their part.. continually updating it as appropriate for each field.

VI: What is being done today .. it's that .. there is a stack papers and another batch of photos ..

PE: Yes ...

JS: .. And an unfortunate junior who will be running three systems simultaneously.

VI: Yes – we cannot have that.

JH: Can a part of the screen used for video conferencing .. context ..

BIO: Yes.

JH: When can a have a picture there (I think that's what he says here) .. and communicate with people ...

BIO: We are actually looking at some video later .. so you'll see that the wall actually "lives" as well - that it is not only still images. Sanjay.

PICTURE 11

BIO: It is more text - and .. Yes - there are just more variations of .. (Gives character to the next photo to Sanjay)

PICTURE 12

BIO. (Pending a while. Image with MRI and text. Pending a bit on the comments) Yes (to

Sanjay - next picture)

JH: How big is the screen in meters?

BIO: 230 inches from the top corner to bottom corner.

JS: It's a while until it comes on Elkjøp (local tech-store).
(Laughter)

BIO: There are a total of close to 23 mega pixels, ie resolution - simply the sum of 28 screens. (For Sanjay) Next.

PICTURE 13

BIO: And today, you notice that I need Sanjay to change the picture for me. It had not strictly been necessary if we were a little further ahead. We can create interfaces in other ways. (Signals the next photo to Sanjay)

PICTURE 14

BIO: This concludes the patient-case.

PICTURE 15

BIO: I do not know how big an issue resolution is with medical images ..?

PE: As long as you work with images of CT and MRI as it's a given resolution of the screen that you somehow do not come .. and it is not very high res. So that unlike the old-fashioned film, which has a very high resolution, where you have silver bromide as a joint out of the beam, so that it is the .. It's one thing there with mammography where they should have high resolution, so it is the field that need the highest resolution of our diagnostic check. But with digital images as CT and MRI it is not so good resolution, only that it is as good as you at least get it on the screen.

BIO: But as long as the resolution is not better than it is at these pictures you will get these effects here.

PE: Because it's pixel images that are stored in pixels.

BIO: Yes. (Nods to Sanjay to the next picture)

PICTURE 16

BIO: Sanjay, maybe we just ... Based on the footage we got, so we made some video sequences, just to show you
(The videos of the photo series coming up.)

BIO: Today, if we were to use the image-viewer that we have available here, it would not be scrolled so fast through the image material as what you're used to, but that said, this is something that gets better when one has a large cluster of computers in the background, so ... just a little work and it will be better than that.

BIO: Yes. It was basically what we had in the first place (Applause)

PE: Not bad.

VI: We want such a screen, but then there has to be a smooth background.

BIO: Yes, smoother – it will be smoother.

VI: Yes, it cannot be like this, but it would be great (if they could have one)

BIO: You can say that this wall is an example of this type of technology - and - it was built some years ago, so should you build such a one today it will probably be significantly better - and many of the initial faults will be corrected. And of course - a system that is used for clinical purposes, will of course be completely different requirements.

PE: It's quite nice with back-projecting where you do not have these projectors hanging from the ceiling, but it's clear that it takes some area in the back... You must have an almost equally large room behind, as we sit in.

BIO: You can say that what is the advantage with this approach, that we have so many (projectors), is that the projectors can be quite close to the wall, but if you had fewer...

PE: A few, yes ....

BIO: .. so you would have to have more room in the back. There is currently projectors that are able to yield such a wall .. to display as many pixels, with only three .. maybe three or four projectors, if you take really high-end.

JS: The first PACS solutions in Norway was produced with back (-projection) ... It was Tønsberg who were the first .. high profile, they had rooms that consisted of .. half the room consisted of boxes ... two projectors.
(Pause)

BIO: I do not know what you are looking for you .. if we had set it up one tomorrow in one of your conference rooms.. what would you want to use it for?

PE: At first we would use it as we use it now (in the hospital). Right now we have the two screens. That's what we're used to working with and handle. So we would probably have used it like that to begin with so. But - as we had gotten used to it, we could have added the description - since Trissa (? Kriss -? I think he is talking about the patient records?). The one who sits and demonstrates with us has two screens with these images and one where we sit and look at the manuscript. But we could have had it too (the manuscript). So all could see it. And it is clear - we could have had DIPS (patient records) up there too.

VI: I picture that one could use three different things at once. For what we do - we can only use two at once, one for microscopy and X-rays either before or DIPS [...] or maybe even more things if it was possible...

BIO: It's the first two, obvious uses of this screen ... It was interesting to see you configuration at the pathology department (addressed to VI, and refers to the visit to the pathologist a few months before, when BIO was there).

PE: It is obvious that with these fields (on the screen - divisional screen) then you need one not to change all the time, you could have a field up all the time where it the name of the patient and address and which department the patient belongs to - so one could go through it all. So one could have.. (he's gesturing at the screen as if he wants other, currently relevant detail information (contextual) available on the rest of the screen).

JH: One thing that ... which rather takes my breath away when I saw it was that you got so much information in that they were all .. the small pictures lay across the screen, you get images completely from the bottom to the top ... and what we do the practical now is that we use this technology you showed last time, we scrolling through the images that we run through ... Then we have stored, in a way, the same information, but we do not drown in it. There are four different fields and some different directions in which the photos are different surveys and walk slowly through the back and forth ... is probably easier to digest in practice.

BIO: Yes. Yes - it's interesting that you mention that. It is, also as Stormer says, that it the immediate risk with such a type of technology is to overload the users with information that is not appropriate. But - it's just .. it's a challenge ... that comes with larger screen size. I do not know if any of you have tried such a thirty-inch LCD screen (points back of the room on your Mac screen). I have sat and worked with it and it's a bit the same effect there, where you have to sit myself to control it a bit, so you should not have too much up there at once.

PE: (pointing behind your Mac's screen) But there is the ability to have everything visible - and if you do not need it ... so you can always have more things lying around .. so you can have your mail lying in one place and then you have (…)

(A little break with a joke or two ..)
VI: But can you just edit the size of the area (I'm assuming here that he speaks of a dynamic "partitioning" of the screen, where a change in the division along the way).

BIO: Yes. It's just like a normal screen - you can fully control the (division).
FILM (entertainment, Shrek, etc).

BIO: Here is more of a control-room situation (many movies playing at once). Maybe one could imagine a teaching situation ...

VI: But - this is the fine, as long as it does not go too fast. That there is too much. If you manage to do it slowly and nicely, so ...

JS: It's one of the major challenges today is that one usually when such a limit in relation to information overload. Historically, in relation to the development of PACS, it was believed that PACS would recreate what we had in radiology before, where they had huge areas with lots of pictures. The larger the surface, the more pictures you could hang up at once, the better it was in the ancient world. In the first implementation, they believed that the more things they thought they could roll out on X number of screens

PE: Yes!

JS: ... Then came the brilliant breakthrough in which a man simply said: "Yes, but, you see never more than one image at a time, so the idea of having the top ten high-resolution images at a time is just nonsense. You need to have the opportunity to select one of the top ten and then look carefully at it. It simplifies all problems of high resolution, speed, "etc. etc. - because then select the one picture and then you get it optimized, and the others can just lie there like low resolution images that can possibly be collected later.

BIO: How does the selection process go - how do you see which image ...

JS: It is related to the discovery that the optimum was not six screens, but one or two to look at the pictures - and possibly a third for looking at the text.

BIO: Yes.

JS: ... and they realized that instead of watching a slide show with hundreds of photos that it was much better to look at them in stack mode than to sit and look at it this way (as we have done in the presentation), which we had to before. So .. over the years it has changed. Many had trouble moving from the cascading model to the stack model, but once you got used to it you could never imagine going back.

JH: That was what they did when they had the latest videos (he gesturing the stack model).

JS: No. What I envision is that it is when you work more together and try to pull out the syntheses of things from several different sources, this is where such a wall would be brilliant. -In a multi-disciplinary setting.

BIO: Yes.

JS: Where should one, in a way, set up an information images from multiple sources, it will be very nice to be able to pull things together from different sources. I think you may want to be cautious to collect too much information at once in one image. There are limitations in our minds, which make it... and it does not get better with age ... (Laughter)

PE: But - it could be in such a big screen – if you just concentrate on one thing, but that it is very easy to draw in (he is gesturing that he takes things in from the edge of the wall toward the center) to center that you are going to talk about. So the other information can be there in the periphery ... if you then want see it .. or if it is hidden..

BIO: Sanjay, we may see the high resolution image. There we had unfortunately no medical images available. But we had a couple of others. But it's also what you are talking about: an overview and detail - the combination

JS: Great things that, when it comes to visualize - to move from overview to detail.

BIO. Yess. It's sort of Google Earth without Google Earth. (Sanjay Zoom in and pan across the image). The closer he goes so you can see that, had this picture had more resolution, there are actually pictures with more resolution, so you can actually go as far as you want. If you had a pathology image with ever-so-high-resolution ... What you do today (BIO addressed to VI) is the scrolling along the samples, is not it? -That 'physically (moving the microscope along the sample)?

JS: How high resolution is here - how far down can you go?

BIO: This picture is similar to the display wall, about seven times three thousand (pixels). Sanjay! The spa The photograph "Earth Spa", a common 8.1 MP image

BIO: A common photography today has eight to twelve megapixels and it is, what - three times four (thousand pixels). Here is a common ... “press one” (BIO wants the picture in 1:1 on the wall, the picture is a little less on the wall). Here is an eight-megapixel photos - and this is the size that the photo takes on the wall. When you see that in order to see the entire photograph from a relatively standard camera today, so you need to have such a large screen. -Without the software doing something with the image to reduce it to fit the screen size.

BIO: Shall we go to the back room? (The audience go in the back room to see how the wall is built up. The microphone in the camera can not capture the discussion in the back room).

--------------------- END OF DEMO ---------------------

35 min: Visit in the projector-room

38:20 Back for Further discussion and coffee

11. APPENDIX C: appendices to 'A document approach' (chapter 5)

In (Olsen et al., 2012) Paper 9 we have described the individual parts of the document analysis. In a first attempt to gather empirical data on the suitability of the method for systems analysis we here present a preliminary analysis of a prospective documentation system, describing a telemedicine service that presently does not exist. The documents in question (or system of documents) are in a system that is to provide psychiatric specialist-services into (geographical) areas where the psychiatric expertise is not presently available. The case to be presented consist mainly of the work done during my research stay at UC Davis (2007/2008). The analysis is based on informal and unstructured interviews with the researchers in charge of the S&F Telepsychiatry project, Drs Peter M. Yellowlees, Alberto Odor and Don Hilty over a period of about 10 months from Sept. 2007 to June 2008. The (Medical Informatics-) researchers were also, to a varying degree, designers and "consultants" for a prototype system build for the purpose of their research project and situated within the UC Davis campus network. This meant that for the document analysis (DA) done below, the primary informants had both technical skills and specialist- medical skills.

During the period of investigation (ca. 10 months), the (S&F-) research project went from research design into data-collection, where local clinics in the vicinity of Visalia, CA, accepted to be a part of this research and welcomed the clinical personnel at their local clinics to do videotaping of clinical interviews with selected and volunteer patients. Prior to the Visalia clinic, preliminary test were done with (volunteer) patients at a local clinic within the UC Davis health system, a total of about 10 patients. I was present at two of these preliminary interviews as an observer. I was also present at the initial negotiations between the Visalia clinics and the municipality in Visalia. Several observations were done in Visalia where I was present during (video-captured) patient interviews. The analysis below may be considered an extract of the observational data collected – composed into a document analysis following the derived model (in Paper 9).

The DA that follows is not to be regarded as exclusively an analysis for systems design – as it is also a part of two research projects as well: the S&F Telepsychiatry project, and our current conceptual DA-project. I will make references to the theoretical aspects of the analysis underway – which will affect the communications-aspect of the DA as a systems-design and development tool (*communicating artefact, boundary object*).

Below follows the "experimental" document analysis of the system according to our document model.

11.1.1. A description of the system to be built

A store-and-forward psychiatry system is based on the concept of asynchronous medical services, where an information system is utilized in order to describe a problem (an illness) of a patient and to request a specialist opinion (service). In other words, information about the patient and the illness is first collected before it is stored within the system and transferred to a remote site for evaluation by a human agent – who in turn evaluates the patient and the problem based on the available (provided) information and issues a response when the evaluation is finished.

Typical areas of medicine where this method is applied is for instance radiology and dermatology, where images of the patient, along with supporting information is transferred using network technology in order to get expert evaluation in places where the expertise is either a scarce resource or not available.

Traditionally, the service in question has been provided in the way that a first-line service – either a GP, or physician's assistant or a nurse practitioner evaluates the patient using established structured interviews, which are designed to detect psychiatric illnesses. If the patient shows signs of such illnesses he or she could be referred to a specialist psychiatrist for further evaluation.

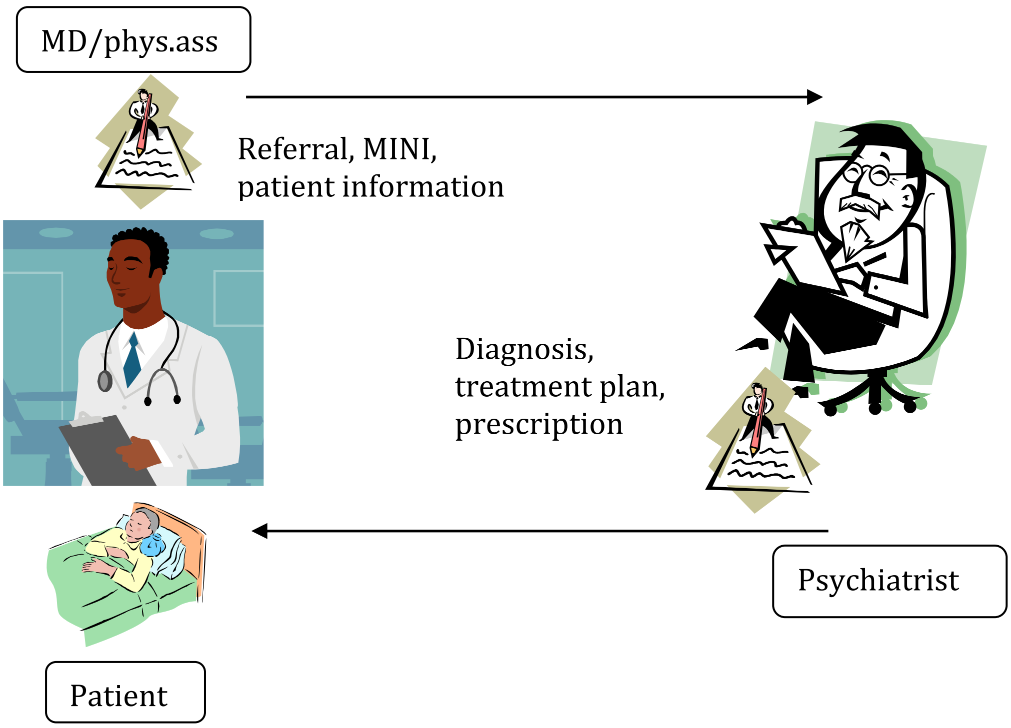

Figure 22 The psychiatry prescription process

Figure 22 The psychiatry prescription process outlines the sequence of events for a psychiatric disorder, at least as far as the scope of this project goes. It is a very crude schematic view of the system, but suffices for explaining the concept; the MD/Physicians assistant makes a referral of the patient, where he creates a multimedia document that describes the patient, the symptoms and the diagnosis found. On the far end, the psychiatrist evaluates the patient from the information available and creates a psychiatric evaluation of the patient case. This is returned to the referring primary care provider (PCP) and used in the care for the patient.

11.1.2. Constraints of the system

This system is intended for adult patients – and is not intended to be adapted to child psychiatric services.

11.1.3. The Documents of interest

As we can see from the description of the system there are at least two documents of interest that need to be produced and exchanged.

1) The MD/phys.ass report – hereafter called the MD-doc
2) The Psychiatrist report – hereafter labelled Psych-doc

In other words, as far as we are interested in, there are two documents in our system – a system of two interrelated documents. We will have to analyse the documents one at a time and describe the relations between them in order to understand our system.

11.1.4. Timeline

From the description above, we see that the MD-doc obviously precedes the Psych-doc in time, and that the Psych-doc is causally dependant on the MD-doc. We will see later that the MD-doc is a part of the Psych-doc. As with any document describing a physical or psychiatric illness there will be a natural timeline associated with the document, from the first visit at the doctor's office, to the potential resolution of the problem when the patient is well again. What happens after the Psych-doc is created is not covered in this document and in this way this analysis of the system is incomplete. The quality of the Psych-doc is dependant on the successive use of it.

11.1.5. Notes on Objectivity

The person or people doing the analysis will always colour a document analysis. In this regard, 'objectivity' is not realistic to assume – but the question becomes: what is objectivity in document analysis? An analysis of a document is – in its turn – is a document that tries to conceptually 'explain' the document of interest, and the explanation will always be done by one or several people who do the analysis from some (common) perspective. In engineering, our goal is very often effectiveness: that any task consumes a minimum of resources and maximizes output. A document analysis from this perspective will differ from one done from; say an artistic point of view that wants to explore other perspectives of a document.

11.2. The MD-doc

We will first describe the document created from the primary care centre where the patient first meets with his doctor (or physician's assistant/nurse practitioner). Before we proceed, it could be useful to identify potential docemes within the document that are already present at the start of the documentation process. Docemes:

1) Structured clinical interviews: MINI, etc. The physician "reproduces" these at the interview stage, where he/she probably reads through them or uses them as reference point in the interview – in order not to forget some important details.

We should probably inspect this document in more detail as well, as its affordances are crucial to the generation of the MD-doc. An interview in itself has some properties that need to be carefully studied in order to make the process of creating the MD-doc as uncomplicated as possible. For instance, the interview should be designed in such a fashion that it reminds the interviewer of all the questions while also giving him/her the chance to record the answers. In this case, the PCP could have the whole interview taped so that he would not have to take notes. However, having to look at the screen, which could be positioned away from the patient could make the interaction between patient and PCP rather awkward, having to leave the face-to-face position to look at the screen.

11.2.1. The agents of the MD-doc

11.2.1.1. 1. The PCP

- The physician (MD)
- physician's assistant (PA)or
- nurse practitioner (NP)

We will try to use the term primary care provider (PCP) to cover all three. The three are clearly different people acting within quite different roles – even though they are to do the same piece of work in this context: do an evaluation of the patient based on some standardized structured interviews like the SCID (Structured Clinical Interview for DMS-IV), the CIDI (Composite International Diagnostic Interview), or/and MINI (Mini International Neuropsychiatric Interview). These are interviews that, if conducted correctly, should identify psychiatric disorders and provide the *agent* with means to set a diagnosis. If the patient has a psychiatric disorder he/she should be referred to a psychiatric specialist. The question remains: what is the role of the agent in this case?

11.2.1.2. Role

The primary role of the MD/PA/NP is that of a caregiver. The normal role in this context is that the *caregiver* treats the patient from the view that the patient is a system out of balance (equilibrium) and their role is to bring this system back into harmony again. As such, they look at the present symptoms, do a "pattern matching" of those symptoms to a known *disease* and prescribe whatever cure is relevant (from a list of possible treatments, possible including medication, etc.). However, in our case the role of the caregiver is to try as well as they can to diagnose the patient based on the interview and then refer the patient to the specialist and send a referral letter along with the patient.

11.2.1.3. 2. Technical assistant to the PCP

We might need to include one more person into the agents of the MD-doc, which would be a technical assistant that assists in creating the digital document from all the means necessary; video camera, computer with SW for recording video, editing that information and perhaps helping to import patient information into the MD-doc, which should be available within the EPR at the primary-care (PC) office.

Anyone who has tried to edit video into a document has more likely experienced some issues in doing that. Requiring that the medical doctor, or any PCP in his place should be able to effortlessly produce the complex document would likely require a great deal of training, in addition to a system with a flawless user-interface. In addition, the data-capture equipment would also have error-free, as video-equipment tends not to be.

The PCP with necessary equipment is illustrated in Figure 23.

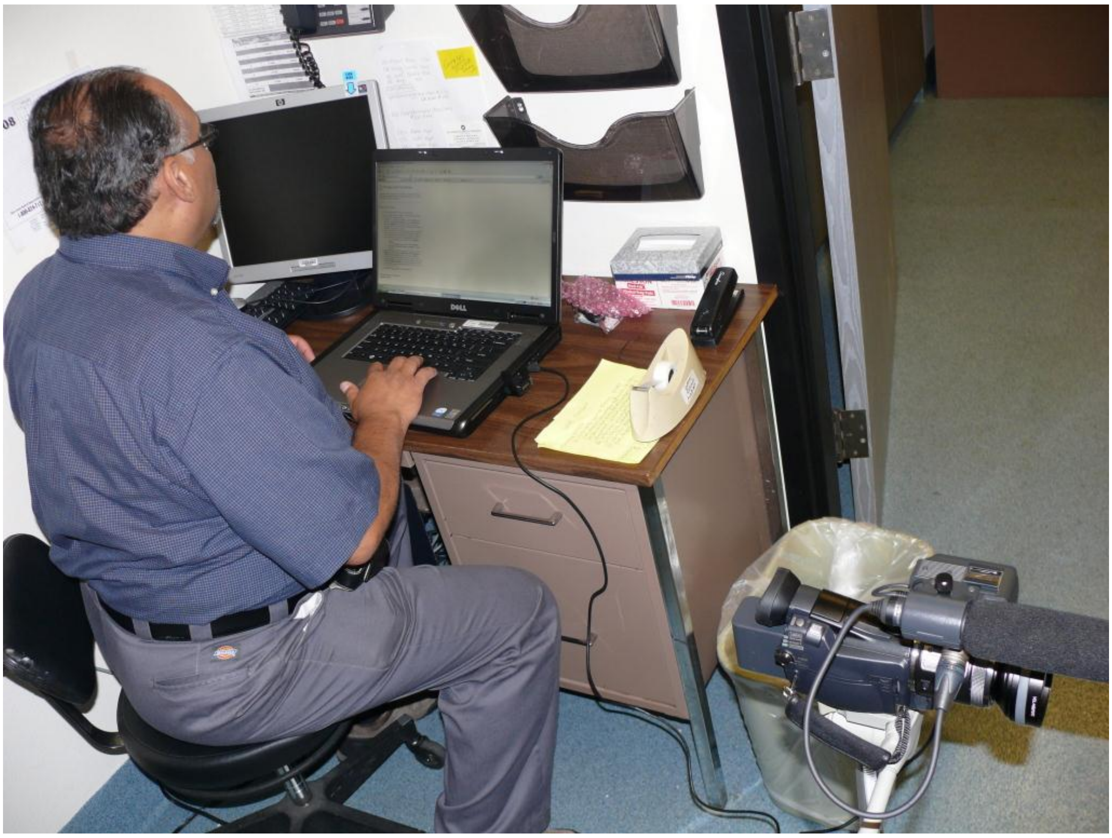

Figure 23 Physician with a laptop computer capable of video capture

11.2.1.4. Role

The technical assistant would be just that – a technical “specialist” assisting the PCP in order to produce the MD-doc – but he/she would probably have some knowledge about medical data and information as well, especially an experienced technician.

11.2.2. The means of the MD-doc

The means available to the agents are, as also illustrated in Figure 24,

Figure 24 Video recording equipment case

1) Audio/Visual recording equipment to capture the interview
    a. Camera
    b. Microphone
    c. Keyboard/mouse
    d. Other potential input devices?
2) An interface where the referral information, along with results/notes from the interview(s) are registered
3) A computer/communications system that allows referral of the patient
    a. Clinical
        i. Capturing/Storing of the patient data
        ii. Registering the data in a common format (allowing the specialist to see them)
        iii. Transferring the data to the specialist
    b. Administrative
        i. Potentially requesting the referral (specialist resource for the patient)
        ii. Billing, etc.
4) An appropriate interview (MINI, SCID, CIDI) – documents in their own right
5) An interview room
    a. Private
    b. Quiet?

c. Large enough to get both interviewer and patient captured on video, as illustrated in Figure 25.

The modes of the MD-doc

Exploring the total mode-space for any document is neither feasible (the space is virtually infinite), nor interesting in this context. The interesting space is limited by the *means* that we have already noted and the relevant set of choices that we have for each of them. The most straightforward way of analyzing them is to list the means and the possible/interesting modes that they allow

1) Audio/Visual recording equipment to capture the interview
   a. Camera

   The camera works in one out of two modes: still image or video. We have already said that we are interested in video, as still images would probably not give the evaluating psychiatrist any useful information. Within the video-mode for the camera there are several other choices of modes that appear:

   Camera-specific:

   - What kind of camera is needed?
   - What kind of format should the video have (mpeg4, avi, flv, etc.)
   - What resolution is sufficient (640x480, 720p/i, 1080p/i)
   - Wide/narrow angle (fisheye?) – related to the facilities (small room?)
   - What kind of h/w interface is needed? USB/IEEE1394, etc.?

Figure 25 Example interview room with camera

Other

- Positioning of camera: where should the camera be placed in order to capture the patient and interviewer
- Should the camera tape the patient only or both the patient and the interviewer
- Spatial requirements: what facilities does the interviewing room have to have? Size (area, distance to the camera, etc))?

b. Microphone

Technical:

- Separate from video – or is only combination video/audio important?
- Quality of recording
- Background noise reduction, etc.
- Recording format (wav, mp3, etc.)

Other

- Placement: where should the microphone be placed to ensure the quality of the recording
    - Long wires?

- NOTE: The camera/microphone equipment that was tested during the Store and Forward Tele psychiatry project showed that webcameras of today proved to be not quite sufficient for the needs of S&F Telepsychiatry. The biggest problem was the quality of the sound. The final choice of technology for this project was an approx. $ 2000 camera, a Sony HDV camera with an external microphone. Also considered were small strap-on microphones (on the shirt-sleeve on the patient/provider), which were considered an "intrusive" solution, not suited at this stage.

- Tried 2 web cameras
  - Bad sound
  - Tried external microphone, worked
  - Do not know until afterwards if it works or not
  - Not designed for this use – close distance and constant feedback ("your picture is not alright..")
  - Main problems
    - Sound
    - Recording distance (i.e. shape/qualities of the room)
- Tried 2 video cameras
  - First one had problem with sound (had to amplify sound in software – "got a hiss" (quote from a MD))
  - Second one worked "flawlessly".

c. Keyboard/mouse

d. Other potential input devices?

2) An interface where the referral information, along with results/notes from the interview(s) are registered

   a. This could be a local computer within the room where the interview is conducted – or it could be computer (or other device) where the data is collected and structured post-interview. Interviewing is a technique in itself that has to be practiced by the caregiver. It usually includes a notebook (or interview-schema) where the caregiver records the answers to the questions. Having to type in answers on a computer during the interview might prove inconvenient both for the interviewer/caregiver and the patient. However – this is not clear at the present. This interface is a crucial part of the system in that it is constitutes the "primary care tool" for the clinicians, who might me more or less trained/familiar with technical equipment. Alternatively we would have to include a second actor who installs equipment on an ad-hoc basis and helps with recording data for the MD/PA/NP.

   For example, we could assume that the video/audio is pre-installed and available from a known place on the recording device (computer) after the interview.

   At this point the question of how much of the interview should be stored with the patient data? Primarily the parts of the interview that support the diagnosis are to be sent to the psychiatrist. This is to be done by marking/tagging the recording of the interview where the caregiver feels that the patient is responding to key questions or giving key comments. The idea was to record a certain amount of time before the mark and after – so that the clip would capture both introductory comments/questions leading up to the "triggers" that tell the physician/caregiver to start record.

After the interview the collected data would have to be entered/structured/formatted in order to "facilitate" the transfer of the patient to the specialist. This could for instance be done easily with a:

- Web interface
- Other "ad-hoc" interface

A (store-and-forward) "telepsychiatric service" could include both an interface for registering/uploading data (usual client-server architecture) and administrative support for transferring patients.

3) A computer/communications system that allows referral of the patient

Some of the issues of this system are mentioned above. This is in general a difficult issue at the time being, as very few systems are interoperable with each other, so that these routines are often built into the administrative functions of the primary care facility and the psychiatric clinic where they both probably interface either a medical insurance company or government agencies for reimbursements. In this context is suffices to say that this component is needed in the future, but we will assume it present (or absent – in which case it has to be made ad-hoc).

Furthermore, the MD-doc is created at some geographical location: most likely the office of the MD. This room, in itself, has some properties that facilitate the production of the MD-doc – or impedes it. For instance, the room will have to have physical dimensions to accommodate the camera, the microphone and distance in order to capture the subject(s) on film. In this project, we have specified that both the interviewer (MD) and the patient be captured on the film in order to capture the interaction between them (body language, etc.). This room has been specially designed (hopefully, and presumably-) for the patient visit. The question is whether the room needs to be designed in a special way in order to accommodate recording of multimedia. In the end, it could be important that the acoustic is good and that the video quality is at a certain level in order for the psychiatrist to do a proper evaluation when viewing the recording.

11.2.3. The results of the MD-doc

The resulting document from this documentation process is an electronic document that *facilitates efficient and safe referral/transfer* of the patient from the primary care clinic to the specialist psychiatrist *and* provides the psychiatrist with enough information about the patient and the illness in order to make an accurate assessment of the illness and proper treatment/medication and follow-up of the patient.

In the current case this could well be anything from a BLOB containing the video/audio along with patient- and referral information, to a HL7 CDA-document containing the above.

11.2.4. Configuration (cognitive)

As for the mental configuration of the MD-doc this would be the perception of whom? -Mostly the referring doctor (PCP), the person doing the interview. It is his/her perception that is the most important one for the system. The quality of the document relies on the main producer. “Quality” is defined from the described function of the system. Let us say that the most important task of the system is to provide the best possible health care to the subject (which, of course, should be evident, but sometimes is forgotten as other issues are given higher priority). It is important that the main producer of the MD-doc describes and communicates the problems already unravelled with the patient in the most “effective” way (presumably). The latter also says something about the need to cost-minimize the health-care so that we do not waste resources – for instance the time of the psychiatrist, which is very expensive and often a scarce resource. In other words, the most fruitful way to look at the cognitive configuration of this document is to control the data-collection process that the MD does when they interview the patient and gather information to send off with the patient to the psychiatrist. The resulting question to answer is: how does the interviewer, the MD/PA/NP *perceive* the document that they are making – and how do we want them to perceive it?

As was stated in the description of the cognitive or Configuration part of the document earlier, the description of this part of the document can be done in several ways – all the way from a crude description of configuration as is expected from the system designer (often the system designer or user interface designer) trying to see the system from a user’s perspective to some kind of cognitive- or activity- or work- analysis of the document. Historically, the first one – the system designer trying to see the system from the user’s point of view, is a risky an error-prone approach (see for instance (Norman, 1988)(p 170) for a discussion) and should not be applied unless the system is not to be introduced to the “real world”. There are several things we could do in this situation; all included what is called Human-Computer Interface methodology:

- One is to study the main agent in his work, and deduct the cognitive perception from his/her doings today. The weakness is, of course, that the system does not exist and any observation of the current document might not give relevant information about our final document.
- Alternatively we could *ask* the PCP about his/her perception, describe the functions of the system and create a relevant description of our document from their answers. Interviewing, and what is referred to as user-involvement (participatory design), is much the preferred method of interface designers today.
- One could also create sketches and visual/physical models of the “document” (“unfinished versions” of the system) in order to support the description. This would help to focus the responses from the agent(s) on how they perceive the document. This kind of technique is called *prototyping* within computer science and is an important method within usability engineering – the process of making (engineering) systems that are perceived as *usable*

There are other methods to apply and our aim is not to have an exhaustive list, but rather to point to a set of relevant methods to model the cognitive side of the document.

The patient

Although the patient is not a producer of the MD-doc per se, the patient's reaction and feelings are important for the MD-doc. Consider for instance how taping the interview is different from the normal situation where the only documented facts would be the written document and forms that the provider (the provider of health care/primary care physician or similar). Whether the camera is a large, TV-production unit on its tripod in the middle of the room, or a hidden camera behind a reversed mirror, the patient would be aware of that he/she was being taped. For many people, this fact would not influence their willingness to come to a consult; however, this might be an issue for many people. This issue might also vary between the different illnesses that patients would have. A schizophrenic might have large issues with being videotaped and this might even influence the interview and the responses given, while a manic patient would be quite willing.

The willingness to be videotaped in this situation might be dependant on several factors. Culture is one. In some cultures people might be more outgoing than in others. In other cultures the cultural taboo of psychiatric illnesses might make people very sceptical being videotaped in such a situation, again – influencing the quality of the process.

11.2.5. Connection (social)

Who relates to the MD doc? -The agent does, of course (producer). The patient probably does too – as he/she is the one being transferred from the doctor with this document to the psychiatrist. The psychiatrist also relates to this document and this is the next document to analyze. Is the telepsychiatry-system a "closed system" of documents where none other than the referring doctor, the patient and the psychiatrist are relating to this document? In figuring the answer to this question out we have a couple of issues. First, the documents in question do not exist today. We are describing a research project, in which the purpose is to validate this kind of medical treatment. In other words, our analysis will in any case be experimental, in that it cannot be analyzed from existing practices. The obvious solution would be to analyze the documents as it is today – either in paper format, oral – or other. This is probably the referral document today. The apparent consequence of this will be that we will have to make many assumptions of how certain aspects of the new documents will affect the existing document. Additionally, and perhaps even more troublesome than that the document does not exist today, is that the existing document could be almost non-existent today. Consider the service being described: tele-psychiatry in rural areas where this service has not been available before. How has this service been provided before? At this point we run into the problem of "culture". First of all a definition:

"behaviour peculiar to Homo sapiens, together with material objects used as an integral part of this behaviour. Thus, culture includes language, ideas, beliefs, customs, codes, institutions, tools, techniques, works of art, rituals, and ceremonies, among other elements."[58]

It is of great importance in which *culture* the system is to be deployed. This specific system is for instance (potentially) meant to be deployed in California, USA. This fact will affect the health care model that is present and – in turn – the

[58] Encyclopædia Britannica

practices for giving this particular kind of health care, providing psychiatric services. There are both healthcare-specific and political/social systems and incentives to consider. Again – analysing all of these variables could prove much too time- and resource consuming. If all possible aspects should be mapped we would probably see few systems ever being made. However – if we could find the competence on these issues and if it were readily available we would be much closer to figuring how these aspects could affect the documents and the system as a whole. Say, for instance, that we knew that the kinds of patients that would be using this service: mainly minorities within the Central Valley area of California, many of which are (often illegal-) immigrants from Mexico (these are primary 'patient-users', as the research project is situated here). These patients are currently not receiving any services for such psychiatric disorders that this system is offering. Still – these patients are a part of the communities that they live in. One could readily see that the local communities where such a service is to be offered would be connected to the document in some way. They are probably the ones who would pay for the service, as many of the patients (a majority perhaps) would not have health insurance. Already we see that the document is changing current practices and offering a service that presently is not there.

At this point, analysing the complete social connections relating to our document is out of the scope of this project (although a very important part of the final document analysis to support engineering of the release-ready sercice). In this crude document analysis it suffices to list the most important connections (for demonstration purposes) and outline some of the properties of these 'connections'. Here are a couple of suggestions of how to go about analyzing this part of the document:

- Study how current practices for patient referral to psychiatric specialist.
    - How does this practice work – or how does it not work?
    - What does making the documentation of this process electronic change?
    - Are there any specific relations between referring MD and psychiatrist that need to be accommodated (for instance in knowledge transfer either in medication, treatment planning, etc.)?
        - Will these be changed in a more direct electronic communication between the psychiatrist and the MD?
- Study cases where patients have been referred from the specific environment (central California valley) to psychiatric specialist (presumably assigned a psychiatrist in the larger cities)
- Try to suggest how the current document will be – and what consequences it will have for the social connections

In other words we have the following social connections (thus far) for this document:

- The MD/PA/NP
- The psychiatrist
- The patient
- The local community authority

- The local community/people
    - Family/friends of the patient

As mentioned – not all the connections may be worth studying in more detail at this point, but having them listed may help design the system in that we know what we have *not* studied.

11.2.6. Construction (physical)

The physical construction of the MD-doc is the collection of the video, interview and supporting information history/other that the MD/PA/NP is able to transfer to the specialist. As the document is not created, but rather that this is more of an experimental document, we have several options to choose from in the final document. What we can do in the process of analysing the document is to suggest certain docemes for the document and watch how these affect the document and the document complex (system of documents).

11.3. The Psych-doc

It could make sense to make the MD-doc a doceme for the Psych-doc. Without the MD-doc there will be no Psych-doc, as the causal relationship already described implies. At the same time this establishes a sensible relationship between the two. However, within the Psych-doc, the MD-doc is also seen by the psychiatrist, making him/her a *reproducer* of the MD-doc. This means that we should probably have updated the MD-doc's agents to reflect this fact.

11.3.1. The agents of the Psych-doc

- The psychiatrist, a specialist MD who's expertise is about the psychiatric illnesses and possible medical treatments (and other, i.e. cognitive therapy, etc) for those.
- MD/PA/NP: the agents of the MD-doc
    - Important to remember at this time is that the authoring of the Psych-doc is happening without the agents of the MD-doc. There is obviously the question of whether the psychiatrist would call, or otherwise contact the referring doctor in his evaluation, in which case he/she would be directly affecting the Psych-doc.
    - One question remains: what happens to the Psych-doc once the psychiatrist authors it? How is the document used from that time on; - who reads it? How does the document *act* and between what people - from this point in time?

11.3.1.1. Role

The role of the psychiatrist is the specialist. He/she will both be a quality-assurance of diagnosis and a source for more in-detail knowledge of both potential other diagnosis and about the specifics of any psychiatric problem that the patient might suffer from. A quote from an experienced psychiatrist: *"it takes me about 10 minutes to figure out what it takes a newly graduated psychiatrist a couple of hours of work with the patient."* Another statement from a psychiatrist is that he regards himself as a "pattern matching agent", where he matches patterns of behaviour or patterns of symptoms with all possible diagnosis – as probably every specialist clinical MD does. In other words, the psychiatrist has the role of the medical doctor who has the highest probability of diagnosing and treating psychiatric disorders. The psychiatrist is still the caregiver, but also something more. When the patient has received the appropriate amount of treatment from the psychiatrist he/she might return to the family practice MD (primary care) with a diagnosis, prescriptions and a treatment plan. In our case, this *research project* does not state other than that the psychiatrist should *evaluate* the patient. In other words, the psychiatrist has no other role to the patient than the evaluating expert who perhaps will guide the referring MD in treatment and follow-up of the patient. If this is to be the case with the finished system, care should probably be taken to make the Psych-doc as good as possible in communicating to the referring MD all relevant treatment information - and the Psych-doc will, hence, both be informing about the patient and educational in teaching the MD about the illness (-es), perhaps suggesting relevant literature?

11.3.2. The means of the Psych-doc

The main mean of the psych doc would be the computer terminal (human interface to the patient information provided by the MD-doc) where the psychiatrist evaluates the patient, from the available MD-doc. Unlike the referring doctor, the psychiatrist is also a reproducer – or at least to a larger degree. One could argue that there are documents within the MD-doc that are reproduced, like the structured clinical interviews already mentioned, but the Psych-doc is produced solely on the contents of the MD-doc with no other input than the knowledge and experience of the psychiatrist (potentially reference-literature and advise from other/senior psychiatrists, but which is out of the scope of this system).

The psychiatrist would presumably use a computer display and keyboard (input)/mouse (pointing-device) to read the contents of the MD-doc and use the same equipment to produce the Psych-doc.

There is also the question of how to engineer the software component if the MD-doc. The possible choices are basically either some kind of client-software that connects to a server that has the MD-doc, or a web-solution – still a client, but made with a very standard web-interface.

11.3.3. The modes of the Psych-doc

The number of potential modes of the Psych-doc seem a little more restricted that with the MD-doc. This is natural, as the timeline has progressed since the MD-doc. We have the different means with their modes:

Computer terminal:

- basically any computing device that allows for the psychiatrist to access the MD-doc
    - Computing device
    - Software to access the MD-doc and author the Psych-doc
        - Client SW
        - Web-interface
- Network access
    - Intranet
    - Vpn
    - Secured webbrowser

Computer display:

- Any kind of adequate display will suffice. There are choices of size and resolution for ease of reading and ability to gain overview. Perhaps we could provide two displays for the psychiatrist – one to view the patient information and assessments of the referring doctor and one display to write their own assessment/diagnosis and treatment plan.

Input device

- In general, keyboard and mouse (pointing device). The ability of oral input is already available in some EHR-systems and might be considered (speech recognition software).

Geographical location and amenities.

- We assume that the psychiatrist has a private room/office in order to do these evaluations. In the usual evaluation this is not a problem – the patient always meets the psychiatrist at the office, or at some designated, private place. Perhaps will the psychiatrist write up the evaluation afterwards at another location, but most of the assessment of the patient is done in seclusion (plus the patient, of course), while in this novel situation the "do not disturb" sign (metaphorically) might not apply. This means that the new situation provides for the possibility that the psychiatrist might be interrupted several times before completing the assessment – a change from the ordinary situation – perhaps?
- If we assume that the psychiatrist still will do the assessment in seclusion, either in his/her office or home-office this provides some alternatives as to the modes of the document. Options are available as to visual and auditory experience of the MD-doc and the physical attributes of the "office" itself.

11.3.4. The results of the Psych-doc

The results of the Psych-doc is an evaluation of the patient with the following example content (taken from an example form that is currently provided by a professional specialist psychiatrist):

I. **Clinical Psychiatric Disorders**
II. **II. Personality and Development Disorders**
III. **III. Medical Conditions**
IV. **IV. Psychological Stresses**
V. **V. Global Assessment of Functioning**
VI. **Treatment Plan**
   a. **Educational**
   b. **Psycho-social**
   c. **Pharmacological**
VII. **Plan of follow ups**

In other words, the resulting document sent back to the referring physician is basically a psychiatric assessment of the patient, summary of diagnosis and a treatment plan (the latter in 3 parts). One question would be whether on not some of the other content in the MD-doc would be returned, as there are likely to be references to this material in the Psych-doc. If, for instance, the system would allow for annotations to the video, this would have consequences for the communications (protocol) between the institutions.

11.3.5. Configuration (cognitive)

The cognitive configuration of the Psych-doc is the configuration in the psychiatrists mind. Obviously, the MD-doc is a part of this. The way that the patient information is collected and presented plays a key role. There is obviously textual, video- and auditory information to be comprehended and evaluated in regards to the “pattern matching” process that we assume is going on in the psychiatrist’s mind. Furthermore, the video and audio together provide information about the interaction between the patient and the interviewer that can be interpreted. There is obviously some common sequence of events that can be assumed about this evaluation process done by the psychiatrist: first reading patient info, biographical information, medical information, reason for referral – trying to make a mental image of the patient’s situation. Then the psychiatrist might move on to the evaluation done by the referring physician, while at the same time start looking at the video footage that presumably support the conclusions of the physician. At some point, the psychiatrist will start authoring the “reply”, the evaluation of the patient. Whether this is after looking at all of the information provided by the MD-doc, or at some point – in parallel with viewing the information might vary from psychiatrist to psychiatrist. However, as we have hypothesized that having an extra display available for the psychiatrist so that she/he can both review the patient file while authoring the assessment, can support the creating of the Psych-doc better than a single display. Traditionally this process is probably supported by several means available to the psychiatrist while authoring the evaluation report: having the patient in front of her-/himself, taking notes underway – potentially reviewing literature, etc. They could even have a blackboard to brainstorm with and potentially colleagues in the neighboring office that they might ask for advice.

-Again: doing a thorough analysis of the mental configuration is possible through the tools of cognitive analysis (as with the MD-doc and any other document):

- One is to study the main agent in his work, and deduct the cognitive perception from his/her doings today. The weakness is, of course, that the system does not exist and any observation of the current document might not give relevant information about our final document.
- One should also consider making a map of the *activities* that the psychiatrist would perform in order to reach the higer-level goal of a psychiatric evaluation. This way, one could break goals into actions, sub-actions and so on in order to see the whole picture (using Activity theory).
- Alternatively we could *ask* the psychiatrist about his/her perceptions, describe the functions of the system and create a relevant description of our document from their answers. Interviewing and what is referred to as User-involvement is much the preferred method of interface designers today.
- One could also create sketches and visual/physical models of the “document” (“unfinished versions” of the system) in order to support the description. This would help to focus the responses from the agent(s) on how they perceive the document. This kind of technique is called *prototyping* within computer science

> and is an important method within usability engineering – the process of making (engineering) systems that are perceived as *usable*

Other techniques are surely available, but the main point is: we cannot assess the mental qualities of the Pshych-doc without probing the main producer: the psychiatrist. Moreover, the psychiatrist is, as the "users" tend to be within the medical domain, a domain expert. Hers/his knowledge and experience background is invaluable to the requirements analysis of the Psych-doc, and cannot be reproduced by any systems designer. The trick is then to get insight into how the process of psychiatric evaluation of the patient actually takes place when they view the MD-doc in order to support that process as best possible.

11.3.6. Connection (social)

Who relates to the Psych-doc? -Again, mainly the producers and the "object of study" - the patient too. Furthermore, the Psych-doc is also the communications channel back to the referring physician and as such, the physician becomes a part of this document's social connection.

Furthermore, the Psych-doc does not exist today. We are doing an experimental analysis. Does a similar document exist today? Yes – the psychiatrist writes a patient report today that looks rather like the Psych-doc. There is most certainly a prevailing "culture" between psychiatrists and primary care providers, which almost certainly has been studied before. If not – we are probably not likely to figure out the social role of this document without some investigations into this relation. You might ask at this point: how does this affect our making of the system or interface that the psychiatrist is to use? This particular issue might not influence it at all – or it could have important implications. There is the whole spectrum of potential impact. -Say that (ideally), the psychiatrist also wants to, in order to secure best possible continuing care for the patient, "educate" the referring physician, or that the referring MD asks for this feedback explicitly. If there were a relation between these two medical professions that does not emphasize such a knowledge transfer, this would influence both 1) the psychiatrist's motivation for creating documents with such an "educational" character 2) the referring physicians likeliness to actually read such recommendations in the reply. This, in turn, would likely affect the incentives for us as systems engineers to provide "writing space" for such comments in the Psych-doc in "availability", "visibility", etc. (within the interface to the Psych-doc). There could also be professional incentives to this educational activity within psychiatry or medicine in general, in addition to any legal incentives to transfer any information or knowledge.

Also, there is the question of who gets to see the Psych-doc. The modes of this document might set restrictions on who gets to access it. Does the patient get to see it him/herself? If so, perhaps this needs to be a different document, with only subsets of the contents of the Psych-doc. Is the Psych-doc a legal document? Most likely it is – in turn affecting the psychiatrists relation to the document and the selection process of what goes into it (fear of malpractice, etc.). The Psych-doc is definitely related to other documents, for instance prescription (especially for psycho-pharmacological meds), as it would be the basis for authoring such prescriptions (also something the psychiatrist would do). Some medications might even be 'required' based on information from the Psych-doc. This might be because of, for instance, workplace requirements. Someone with a treatable disease might not be allowed to perform certain occupations without documenting their continuing treatment.

A couple of suggestions of how to go about analysing this part of the document:

- Study how current practices for the psychiatric evaluation report.
  - How does this practice work – or how does it not work?
  - Does making the documentation of this process electronic change it?
  - Are there any specific relations between referring MD and psychiatrist that need to be accommodated (for instance in knowledge transfer either in medication, treatment planning, etc.)
    - Will these be changed in a more direct electronic communication between the psychiatrist and the MD?
- Study cases where patients have "returned" from psychiatric treatment to the specific environment (central California valley) and how the psychiatric report has been used in the past.
- Try to suggest how the current document will be – and what consequences it will have for the social connections

In other words we have the following social connections (thus far) for this document:

- The MD/PA/NP
- Other psychiatrists
- The patient
- Other potential caregivers to the patient; friends, family
- "Legal entities", insurance companies, etc.

As seen from the above paragraphs, the Psych-doc is not very different from the MD-doc (apparently) in regards to social connections.

11.3.7. Construction of the Psych-doc

The physical 'instantiation' of the psych doc will most probably be a HL7-compliant clinical document (according to CDA), i.e. a digital representation in the structure outlined in 11.3.4. or something similar. In an end-system this document is probably integrated into a local hospital information system (HIS) or at an outpatient clinic (or local MD-office) in their respective systems. Hence, the layout could very well vary, as long as the document complies with the CDA. The most important part for the MD/Phys. ass. in the Psych-doc is probably the 'Follow-up' section that describes suggested measures to be taken and advices from the specialist (psychiatrist).

11.4. Design suggestion as a consequence of the document analysis

In regards to systems-design implications for the document model we have created a basic process chart for the S&F telepsychiatry healthcare model, as illustrated in Figure 26. The process starts with initial patient contact, where information is collected in the first process box, resulting in the first document, the MD-doc. The process of document creation is not specified in detail here, but rather just composed of data (i.e. *"Video + sound"* or *"Patient data, history, etc"*), tasks (i.e. *"Do interview"*). This illustration provides a schematic overview of document flow and processes within the novel S&F Telepsychiatry system.

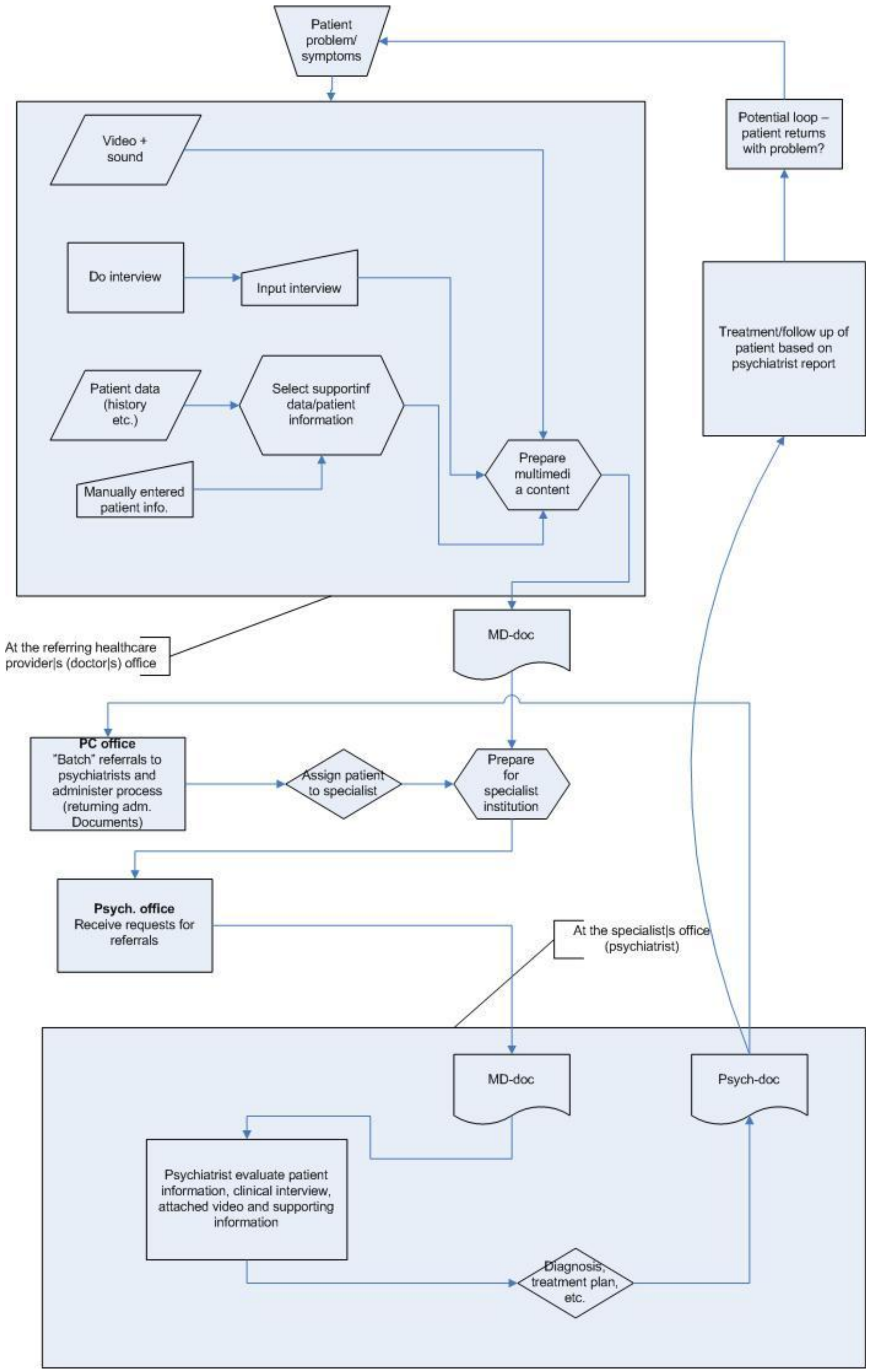

Figure 26 Crude process descripion of the Store and Forward Telepsychiatry system

Endnotes

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[i] One might argue that a technology-researcher would not assume anything about opinions that clinicians or medical researchers' attitude towards novel technology, but rather interview them beforehand. However – this approach requires that the subjects of the interviews/inquiries have experience with and/or knowledge about the technology. In the case of LaHiRD technology – especially at the time of this investigation – this was not the case. Only technologists and researchers in particular had experience with such equipment, let alone any experience using it (for work-related purposes).
[ii] The delay in the update is caused by two so-called remote desktops (RDs) that enable us to transfer the image from the laptop computer to the display wall. There is one RD residing on the server machine that runs the enlarged desktop that covers the entire wall (7168*3072pixels). This is a Virtual Network Computer (VNC) server that forwards this desktop (resides within the server machine's memory) to the 28 cluster machines that each project one tile of the total display wall. In other words, the (laptop) desktop is transferred in two stages, first from the laptop computer to a software server residing on the server machine (physical computer) hosting the VNC server. From there, the image from the laptop computer is scaled up 4 times in order to fit the entire display wall and transferred to the cluster of machines that run the display wall. The first step (laptop to software server) is measured within the software to be somewhere between 50ms (min) and 100ms (max). The longest and most varying delay is introduced by the VNC server scaling the image (4x) and sending it to the cluster, measured to be between 400ms and up to 1000ms from key-press to update. A simple calculation gives a smallest delay in updating the display wall on 400 + 50 = 450ms and a largest of 1000 + 100 = 1100ms. Assuming uniform distribution of these delays this would yield a mean delay of 775ms for each trial on the large display, compared to the small screen setup. However, it should be noted that the small laptop screen also seemed to induce a certain delay in update. As the software timer started at the press of a key, any delay from loading the image onto the display would also be added to this trial condition. Superlab® has also confirmed this issue. The images used in this study were bitmap-images (.bmp) of around 3-400 kb and the fact that participants did not notice a big difference between the two display conditions in image-update this could also be viewed to support the claim of a lag in updating the small screen as well.
[iii] My first attempt at describing the document concept as an analysis framework for systems design was done in my first couple of months as a researcher. We delivered a 12-page manuscript to the annual DOCAM conference in 2005 and presented this work in one of the parallel sessions (labelled "HEALTH CARE"[iii]) at the conference. We were subsequently invited to re-submit this material to the bi-annual International Conference on the Design of Cooperative Systems (COOP). We re-wrote the manuscript to better fit the call for papers at this venue (also constituting a reviewing of the CSCW-field for me as the first author). Our paper was accepted as a short-paper, and published as supplement to the proceedings from COOP '06[iii]. I have not included these works in this thesis, as I consider them preliminary works better described by the work included here,

essentially all this work is contained within the scope of Paper 9, or in the background-work leading to it.

[iv] The "task", as it was, - in the start of this project in 2004 - implied either studying people collaborating with such technology, or build the technology for them (most likely clinicians) to use. This was a rather classic version of hen-and-egg problem, with the technology (Display Wall) at its current development stage.

[v] This topic was especially relevant at the mentioned DOCAM '05 conference where I presented our initial ideas. As such, my ideas to *use* it (the theory) – as a tool, or framework for engineering – was rated as "*radical*" (as one of the anonymous reviewers from the COOP'06 conference labelled it), but also felt, again, as somewhat premature. 'Premature' was perhaps only a subjective feeling – seeming that 'Documentation' was, apparently, in its "infancy" – again, and that the field of study was seemingly in some sort of "identity crisis" at this time. Nevertheless, my experience from the use of the theory, from the practical work performed at the School of Documentation Studies at University of Tromsø (as described above) lead me to believe firmly that there *is potential* for the engineering sciences to learn from these methods.

[vi] Coiera here treats 'Sociotechnical' almost as a synonym for CSCW methods and applications, as illustrated in the figure on page 99 (ibid.) 'Sociotechnical' – theory has, it seems, has different meanings – as the methods and research originates from systems theory. Today, I would say, we are witnessing a merge of this term with the approach to analyze the social aspect of systems, implying that it becomes an umbrella term for studies of human- and social aspects of systems, as exemplified by a workshop at INTERACT'09, labeled "NEW SOCIOTECHNICAL INSIGHTS IN INTERACTION DESIGN" (http://www.interact2009.org/?q=node/51, accessed Feb 2012)

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