IPRO 372
Medical Informatics

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Abstract

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Objectives:
The objective of IPRO 372 was to explore solutions for the field of medical informatics, specifically, to create an ecological display that would be effective in communicating information to clinicians and further improve healthcare for individuals. This work is necessary because of the current limits of systems and technologies in the medical field in displaying and communicating useful information in a complex environment that deals with patient data. The shortcoming of developers of these systems in realizing the complex array of data and its corresponding relationship with the cognitive aspects involved in patient care and monitoring has put clinicians and staff at a disadvantage in current healthcare environments.

Conclusions:
In this project, the team has come up with several key findings through research, and observations made in real world settings such as the intensive care unit of a hospital. One aspect that the team has explored is the cognitive nature of the decision making process in working with large amounts of data. We have surmised that technology is only effective when information is displayed in a comprehensible and non-cognitively taxing way. Other findings include those that make an effective ecological display such as the ability to view different types of patient information in one screen and having a user-configurable display that provides the most pertinent data available to the clinician.

Results:
The IPRO team has come up with several criteria and solutions in creating a practical and effective ecological display that include observability, the ability to accurately synthesize data and ease of clinician programming. Furthermore, a usability assessment can be done of the prototype ecological display in order to eliminate or improve upon the tasks that caused error during task performance. Further work would need to be done in developing display systems integration and intercommunication. Also, ethnographic research in the healthcare work domain is necessary to enhance the effectiveness of such displays.

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[1] Introduction

What exactly is medical informatics? It can be described as "the scientific field that deals with the storage, retrieval and optimal use of information and data. Rapid development is due to advances in computing, communication technology and an increasing awareness that the knowledge base of medicine is essentially unmanageable by traditional paper-based methods."

Medical Informatics is a multi-billion dollar industry and so is the information technology industry that drives it. An example of how fast medical informatics is growing, we can take a look at some results found by the Agency for Healthcare Research and Quality, "Over the past 40 years, medical information has grown at an astonishing rate. For example, MEDLINE®, a database that contains references to articles in the biomedical literature and is maintained by the National Library of Medicine, added more than 460,000 references over the past year. This makes it virtually impossible for physicians to keep up with the large amount of information that results from clinical trials and other studies, information that they could be using to guide their medical decisions." Another problem is actually getting the information together and actually understanding what it means.

Medical informatics is a combination of information technology and healthcare support. In order to understand medical informatics we must first know the definitions of these two words. Information technology can be defined as: "technology that encompasses all forms of technology used to create, store, exchange, and use information in its various forms (business data, voice conversations, still images, motion pictures, multimedia presentations, and other forms, including those not yet conceived)." Healthcare can be defined as: "the preservation of mental and physical health by preventing or treating illness through services offered by the health profession."

Medical informatics brings together information technology and healthcare into one field. Bringing their forces together to help solve medical problems. Even with all the advancements of technology, the field of Medical informatics is still growing. The failure in Medical Informatics is not because of a lack of technological advancements but a lack of communication between software manufacturers and actual clinicians. Most of the time when this software is being created, manufacturers are communicating with people that know little of what patient care is comprised of. They also do not have the experience, nor does the software manufacturer, to know what kind of display clinicians would need so that the information can be displayed effectively. It has been stated that there are "too few experts to lead the effort, limited funding to pursue substantial research questions, and pressing needs to educate citizens and both entry level and practicing health professionals." It is in this area that significant attention needs to be placed. There is a strong need to bring this topic into the light, too many innocent people are dying due to medical mistakes that can be prevented. Medical informatics is a great opportunity to help save lives and even with this field growing rapidly; there is still room for more improvements in the field. This could dramatically decrease the amounts of lives being lost due to improper medical treatments.

The two previous IPRO's dealt with medical informatics. Both IPRO's created abstracts on Medical informatics.

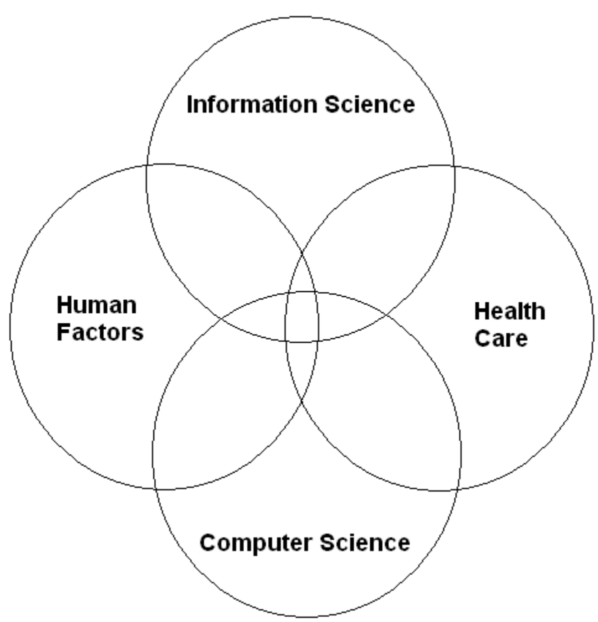
Fall 2003 Abstract Summary

The Fall 2003 team acknowledged the increasing need of heath care, and how hospitals and companies are trying to reduce costs. The problem that they face is providing adequate health care, and even possibly increasing the quality of healthcare to help assure a patient's well-being. They believe that in order to increase patient safety, "changes in the structure of work in health care, particularly through the use of software and tools to make tasks both effective and efficient." To find out what was the true meaning of Medical Informatics was they decided to do their research on automation. Other than just researching for the topic, they spent a day at the University of Chicago Hospital to gather more information from knowledgeable people currently in the Medical Informatics field. They found examples to help people understand more of automation. "ACORN is an example of a tool that has automated the process of diagnosing a patient for intensive heart care, and evolved through a process of reducing system failures." They found that ongoing training to be the best tool to help bring software users and designers together to help strengthen their knowledge of the Medical Informatics field.

Spring 2004 Abstract Summary

The Spring 2004 team concentrated on solving software solutions to help exchange and transfer large amounts of medical information. They believe that the problem lies in the "limited understanding most system developers have about the nature of collaboration and coordination between medical staff and the persisten use of cognitive artifacts that are not adequately accounted for." They found that some automated tools have helped "dramatically increase efficiency and effectiveness of practitioner work." However, they also find cases of how some automated tools do not help much and all, and in some cases confuse the users. Their entire report focused on the "study of current tools and technologies, how practitioners are affected by these tools, and a review of insights and conclusions about the nature of automated systems" in healthcare.

Fig.1 Fields of knowledge for Medical Informatics



Each group plays a critical role in the development and further advancement of the field. In order to grow even further, all the groups must work together to create a better understanding of what they are trying to accomplish in the field of medical informatics; which is creating more effective displays.

Both teams had some similar ideas for the groundwork for medical informatics. They provide a good foundation, but with this new team there will be new information being researched and introduced: Information Display and the Virtual ICU. This team will build off the previous teams and come up with even more effective information, which would help further advance the health care field. This current team, will research the scope of Medical Informatics and the reader will know how important it is to help bring along further advancements in the Medical Informatics field. There will also be even more information on displays, and how to make them even more effective. This team will also help improve the clinicians tools to help them do better work, thus increasing the quality of health care. All these new innovations could dramatically increase the effectiveness of Medical Informatics, by helping clinicians make decisions based on information that is processed through effective displays. The Virtual ICU could help doctor's contact and analyze patients from hundreds of miles away, having the opportunity to help them at a moments notice.

[2] Background

Trends in Information Science and Information Technology

Information Science plays a very important role in health care. Everyday we hear about new researches, new medical procedures, new surgical interventions and all sorts of different medicines that rule today's world. But without Information Science, all this would not have been possible. Health Care would not have been able to climb that ladder to the pinnacle that it has been climbing for the last few decades.

Information Science is the study of how health data are collected, stored and communicated; how those data are processed into health information suitable for administrative and clinical decision making; and how computer and telecommunications technology can be applied to support these processes.

We have come a long way in a few decades. The computers, which were only used for billing and federal reporting services are now being used extensive functions like inventory control, electronic medical record keeping, clinical decision-support and physician order-entry. The newest applications nowadays, eliminate the need for intense paperwork, avoid duplication of information, and expedite the whole process making healthcare more efficient and effective. Linda Kennelly, a member of the graduate nursing faculty at Excelsior College, tells us that "in patient care areas, specialized computer applications can be used to schedule tests, transmit medication orders directly to the pharmacy and access current as well as historical lab results." She also tells us that "an electronic "patient health-card" system is being researched as an information tool. People would carry their health record with them so that in emergency situations this vital information would be immediately available. Informatics brings all this data together and can make a patient's previous and current symptoms, treatments and medications readily accessible at a central resource, eliminating time-intensive information gathering and transfer." (Kennelly, 2003, p. 2)

We have come a long way, but we still have a long way to go. Raj Reddy and Irving Wladawsky-Berger, who are the co-chairs of the President's Information Technology Advisory committee (PTIC) established several panels to examine specific issues, including a panel to review the ways in which information technology can transform health care and increase access to care for all citizens. Through these panels, PITAC found that at present the U.S. lacks a broadly disseminated and accepted national vision for information technology in health care. In one of the reports that they prepared for the president in February 1999, they say, "The quality of U.S. health care and medical research are the envy of the world, but U.S. health care costs as a percentage of gross domestic product are among the highest in the world and are increasing despite recent changes in health care organization and financing. Significant improvements in care would be possible if modern clinical information systems were widely implemented and a sound national health information infrastructure were in place" (PTIC, 2001, p.13-14). They also say that, "Information technology offers the potential to expand access to health care significantly, to improve its quality, to reduce its costs, and to transform the conduct of biomedical research." (PTIC, 2001, p.14)

Electronics technology in general has evolved rapidly over the last few decades. The changes in communications, computers, and video technology are, perhaps, the most profound.

Fig.2 Source: http://www.mantex.co.uk/ou/t171/t171-07.htm

Year	*Information Technology Timeline*
1642	**French mathematician and philosopher Blaise Pascal constructs and demonstrates a mechanical adding machine.**
1823	**English engineer Charles Babbage invents The Difference Engine - the first mechanical computer.**
1834	**Babbage designs and starts to build 'Analytic Engine' - Augusta Lovelace [Byron's daughter] writes the first computer program.**
1847	**English mathematician George Boole publishes 'Mathematical Analysis of Logic' and uses the ideas of binary numbering to fuse logic with algebra.**
1925	**American engineer Vannevar Bush designs and builds the first multipurpose mechanical analogue computer.**
1936	**English mathematician Alan Turing puts together binary notation and Boolean logic to produce tests for mathematical probability.**
1962	**'Spacewar' - first graphical computer game.**
1968	**Douglas Englebart demonstrates 'windows' and mouse in San Francisco.**
1969	**Myron Krueger develops first prototypes of virtual reality.**
1975	**Bill Gates and Paul Allen found Microsoft.**
1978	**Philips and Sony introduce the laserdisk (analogue video).**
1981	**IBM introduces the first PC .**

1983 **Microsoft launches its first version of Windows. Myron Krueger Artificial Reality.**

1984 **Apple-Mac launched - DNS (Domain Naming System) introduced - Number of Internet hosts reaches 1,000.**

1989 **Tim Berners-Lee develops Hypertext Markup Language (HTML).**

1991 **CERN launches the World Wide Web.**

1993 **Marc Andreessen, NCSA, and University of Illinois develop Mosaic - the first graphical interface to the WWW. A recorded 341,634 per cent growth rate in Web traffic.**

1994 **First eCommerce (shopping malls and banks) arrive on the Web, and Web traffic second only to FTP-data transfers. Linux 1.0 open source operating system released.**

1995 **First search engines developed. Sun launches JAVA programming.**

1996 **Browser wars begin between Netscape and Microsoft. Web censorship in China, Saudi Arabia, Singapore, Germany, and New Zealand.**

2000 **Dotcom crash begins (April). Size of Web estimated at one billion pages.**

2003 **Google claims a searchable database of 3.6 billion web pages.**

Several new types of communication technologies are being developed and installed. A variety of communication services are now available to serve different needs. The cost of communications, particularly high speed, long distance data transmission has dropped. Communication networks have become easier to use, so that users can build distributed networks of interlinked computers and terminals. Much larger volume of data can now be carried over the lines.

Cable television, now, transmits the signal to a television receiver directly through a wire rather than through air waves. Its principal advantages are better reception, the ability to direct specific signals to specific receivers, and the availability of more channels for use.

The basic technology of the telephone network and its use has changed. The principal shift is from an analog-based system to a *digital-based* one. In analog transmission, the human voice (or any sound pattern) is transformed into electrical wave form, similar to the way music is stored on a record as a series of wavy lines. Digital transmission, on the other hand, encodes the information as a series of discrete pulses. Digital technology allows the transmission lines to carry more information at higher rates.

The fundamental technological base for computer hardware has undergone revolutionary changes over the last decade that are expected to continue in the next. In 20 years, computer designers have advanced from using vacuum tubes, through solid-state transistors, to using microelectronic integrated circuits on single silicon chips the size of a dime.Technology for storing data is steadily improving, for both large and small computer. Many desktop systems are designed to operate programs stored permanently on silicon chips in a high-speed memory that cannot be changed. This so-called “read-only memory” (ROM), is plugged into a socket on the computer. Now, economical bulk storage systems that use hard disk technology are becoming available for small computers. These systems have many times the capacity of floppy disks and are much faster and more reliable.

With electronic conferencing, a meeting can now be conducted in which geographically dispersed participants talk with one another over telecommunication lines. There are three categories of electronic conferencing, depending on the technology used:

- *Audio conferencing,* which uses the telephone: individuals at different locations are linked together by a conference call wherein both a loudspeaker and a microphone system are used at each location.
- *Video conferencing,* which supplements the voice connection with television images of the participants or of display charts, tables, or other graphics under discussion.
- *Computer conferencing,* which transmits messages through a central computer that stores them and forwards them on request to another participant.

The three areas of information technology–computers, communications, and video have grown up separately, connected only by their joint dependency on microelectronics. Now it is becoming increasingly difficult to tell them apart. The technologies are becoming integrated. The digital network uses computer technology; distributed computer systems use telecommunication services; video disks are controlled by microcomputers. New types of information services that make use of all three technologies are being planned and offered.

PTIC (Presidents Information Technology Advisory Committee) throw more light on this topic by telling us that, “Specialists use videoconferencing and telesensing methods to interview and even to examine patients who may be hundreds of miles away. Computeraided surgery with Internet-based video is used to demonstrate surgical procedures to others. Powerful high-end systems provide expert advice based on sophisticated analysis of huge amounts of medical information. Patients are empowered in making decisions about their own care through new models of interaction with their physicians and ever-increasing access to biomedical information via digital medical libraries and the Internet. New communications and monitoring technologies support treatment of patients comfortably from their own homes” (PTIC, 2001, p.13).

One of the applications recently adopted is PDA. PDAs are intended to provide support in field work. They are designed to fit comfortably in your pocket. It offers the ability to record data electronically as soon as you come up with it. Recording ideas/data electronically anywhere and anytime makes it easier to search it and manipulate it. But there are certain disadvantages associated with it. As Chuck Frey says, “PDAs are well suited for recording words, but are poorly suited for recording ideas as pictures or images. Also, because most PDAs require that you use a stylus to input text, you may find that spotty handwriting recognition may interrupt your creative ‘flow’” (Frey, 2003, p. 2). Unless we understand what the drawbacks of a particular technology are, we won’t be able to design efficient applications. Thus, technology is a great boon, but it can prove to be a curse if we don’t know both the positive and negative sides of it.

Looking at all these trends in the past few years, we can definitely say that there is a lot of potential in developing ecological displays that could solve the issues in health care. “To Err is human”, but we should not keep on erring all our lives. New information technologies have the potential to dramatically improve our health care system as it exists today, and the sooner we realize that, the better.

How communication of information has evolved in healthcare

The communication of information in healthcare settings has evolved over time to adjust to the needs of the clinicians. Communication of information in the healthcare setting embodies many different issues, namely interpersonal communication, healthcare records, and privacy.

Interpersonal communication in a healthcare setting does not just include a physician's ability to communicate with patients; it also includes communication between administration and clinicians and communication between clinicians. While a good "bedside manner" is extremely important for physicians to have with patients, there is also a concern of whether patients are receiving feedback information in a timely and proper manner. Feedback information can be thought of as results from a visit, such as lab or test results. The current trend is to send paper letters, meet in person, or telephone results to the patient. However, with the growth of the electronic health record, the question arises of whether patients and clinicians would benefit from an electronic communication. In an article by A. Hassol et al., an online survey was conducted for 4,282 members of a health system, as well as patient focus groups and one-on-one interviews with physicians, to find their opinions of an application that allows patients to communicate with providers electronically and see portions of their electronic health record online. While patients had mostly positive attitudes about the service, a minority was concerned about privacy and learning about abnormal test results electronically. The clinicians had more negative attitudes toward using an electronic system to convey feedback results. Communication between administration and clinicians is another important area of interest. What problems exist in communication between the two groups? In a study conducted by J.M. Patterson and R.L. Allega, they assessed "the timing, legibility, and completeness of handwritten, faxed hospital discharge summaries as judged by family physicians and [obtained] their opinion on the information categories on a standardized discharge summary form." They found that there were often incomplete, illegible, or clerical problems (such as no signature or fax number) with the reports between the groups. Another article, by D. Bonacum, S. Graham, and M. Leonard, discusses the need of effective communication and teamwork to avoid inadvertent harm to patients. They believe that this can be done through standardized communication tools, an environment receptive to communication, and a common “critical language” to be used during unsafe or emergency situations. Doing these things could help prevent miscommunication, lack of communication, or other errors that could lead to further problems.

A critical piece of information in a clinical setting is a patient’s healthcare record. While the past, and some current facilities, used mainly paper files and film media, the development of electronic health care record, or HER, is growing in usage among health care facilities (Brown and Reynolds). Physicians can be seen walking around with a PC tablet that measure about 8.5" x 11" x 0.5", which they can use to gather and record patient information. This eliminates the need for the numerous paper forms that can be seen in facilities not using EHR technology. EHR technologies were created in part to “alleviate staff frustration and [to] increase the level of patient care.” By using EHR for patients, physicians should be able to access and add information quickly and easily. However, problems may arise with this use. Clinicians use their cognition to describe decisions by including it in medical records. However, with the introduction of electronic records, which can be subpoenaed, clinicians do not input their thoughts- they use paper instead, in the form of sign out sheets (Nemeth).

A major concern, both the patients and clinicians, concerns privacy issues with the use of EHR. Since electronic records are easier to send, and can be sent to multiple people easily, could privacy and confidentiality or patients’ records be risked? In 1996, and amended in 2002, Congress enacted the Health Insurance Portability and Accountability Act, to counter any problems that may arise from electronic records. HIPAA ensures patient confidentiality in medical records and other health information, gives patients more control and access to their own records, and holds violators responsible through civil and criminal penalties. This is the first enactment of a federal standard to protect individual's personal health information and records.

Trends in Healthcare

Today's healthcare is much different from that of your parents or previous generations since the advent of new technologies, strategies and advancements made in the medical and technology fields of science has vastly improved the tools and systems clinicians and medical practitioners. According to Hutt (2003) "before the early 1970s, nearly all surgeries were performed in a hospital and included an overnight stay. As technology improved and insurers found they could lower costs, surgeries began to move from hospitals to outpatient surgery facilities, where the patient goes home the same day the surgery is performed".

Already, the U.S. spends approximately 14% of its gross domestic product on medical care. Within a decade, many sources are predicting the U.S. could be spending up to 17% of the national on healthcare. Much of the growth in healthcare is due to innovation primarily in technology, but also to the needs of aging Americans in need of ever-more-intense levels of care. Technological developments have affected healthcare in several ways; it has lowered the overall costs, offered a competitive advantage and improved patient care on a variety of levels (Hutt 2003).

A growing trend among hospitals and clinics is the use of virtual ICUs or virtual intensive care unit. Digital cameras, microphones and special software will link patients and their caregivers to a team of intensive-care specialists who also will monitor their care -- from miles away. The systems are a growing trend in the nation's hospitals, which are struggling to improve care in intensive-care units while coping with a severe shortage of intensive-care medical specialists. "By the end of the year, more than 100 hospitals will use the "eICU" systems to monitor more than 2,000 intensive-care patients" (Salmon, 2004)

Cameras and microphones installed in each intensive-care room and special computer software will allow those at the remote site to monitor heart rates, blood pressure, respiratory rates and other vital signs of critically ill patients even more intensively than the staff on duty can. The video and audio links will enable the ICU staff to look at the patient and talk to caregivers. So far, the system seems to be working as deaths in Virtual ICU's have dropped by more than 50 percent and the cost and stay of patients has dropped by a third. However, patient care can be stagnated, patchy and there is no national standard. Research is often insufficient, not integrated, inefficient, failing to learn from patients and also poorly funded. "In ICUs where automated data collection systems exist, databases are frequently inadequately constructed. This is largely due to the lack of a standard national format for data base construction in critical care. There also are wide variations in proprietary on-line real-time data acquisitions systems and database storage platforms among institutions. Inter-institutional linking of these idiosyncratic data collection modalities is a major challenge. These realities are a significant challenge for the sharing of data" (www.picu.com, 2004).

Currently there has been much debate about privacy issues in healthcare as well as ethical concerns behind patient confidentiality specifically related to medical records and associated technologies used in modern medical facilities. One in seven Americans has done something out of the ordinary to keep medical information confidential. To protect their privacy, and avoid embarrassment they have often lied or omitted medical information from their healthcare providers and in extreme cases avoided care altogether. Most breaches in confidentiality cost consumers and health organizations time, money and resources better fit for patient care. According to Cross (2002), "in 2000 alone, $250 billion of the one trillion spent on healthcare was used for administrative overhead rather than patient care" With today's technology based on the efficient transfer of information such as medical dictation, x-ray films, or lab results, it is often difficult to secure patient information from ethical breaches of privacy. The results can be disturbing as in one case in California where hundreds of patient records were found on a disk in the parking lot outside a clinic that included diagnosis, credit card information and test results. A banker who also served in his county's health board, cross referenced customer accounts with patient information. He called due the mortgages of anyone suffering from cancer (Cross 2002).

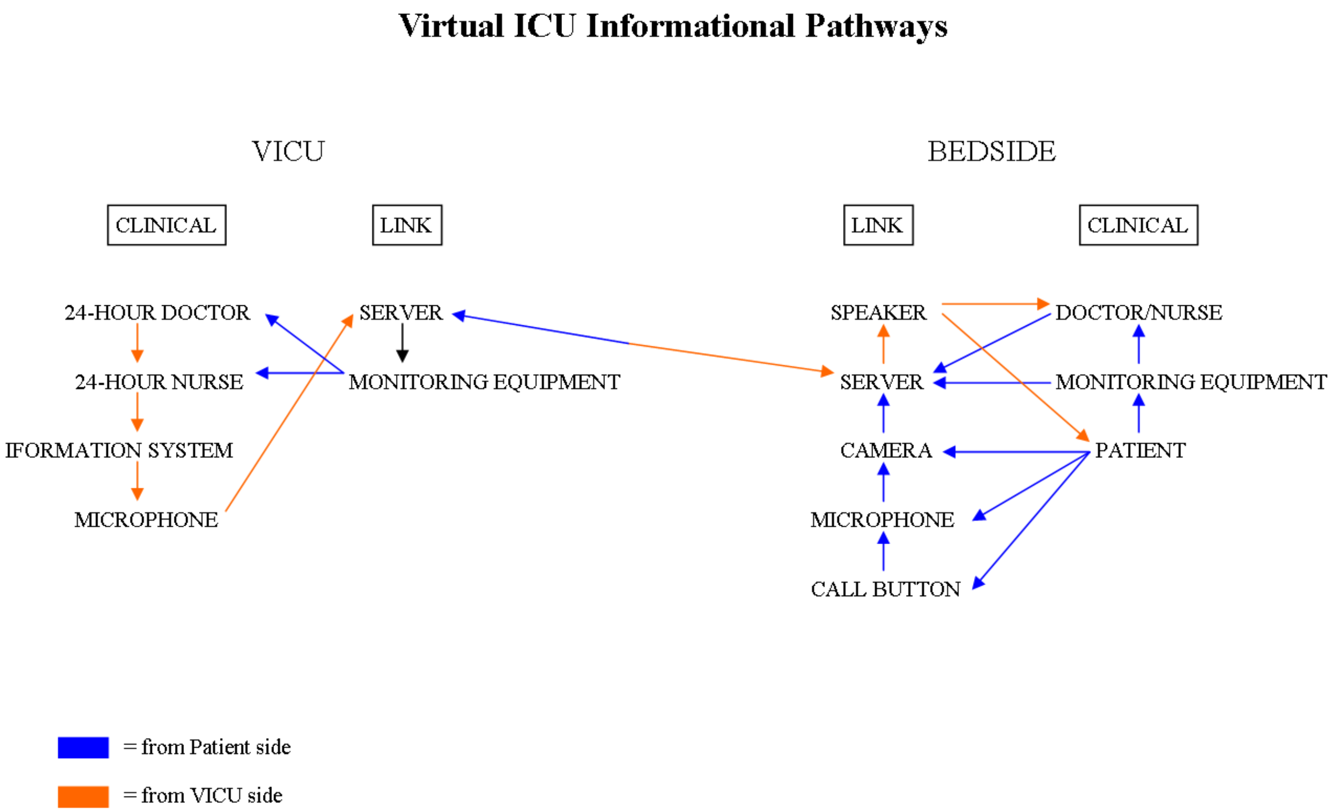
With more at stake, a little less than half of patients are giving incomplete personal information when completing forms, which makes the job of physicians that much harder in providing good medical care. Healthcare professionals are now left with the responsibility of preventing privacy breaches, however, this is often difficult when organizations must deal with technology or computer issues and feel intimidated when dealing with consultants. With the digitization of many health records and patient data it is important that healthcare professionals take steps to insure patient confidentiality, and although these measures may immediately increase the cost of healthcare, it will in the end reap benefits for both patients and the healthcare industry.

Virtual ICU

One up-and-coming medical field is Telemedicine. Telemedicine can be described as the provision of healthcare from a remote location. A recent example of this is the Virtual Intensive Care Unit, VICU, or eICU. eICU, a term coined by co-developers Brian Rosenfeld M.D. and Michael Breslow M.D of Johns Hopkins University, is a healthcare system designed to monitor patients in Intensive Care or IC. "Brian Rosenfeld, now chief medical officer of VISICU, the company he co-founded in 1998 in Baltimore, based on this technology" (Nowlin) and Breslow each have 15 years experience in IC which provided them with the experience to design this system.

In the IC field there is one defining truth, "the difference is speed, about 500,000 U.S. ICU patients die each year" (UPI). Typically, the reason these patients die is the untimely assistance provided by bed-side medical staff. Other reasons also contribute, but overwhelmingly punctuality and the ability to asses what care is needed at the time of crisis is also an issue. Hence the necessity for constant 24/7 monitoring by trained professionals. According to a report done by Anne Nowlin, RN, BSN, one facility in Oakbrook, Illinois is currently using a VISICU system successfully. The system used in the Advocate Health Care System in Oakbrook involves monitoring equipment in the ICU such as a video camera, microphones, and telemedical instruments for monitoring heart rate, blood pressure, and the like. On the other end, specially trained intensivists monitor every patient's specific readings via the telemedical equipment on screens. If a patient's blood pressure drops, an intensivist will be alarmed instantly and subsequently a bed-side nurse will be notified with the exact information needed to treat the patient. In the monitoring room, which is off-site from the hospital in most cases, there are not only trained intensivists, who are experienced nurses who have been trained further in remote monitoring, but also experienced doctors who can guide bedside nurses. The intensivists also have instant access to charts, history, x-rays, etc. that further increases the speed and accuracy of care.

Fig. 3 A diagram depicting the information paths through a VICU



Some fears, according to the article by Nowlin, have been expressed by nurses. "The nurses are the key, sell them and you sell the system" (Nowlin). She explains that many nurses are concerned with privacy. VISICU and their representatives assure nurses, especially with respect to cameras, that they are not the ones being assessed. Some current practices include keeping cameras pointed away at walls until an emergency arises or a "door-bell" of sorts must be rung by the intensivists before asking for permission to scan the room. This practice helps bedside nurses feel more comfortable bathing patients and families when meeting privately with loved ones.

Other positives of this system have been identified by both Rosenfeld and Breslow. Benefits such as cost effectiveness and nurses' turnover are a couple. The article by Nowlin describes how a Sacramento, Ca. hospital which went "live" in February 2003, has been losing fewer experienced and veteran nurses due to burnouts. The hospital management implemented a policy in which nurses switched back and forth between the hospital and the monitoring center and it has proven successful in lessening stress among the nursing staff. A VISICU spokeswoman comments that, "45 systems across 64 hospitals have been implemented of are in setup" (Nowlin). So far the idea of eICU has taken off well enough that in 2001, congress approved 1.5 million dollars to expand on the VISICU eICU systems being implemented in the Army's Medical Centers at Walter Reed in Washington D.C. and Tripler in Honolulu, HI. Although it costs roughly two million dollars to setup an eICU, many centers are finding the benefits outweighing the means.

Comparing an eICU to a conventional ICU, one can see that as far as work goes, a number of aspects have changed. According to community based, non-profit Sutter Health care provider, "they can relieve the nursing staff of many phone calls to physicians as well as confirm intent and detail of orders" (SH, 2003). It is true that the attending physician still carries the primary responsibility but Sutter states that modifying a patient's condition may be delegated to the eICU staff. It is also understood that the attending physician is the ultimate authority over the patient's care. Another comparison is the cost saving aspect of the eICU. An article from *Popular Science* magazine authored by Laura Allen states that, "ICUs are costly and hard to manage" (Allen, 2004). In fact, ICU admissions account for 30 percent of hospital costs and only 10 percent of inpatient beds. The eICU also allows for one technician to observe up to 50 patients at all hours of the day. It is show in studies, according to VISICU, "this type of care model can reduce ICU mortality by 25%" (VISICU, 2004) and it does this by providing constant surveillance. It must be understood that although the eICU is affective, it cannot serve as a substitute for good work on the part of bedside staff.

Cognitive Work

It is all too easy to focus on the more tangible side of medical informatics—the side that stresses different technologies and their implementation in the form of hardware and software. Like movies heavy on special effects but light on acting we get distracted from the main point—the human element. It is the human actor ("actor" technical term used by cognitive engineers) whose work we wish to aid through the use of technology.

Earlier in this paper it was mentioned that many people are dying due to medical error. This term "error" is a highly loaded in its meaning. "Error", in this case, is best understood in the context of medical malpractice lawsuits are used to punish and receive compensation from individual praticitioners (in most cases). It is obviously human practitioners who can commit error so it follows that "error" is really "human error". "The label "human error" is often used as a residual category; it tends to imply responsibility and blame (punishment); it focuses changes on local, incident specific-responses (different people, better motivation). Error attribution is an exercise in hindsight judgment (a two state discrete dimension); whereas prior to the outcome there are only degrees of performance (a continuous dimension) and factors that make it more or less difficult to perform well" (Woods & Roth, 1998). Woods and Roth go on to say that "once performance deviates from its target, it has the potential to be labeled erroneous. Whether it will lead to negative consequences depends on the presence of other necessary factors."

It is important to realize that human error can never be eliminated completely so when talking about "factors" leading to error we realize that individual practitioners vary in skill, experience and knowledge—the lack of which in itself may be the cause error—but are assumed to be competent people when we talk about factors. "Factors" in this case means factors that influence human interaction with the work environment and how does this environment lead to "[p]erformance failure… when designers unintentionally create excessively harsh cognitive environments due to the demands of the world itself and due to the primitive representations available" (Woods & Roth, pg. 15, 1998).

We must remember that it is not the technology that will do the work for us; it is technology that acts as and aid or tool to our work. This work that we must do is called cognitive work. Cognition focuses on mental processes such as perceiving, remembering, reasoning, deciding and problem solving (Smith et al 2003). With the introduction of more medical technology come more demands on the cognitive work the clinician must do. On top of the clinician having to process more desperate pieces of data are those that aid the work in the client setting such as those who are charged with the task of scheduling patients for procedures, billing, medication dispensing and a whole host of other supporting roles. The clinician does not work alone but often times in a team that are part of the greater whole of the work environment. It is the interaction between the clinician's inner cognitive world and the outer world that that together influence what the cognitive environment will be like.

The way that a human being thinks is different from that way that machines that humans have devised, mainly computers that come closest to "thinking". The computer, however, acts like more of an idiot savant where it do some things incredibly well beyond the capabilities of the human brain yet is clearly limited in its ability to "understand" even the simplest things that a human can. So, we know that there is a way that the human mind works and it is different from a computer. Now consider the computer some more. If you were to input some data into the computer, more specifically a computer program, there will often times be a specific way that the data must be formatted so that the computer can "understand" what it is receiving. Now take this example and apply it to the human way of dealing with information it is receiving. Some information you are receiving now is in the form of sensory data, how hot or cold it is or how rough or smooth this paper feels like. Other data you are receiving are things like being able to read these works—the syntax and semantic information of my words. These are just basic elements of the data you receive but taken together the data you receive is relatively coherent and you "understand" what it is you receive. The fact humans have written languages say something about the reason for their existence in the first place. They exist because they are one of the best ways humans have devised to communicate and gain information. Language as humans have conceived it seems to be a good format for the equipment (your physical brain and mind) to work with. A "good format" in this case should "…enhance successful performance—to meet cognitive demands of the world, to help the human function more expertly, to eliminate or mitigate error prone points in the total cognitive system" (Woods & Roth, 1998).

With the integration of computers into medical equipment and as part of the day to day operations there is increasingly more types and volume of information that needs to be supplied

Applying the idea that there are ideal ways to convey information to ourselves however, with new technology that is available to clinicians in hospitals comes more formats and volume of information to be made sense of. The problem that Woods and Roth find is that there "…is [a] lack of an adequate cognitive language of description" (Woods & Roth 1998). It seems somewhat vague by what is meant as a cognitive language but it seems to mean that we need to have a way to represent information in a way that is formatted, as mentioned before, so that practitioner cognitive work is minimized. One area which this project focuses on is in developing or improving ecological displays—displays that represent information in the hospital setting that aid practitioner cognitive work—which will be discussed in the following section.

On a billboard for Swedish covenant hospital in the Chicago area the ad says something to the effect that "Technology changes. Compassion does not.". This highlights the key point about the aims of this project which is to decrease error in health care while improving practitioner performance. While the practitioner is at the "sharp end" of health care there are many others who support their work including technology and they all can play a part when error occurs. While technology is often thought of as a solution to "error" and often receives the most attention the real star of the show is the medical practitioner. Technology may change; compassion does not implicitly say that the human practitioner is the common denominator in the healthcare equation. The technology aids the healthcare practitioner not the other way around. Unfortunately, technology itself may be causing problems when important information fails to be represented in a comprehensible and non cognitively taxing way.

[3] Methods

In this paper we used several different methods to gather data. These methods can be divided into two main categories: primary and secondary. The methods we can call primary are observations and interviews and secondary sources of information were literature review and rapid prototyping.

In the primary methods, observation and interviewing, team members visited the University of Chicago Hospitals Intensive Care Unit. The first visit took place on 11/4/2004. One group member was available that day. The team member first met with Dr. Christopher Nemeth the team advisor and then was introduced to Dr. Michael O'Conner with whom Dr. Nemeth works with. Dr. O'Conner is the head of this particular ICU. He was interviewed by the team member present along with getting a tour of the ICU—observation of the work environment and equipment. A second team visit in which five of the six members were present, visited the same intensive care unit (ICU) on 11/15/2004. On this visit Dr. Nunnally and Dr. Cook, were interviewed and gave a guided tour of the ICU to the team members. The team members made their own set of observations. Dr. Nemeth was also present during this visit.

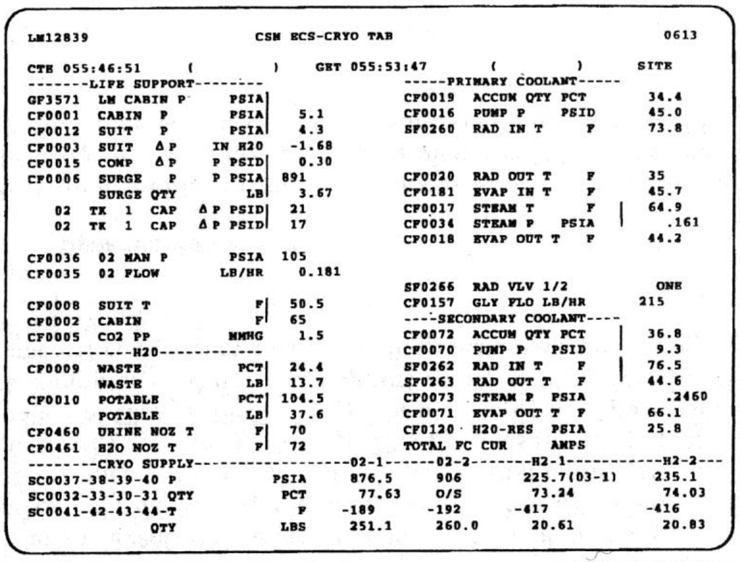
Our secondary sources of information consisted of reviewing literature and rapid prototyping. The literature that was used came from text books, peer reviewed journals, periodicals and sources found through the internet. Another secondary method that the group used was rapid prototyping. In developing displays that we felt would be useful for clinicians to use, we researched the programs that were currently available on the market, and constructed new display ideas using input from clinicians that we met during our ICU visits.

[4] Concepts

The previous section on cognitive work in the hospital setting established that cognition is a central theme in understanding how to improve performance of practitioners and to decrease error. Furthermore, it was indicated that technology that is introduced into the healthcare system provides more information to the clinician but in such a way that is taxing to the cognitive resources of the practitioner which increases the possibility of error. “The finding which has emerged from cognitive science and related research is that the representation of the problem provided to a problem solver can affect his, her or its task performance” (Woods, 1995).

Problem representation in this sense means that the representation does not explicitly tell you there is a problem or not. We are not talking about an automated diagnostic tool. Instead the representation ought to be able to convey information in the least confusing and cognitively effortless way possible so that if the information that is represented is indicative of a problem the one who is looking at the representation can readily see that there is a problem (as defined by the user not the machine). Note figure 6.4 and 6.5 from Woods (1995) on the following page. Can you tell what you are looking at? Can you much less tell that figures 6.4 and 6.5 indicates a disaster is about to occur? Neither could NASA mission control staff—figures 6.4 and 6.5 shows recreated screenshots of the computer display monitoring the state of the Apollo 13 command module just before the oxygen tank burst. “It took a precious 54 minutes as a variety of hypothesis were pursued before the team realized that the command module was dying and that an explosion in the oxygen portion of the cryogenics system was responsible” (Woods, 1995). Woods states some of the flaws with the display in question: “No attempt is made in the design of the representation of the monitored process to capture or highlight operationally interesting events—behaviors of the monitored process over time, for example, the remaining cryogenics are deteriorating faster.

Furthermore, this failure to develop representations that reveal change and highlight events in the monitored process has contributed to incidents in which practitioners using such opaque representations miss operationally significant events (e.g., Freund & Sharar, 1990; Moll van Charante et al, 1993)" (Woods, 1995). Apollo 13 is an extreme example of what happens when bad things happen to good (important) information.



Apollo 13, 906
1/22/92

Figure 6.4. *Partial reconstruction of the computer display (display CSM ECS CRYO TAB) monitored by the electrical, environmental, and communication controller (EECOM) at 55:54:44 mission time during the Apollo 13 mission.*

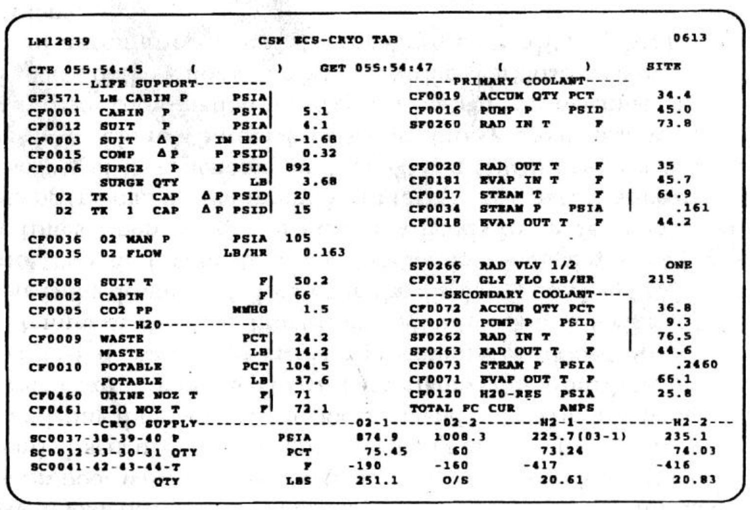


Figure 6.5. *Partial reconstruction of the computer display (display CSM ECS CRYO TAB) monitored by the electrical, environmental, and communication controller (EECOM) at 55:54:45 mission time during the Apollo 13 mission. Note oxygen tank 2 pressure showed a peak at this point of 1,008 psi.*

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Fortunately, some good things have happened in problem or information representation in recent times. There has been a realization that the ecology in which one works and the cognitive processes that humans use to do their work play an important role in the design of information representation as indicated earlier in this paper. In talking about information representation the focus of this project has been in how relevant, in the domain of the intensive care unit (ICU), information is best displayed on various monitors that clinicians working in the ICU may use. Now that we have mentioned the environment we are applying our knowledge to, the ICU and related areas, we can talk about what is meant by ecology.

The Marion Webster dictionary (on line version) defines ecology as "a branch of science concerned with the interrelationship of organisms and their environments" or "the totality or pattern of relations between organisms and their environment" (http://www.m-w.com/cgi-bin/dictionary?book=Dictionary&va=ecologic+&x=25&y=14). The interrelationship between the organism (in this case clinicians in the ICU) and the environment (the ICU) is an important area of knowledge when it comes to designing displays that clinicians will use. In fact the more accurate term we will be using for displays designed for a work environment will be ecological display.

Given that the trend in health care has been to digitize information and that many technologies that clinicians use are computer based, information, to be useful, must be displayed. We can define a display very broadly as any medium which can store and show us information. That can include the little piece of paper you find in a fortune cookie, a part of the sky in which a message was written by contrails or your skin when you write on it with a pen to remember an important number. If the medium is adequate for displaying the information you need then it can be termed a "good display" in that particular case. In the hospital setting, of course, the displays are able to handle digital information.

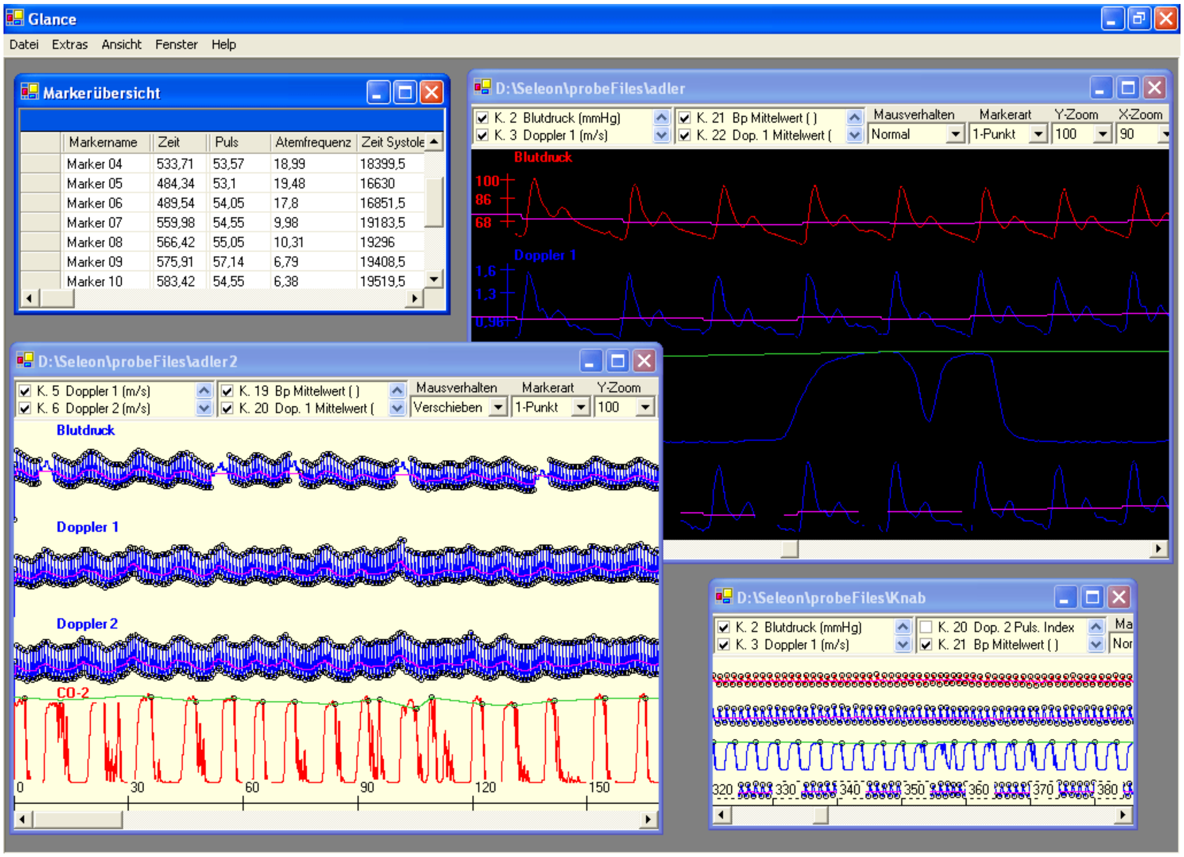
Aside from the physical means of display, a display needs to present information "…to the user based on common metrics of decision making, such as saliency, availability, priority, and mental model match (Lehner & Zirk, 1987; Noble, 1989)"

(Ntuen, 1999). Or put another way displays need to "[be] an efficient representation of what matters here because they represent only the information that is critical in [the] work domain" (Nemeth & Cook).

The important features about a work domain or environment will dictate what will be displayed and features of clinician cognition will determine how to best organize information. In order to understand what the demands of the environment are and to know which way best displays important features about that environment we simply need to study the interrelationship amongst the clinicians and the environment. This area of study is called ecology which the online version of the Marion Webster dictionary defines as: "a branch of science concerned with the interrelationship of organisms and their environments" or "the totality or pattern of relations between organisms and their environment" (http://www.m-w.com/cgi-bin /dictionary?book=Dictionary&va=ecologic+&x=25&y=14). Hence we get the term "ecological display" which is the proper name for the displays we have been talking about. Such displays show information based on an understanding about the environment and the way clinicians work—ecological displays are any displays that aid work.

Ecological displays provide clinicians with the ability to review patient information and to monitor their health through the use of the computer. As powerful as this tool is, there are still some problems arising with the ecological display. In order to get a better understanding of the strengths and weaknesses of the ecological display, one must examine an example of a display that is currently in use by clinicians.

Fig 4. Heart Monitor Wave Graphs



Picture from: *http://www.fdm.uni-freiburg.de/~ckreutz/Glance/*

Strengths

- Ability to view different types of patient information on one screen.
- Clear graphs of patient information, easy to read.
- Can minimize and maximize windows in order to further analyze the information.
- Possible changes with patient's well being can be quickly detected by the program setting off an alarm and warning the caregiver of the patients condition.
- Scalability, the windows and be moved across the screen and windows with greater importance can be maximized for a larger view.
- Displays a lot of data, a rich display, which is very beneficial to the clinicians.

Weaknesses

- Difficulty searching and analyzing the needed information.
- Charts and graphs may confuse someone who is not very experienced with the program.
- A large amount of information displayed on just one screen.
- A program malfunction could cause incorrect information to be displayed on the screen.
- Too many wave graphs could cause some confusion to the user.
- Displays have no ability to communicate with each other
- Possibly pertinent data cannot be synthesized
- With the given display, the user is not too sure where to start analyzing the data.

In order to counter these problems to help create more effective ecological displays, three important factors must be put into place. First of which is observability, the user must be able to easily identify where to start analyzing all of the data presented to them on the screen. Second, the display must have the ability to directly analyze the information to help provide a straightforward and understandable response. Thirdly, in order to produce an effective display, the clinicians should have the ability to program the display to their preferences. Information technology technicians, people who have good intentions, but not much knowledge on medical techniques and information, create most displays. By having the displays programmable, the clinicians can go through several setup settings during the beginning of programs, by checking boxes during the set up, the program will then set the display up, to provide the clinician to view the information that they believe is most important, and the information with the least importance with be displayed elsewhere on the screen.

As Dr. Nemeth (2004:264) says, "a useful product is a good fit between need and solution, between user and artifact. A product that is useful makes it possible for an individual to perform a task more reliably and with fewer errors." To find out if a certain display is useful for the clinicians, usability assessment should be performed. Conducting such a test will show if "there are any difficulties with using a product, and it uncovers opportunities for improvement."

There are a lot of ways to conduct usability tests for assessment. The following table describes eleven approaches that can be used in order to assess the usability of products, systems, or services.

Fig 5.- Usability Assessment Methods

(Source: Human Factors Methods for Design - Nemeth, C (2004:266))

Usability Assessment Methods

Participatory Design	**Incorporation of a few representative users into the design team.**
Expert Evaluations	**Review of product by human factors specialist.**
Walk-throughs	**Investigator leads test subject through actual user tasks.**
Paper and Pencil	**User shown an aspect of product on paper and is asked questions about how to operate it based on task requirements.**
Focus group	**Discussion among 8-10 users, managed by a skill moderator.**
Survey	**Collection of user preferences and opinions by mail or phone**
Alpha and beta tests	**Early release of product to a few users.**
Follow up Studies	**Surveys, interviews, and observations to collect information on usability while product is in use.**
Usability audit	**Compare design against human factors standards and checklists.**
Usability test	**Informal iterative series of tests.**
Research Study	**Formal usability test.**

According to Dr. Nemeth (2004:269), the following steps should be followed when creating a usability test.

- Determine the need for conducting the test.
- Write the test plan.

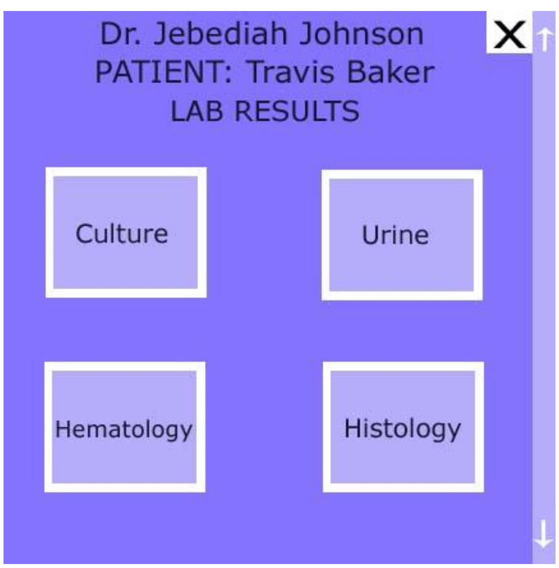
- Recruit participants who will be test subjects.
- Develop test materials.
- Assemble and train the team that will run the tests.
- Prepare the test facility and equipment.
- Conduct a pilot test and adjust the test measures and materials based on what is learned.
- Conduct the tests and provide interim analyses to client
- Compile, summarize and analyze the data that were collected during the test.
- Report and/or present test findings and recommendations for product improvement.

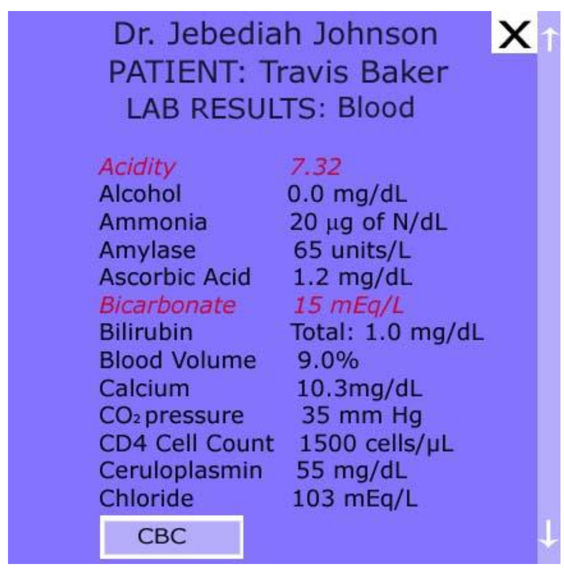
During the analysis phase, the manufactures should take into consideration, "the tasks that were difficult for participants to perform, the errors that occurred during task performance, and the sources of error."

If such a procedure is followed by the manufactures of ecological displays, "it will increase the likelihood that their display will be right before it is released for production." It also makes sure that the displays are made according to the needs of the clinicians and the patients. "Clinicians are more likely to be productive, as they are able to perform tasks without errors being induced." They can also "find the product features on their own without the need to ask others." Thus, such an assessment "affords a variety of benefits to the end user as well as the firms that practice it."

These concept displays were created to help give a visual idea of what concepts help create a good display. Qualities of good displays include flexibility, controllability, and also scalability. Also having the ability for the clinician to be able to configure the display in order to orientate what and where the information will be displayed on the screen. Before the program loads, a setup screen with various preferences that the clinician could select. This would configure the program to display what information the clinician needs and also where that information would be displayed. The clinician could essentially program the display to show the most important information first and the least important information last. Having the ability to quickly push buttons and go through the program quickly will help clinicians obtain the important information that they need quickly and more efficiently.

On the left, is a display concept depicting a doctor's patient list. The patient's names can be touched to enter into a submenu for that patient. On the right is a prototype display on which can be seen various options available to a clinician pertaining to his or her specific patient.





On the left, is an idealized display featuring a submenu of lab test types that could be ordered or viewed at the doctor's discretion. On the right, is a prototype display on which is listed lab test data including concentrations of various elements and chemicals in a patient's blood.

These are all great ideas for an effective display, but there are some drawbacks and limitations. The clinicians do not directly interact with the programmers who design the program. The programmers themselves do not have much knowledge on healthcare and there are the people who decide what information gets displayed on the program. Thus the program many not be effective as it could be if the programmer had received some feedback or opinions from a clinician. There are also limitations to what a program can do. A programmer cannot design a program to do everything that a clinician needs, that task is virtually impossible. They can only program the display to do so much, and usually what they design it to do is inefficient to most clinicians.

[5] Conclusions

IPRO-372's broad purpose was to improve the electronic display of patient information. More specifically, throughout the team's research into the field of medical informatics, different aspects of display technology have been explored and its impact on clinicians and one ICU's clinicians. In doing so, the team discovered a serious disconnect between clinicians and the tools they use to provide care to critical care patients—specifically the displays which they rely on for crucial information about their patients. In order to engage this problem, the team researched primary and secondary sources to determine the specific shortcomings of the tools clinicians operate in the intensive care environment. From this research, the team discovered that the development of technologies used in intensive care are seriously lacking in the ability to assist the clinicians in making the cognitive work easier in terms of how information displayed and subsequently interpreted. Based on the team's direct observation of the displays currently used in intensive care units and through interviewing the clinicians who use the displays, the team learned that data and monitoring systems are not designed with the clinician's direct input into what their needs are in terms of control and cognitive processes. The displays currently in use are varied, data is often difficult to interpret efficiently, and they are limited in the type of data they can show. Data itself is often poorly organized, and poorly identified. Furthermore, the machines themselves are known to be problematic and unintuitive (Appendix). Ultimately, the technologies currently being developed fail at representing information in way that puts the least amount of cognitive stress on and individual, i.e. the amount of mental work put into perception, remembering, reasoning, deciding and problem solving.

The team found that clinicians need displays to be flexible in terms of their ability to display: various types of patient data on one screen, clearly identified graphs of patient data that are also easy to read; the ability to minimize and maximize windows to further analyze the information, and also the ability to scale data in terms of time period, time instances, and scope. Scalability of a display can be especially useful since viewing data over a period of time, an EKG for example, can show trends that may signify a heart condition or abnormality. Clinicians also need to be able to fully customize these displays according to their specific cognitive needs and must be able to do this in the time it takes a clinician to prepare for his or her shift. A clinician should be able to customize a display in order to show the pertinent data, scope of data, and the correct time frame in which to view the data. This is important since professionals of various medical fields such as radiology as apposed to cardiology might want to view data differently. Such being the case, a display should be configured in such a way so that healthcare professionals of all fields can view what is important to their cognitive work.

The next task was to formulate criteria for developing ecological displays and methods for assessing display usability. The group designed a number of idealized prototypical display concepts. Again, the group stresses the fact that these concepts are idealized in the sense that they were designed to be easily navigated and easily viewed. The criteria devised by the group are: observability, ability to accurately synthesize data, and ease of clinician programming. For the group to assess usability, a particular set of assessment methods must be used in order uncover any potential problems and develop solutions for improvement. These include: participatory design, expert evaluations, walk-throughs, paper and pencil, focus groups, surveys, alpha and beta tests, follow-up studies, usability audits, usability tests, and finally research studies (Figure 5). The best displays are the ones in which are best suited for its user and creates less cognitive work to be done.

However, further work must be done before any real conclusions can be drawn about this problem. This work is extensive and will take much effort. One area of further study is the creation of a universal system platform that will facilitate the communication between all medical units in a healthcare facility. In order for displays to communicate with one another, manufacturers will need to cooperate in creating devices whose data can be synthesized and displayed in synchronicity. Another area of extreme importance is to study the ethnographic culture of a healthcare facility. In other words, it is to study the particular work culture and environment of the people working in a healthcare facility. Thirdly, work must go into creating a virtual map of cognitive work done in the ICU environment. The work in this area would go into creating a more effective ecological display in which only certain components or streams of data in a display will be shown in the precise manner a clinician requests. Once the aforementioned issues are addressed, the group believes that ecological displays can be tailor made to the specific needs of clinicians and other healthcare professionals.

One example of a recent development in intensive care is the proliferation of the Virtual ICU. It is a new concept because it allows intensivists to monitor patients continuously from a remote location. This helps bedside staff by increasing response time and diagnosis time. The VICU is not the number one solution, however, since no matter of automation will ever substitute a qualified, experienced, bedside healthcare staff member. It is an especially interesting development because it seeks to care for patients by relying heavily on displays for monitoring and diagnosis. By studying the different cognitive aspects of an effective VICU one can seek to improve upon displays that are used now in patient care.

The potential implications for such changes would be phenomenal since the tools that intensivists, clinicians and health care professionals use, would actually be easy to use, configure, read, and interpret. Doctors and nurses would be less prone to make errors that could save the hospital valuable time and money not to mention the benefits for the human element, which one cannot easily quantify. Patients would receive better care since clinicians would be better able to treat, diagnose and monitor patient's condition due to the improvements in ecological displays. Although putting better tools in the hands of clinicians is the goal, the best display will have its limitations in that it is up to the user of the display itself to correctly convert what one sees as data, into useful knowledge that can be acted upon to the benefit of the patient. Certain compromises, however, are expected, as clinicians who have "adapted" to using inferior displays will need to transition into using displays that are better suited for the tasks they are involved in performing.

The advantages in implementing the procedures necessary in order to create a better display is that physicians and healthcare staff that are actively involved in patient care would be able to input their collective wisdom into creating and improving on current ecological displays. This critical aspect would enable manufacturers to effectively market devices to hospitals and staff and would create a broader demand for better tools in the healthcare industry. However, the potential obstacles in the implementation of improving displays are that some fields in healthcare do not have the time or ability to conduct the rigorous and extensive research necessary in order to create better displays for their industry. Those who work in such environments as the ICU have very little time to conduct extensive tests such as the ones described, or may have very small windows of opportunity to do so due to the nature of the work. There may also be disagreements between professionals as to what data is critical to display or in what manner in which to display it. Manufacturers of displays may also be hesitant to provide the necessary funding in order to do research and development on the cognitive tasks a wide assortment of professionals are involved in. Healthcare is an industry that seeks to minimize cost for both the provider and consumer and some aspects of the displays or implementation thereof may not seem cost-effective when the status quo seems to be “working” in most intensive care environments. However, after much research and observation the consensus reached is that there is significant room for improvement in aiding health care professionals by creating better ecological displays.

[6] Appendix

Interview Notes from UofC Medical Center, by Predrag Barac, 11/15/04.

Dr. O'Connor's comments:

- "Windows© is painful!"
- Too many different view screens, touch screens are bad
- Monochromatic is a problem
- Must understand body function or have in-depth knowledge of machine
- Writing on machines to know what they do
- Can eat lunch while watching "Mother" display, but cannot expand views
- Colors and contrast are important, i.e. x-rays
- Alarms are relative, "Which patient; which machine, what colors?"
- "Don't trust high level automation!"
- Upside, each machine is specific; downside, what if machine goes down
- Cannot do without some old things
- "Displays are engineered like those that make them."
- "The clinician themselves don't really know what they are doing."
- Displays should communicate with each other
- The suits are the people who make the decisions
- The "sign out sheet" is a perfect example of too much data hiding critical data
- Clinicians want to be able to display certain data together
- "The only upside is the actual displaying itself."
- Too much information being displayed can be an obstacle
- VICU don't really help, displays cannot work unless designers know the work
- Clinicians don't have the time to train when new equipment comes in
- A lot of information is on charts, time intervals depend on patients
- Characteristics of waveforms are not recorded
- "Monitors are showing a lot of noise when patients aren't even moving."
- To see monitors is important, setup of ICU is important
- Nursing staff takes care of monitoring better than monitors
- Mobile displays are not incredibly necessary
- 5-10 minutes isn't bad to setup a display
- "The culture of people working here must be studied."

Interview Notes from UofC Medical Center, by Mehak Dhingra, 11/15/04.

Meeting with Dr. O'Connor

- Windows display has graphs showing EKG, BP, breathing and pulse rate. Once can change the format, but it's really hard to change. Things change if you touch anywhere, even by accident.
- All the information is in a darkened space in the infusion device.
- The Respirator has a better design than the rest of the equipments. It makes sense to the people who have a basic understanding of the ventilator. It has small icons like the lung, a waveform. Pressing these icons give results. For example: Pressing the waveform icon gives us a waveform with all the data plotted on it.
- You can see the x-ray machine better only if you turn of the lights. Having a light box with it will be great.
- The displays have false alarms. There is no indication as to what the alarm means. It is just a cue to look at the monitor.
- Information in the displays is split up. The advantage for that is that everything for a particular machine is right there, while the disadvantage is that, if one display is bad, then you are stuck.
- There are different kinds of machines. So nurses/doctors have to learn to operate different kinds of technology.
- The displays are designed by people who have no clue why and how that particular display is going to be used. Those designers should actually go and watch how the clinicians actually use these devices.
- The design is pretty bad currently. The machines don't have the ability to communicate with each other. There is no dimension of time on the infusion devices.
- Since doctors can't carry these displays with them, it is much easier for them to use miniature charts – it has all the critical information about a patient in it.
- Bad displays make work much harder. A better display would be one which allows clinicians to see what is important.
- Flexibility plays an important role. Sometimes you don't always want bright displays. You should be able to adjust according to what you need.
- You cannot design a good display unless you understand the work that the clinicians are doing.
- Practitioners learn to adapt to the design that the engineers make. They have no say in how they want the design to be.
- In real environment, there is no time for learning a new procedure. Thus, a display should be easy to learn.

Meeting with Dr. Nunally

- Records a lot of information of charts.
- Waveforms are more useful.
- A good display should be able to be seen from a little distance.
- On a regular basis, doctors would like to spend no more than 10 seconds configuring a display.
- The color of the waveforms matter. A yellow waveform may mean one thing, while a blue waveform may mean another thing.

Interview Notes from UofC Medical Center, by Ricardo Herrera 11/15/04.

Dr. Michael O' Connor

- Devices do not have capability to communicate with one another
- infusion devices lack rate of infusion and other pertinent information
- those involved in deciding which devices are purchased include: regulators, hospital administrators, legislators, 3rd parties, (Medicare and Medicaid) however, they add nothing in terms of improving process
- sometimes viewing conditions are worse on new flat screen monitors than on antiquated light boxes for x-rays
- a good ecological display was a respirator, which showed only highlighted buttons were able to link to different data screens
- some equipment is usually predicted to go on the fritz, or malfunction in some way
- right information on display is more critical than the amount of information that is on a display
- devices usually have very clunky design, buttons are worn and wires are strewn throughout
- vICU cannot substitute for seeing the patient
- everything that happens in vICU is usually happens at night, when doctor is not usually present

Dr. Mark Nunnally

- waveforms were placed at the head and foot of patient's bed but both are additive and could be useful to have together
- waveform monitors do not record data, only display real time data
- patient movements may disturb readings, give false readings, machines cannot differentiate
- automation can sometimes cause problems
- culture of the ICU cannot change too much
- would take 5-10 minutes to somewhat permanently establish a programmable screen
- 2 min is too long if process must be done repeatedly
- charts are made in a way that displays pertinent data

Interview Notes from UofC Medical Center, by Samantha Paruchuri 11/15/04.

Dr. O'Connor

- Displays are hard to change, easy to mess up. They are not personally configurable. They need to be easy to read.
- Displays don't "talk" to each other.
- A good display is easy to use, can only change things that are highlighted (not just by touching anywhere)
- Touch screen is important!
- Viewing conditions affect image viewing greatly. Should have unlimited control over contrast controls.
- Alarms should be completely configurable, like everything else.
- People usually ignore alarms because it is usually a problem with the machine- artificial intelligence deciphers things wrong.
- Displays are made by people who only know what needs to be displayed, but do not take into account how clinicians think.
- Dim displays hide critical information
- Doctors don't really know how to use devices.
- History would be an important function.
- The right info. Is critically important.
- A bad display makes it harder to do work.
- Virtual ICU: cameras are not the same as seeing the person in real life- no display can compensate for that.

Dr. Nunnally

- Prefers paper, easier to change and use.
- Waveforms are better than numbers, though numbers are used for record keeping
- History of waveforms is important
- Alarms are usually false (i.e. due to shivering or other patient movements)
- Would like displays that you can see from the hallway (like waveforms)
- Would spend 5-10 minutes for making a template that can be used in the future.
- On a daily basis- 10 seconds to configure things
- Colorblind users.
- Color is important. Should have researchers study and make conventional for all machines.

Interview Notes from UofC Medical Center, by Oliver Skuza, 11/4/04.

Oliver's Visit to the ICU at the University of Chicago

Note: This is a transcription from a tape that I made while interviewing Dr. O'Conner using Dr. Nemeth's tape recorder. I have made my best effort to accurately transcribe what was recorded but being that the medium I recorded the conversations on was of not the highest fidelity equipment and not the most ideal recording environments; some words may have been inaudible to me. I have made an effort to edit out irrelevant parts of the interview and to remove the "ah's" and "umm's" and other superfluous things people say when they are speaking unscripted.

OS = Oliver Skuza
Dr. O = Dr. O'Connor
Dr. N. = Dr. Nemeth

Os: one of the things we are concerned about is how technology gets in the way. Like you said you had to learn a new way to input data

Dr. O: Yup.

Dr. O: there are all sorts of ways to hid information from people. One of the easiest ways to obscure information is to automate it's input in places that people look for information.

OS: So it's no longer transparent then?

Dr. O: You're looking for a needle in a haystack. If you're interested in one critical piece of information and people have spanned your electronic documentation with 10, 000 pieces of extraneous information because your administrator or regulator thinks its important then finding important information in that mix of dross is next to impossible and of course you can have anything in my world but time. And to say that all you have to do is sit down and sort though all of this it's a non starter.

Dr. N: …intensive care needs to be able to receive care that is above and beyond what you get in the patient ward so that's what intensive care is all about. Is that you receive superordinant amount of care by comparison of the patient ward. So, these are folks that have either sustained major trauma came here though the emergency room or from another hospital or just came out of a surgery or who have disease processes that render them unable to care for themselves and other people that may care for them are unable to care for them because the degree of illness is so severe.

Dr. N: My complaint in the medical informatics course is to provide all the team members with an opportunity to be exposed to the real world rather then to have some sort of fake or simplistic sort of environment to me its more valuable for you to have the opportunity to deal with something that is difficult, complex, challenging and almost intractable rather than to have a canned, easy, simplistic environment because you don't learn much from… you are actually are exposed to a genuine challenging environment

In the areas of stack of four infusion devises those are actually ecological displays

Everything has its own semantic structure but also grammar in terms of the way it represents itself on the screen.

OS:

Dr. O: This is an example of a nice display [sitting in front of a panel of LCD monitors displaying angiograms]. First of all, it sounds really silly, the environment is very favorable for seeing the information and since the room is dark increases your ability to appreciate the contrast on the display and second of all there is no paucity of display real estate your eye can see four high resolution images right next to each other. In the old days I looked at four x-rays alongside each other, there were five I think, and when people can look at them one at a time you can't see how things change from x-ray to x-ray you can look at all four at once and your eye can move almost instantly from one to the other and you can see the information that's there. Flipping back and forth between the images is much, much, much less [inaudible] we also have this other computer or other display that allows us to look at yet other images so that we can loot at the ct of the chest at the same time as we look at the x-rays of the chest so we have just an enormous amount of real estate available to us. It sounds really silly but the other reason to come down to here is to look at films is that these monitors are almost always perfectly maintained. Monitors in the world of clinical medicine tend to get fairly heavily used and it's a physically fairly hostile environment and the displays tend to get beat up and when budgets get slim their maintenance both preventative and repair gets cut and so if you really want to see the best quality images you want to go to the people who absolutely won't put up with anything other then the best and use their monitors it's always in radiology. So even though we have monitors that we can look at them on up stairs you can see my residences look at them I come down here and I can easily see things that are invisible to them everyday and I'll say "did you see thins guys bowl, or did you see this guys fluid collection or did you see this strange abnormality or did you see this mass here".

Dr. N: How do displays help you in that regard?

Dr. O: What do you mean?

Dr. N: Well you talk about good displays and bad displays, well what role do displays have in your ability to do what you just described?

Dr. O: Bigger and higher resolution is better.

Dr. N: Even with displays that are poorly configured?

Dr. O: Bad configuration is a great way to hide information.

OS: So, are you able to look at images with different filters?

Dr. O: So you could colorize it. I mean I can flip this image around, sometimes I'll look at them upside down, yes I can change the gray scale here. There are a variety of things I can do that can change the image. I can measure distances.

Dr. N: So, he also gave you another data burst there in terms of the physicality of the display so he talks about the ability to get all the information that you need rather then having to select images that key hole display aspect of only being able to look at little bitty bit of information having to flip through images or having to move around can be problematic so you'd like to be able to see items for a number of different purposes those purposes are probably going to include things like comparison and contrast side by side analysis. It's not just because we all say it matters it's because his ability to do what he does matters and he needs that sort of ability to compare and contrast to effectively make decisions using his clinical judgment that he cant do if the display doesn't give him that sort of resource. Also, the ability to compare side by side with different media so for example you've got x-ray and you've got a cat scan at the same time so if you are dealing with the same patient with the same [inaudible] but have different types of imagery that are available to you want to be able to call them up and look at them simultaneously rather than sequentially so simultaneous information display matters here. So that's another aspect is simultaneity at one time. Because you are thinking synthetically rather then serially and when you're thinking synthetically you have to have all your options available so that you can digest them rather than have to say ok I'm going to hold image a in my head and to image b and by the time I have to go to image c and d I have to remember what image a was to try to compare them. So that level of granularity and complexity is nearly impossible to do. Because we are serial processors as people we think about one thing at a time. And so if we have multiple things available to us we can consider them simultaneously but trying to keep them all in our mental buffer all at a high level of detail as we do it in nearly impossible. So, his comment about the fact that you can compare and contrast using large amount of real estate in front of you matters because that's the case in terms of the way that people do what they do.

Dr. O: So, on this machine I mean it sounds really silly but I bring up this display and pick my patients out so that I don't have to flip back and forth between the main screen. The people that make the main control screen make me do that so this is radworks, that's the software we are using right now it is loading up the patient list and it wants me to come back to this main screen every time. But the 10 or 20 seconds that it takes to do that adds 10 min to my time reading x-rays. And it sounds like that's not much time but it will kill you at the time of the day that gets around to reading x rays.

OS: It adds up.

DR. O: It adds up. And I try to teach my residents a thing or two and it sounds really silly and if the image is of sufficiently high quality I can look at it and compare it to its predecessors. I can tell in an instant what I need to I can see what I need to see faster than I can speak. Literally I can look at these things and I can turn around and talk to my residents for 5 or 10 min about what they should be able to see on this film compared to yesterday. If you don't believe me you can ask her she [student present with us] has seen me do it already. It's amazing how much information… but here they want me to do this they want me to flip back and say oh well here we go where back here and we go a head and look back up and were going to look at [patients' name].

Dr. N: Can you talk to us about patient monitors?

Dr. O: We can go back and look at a patient monitor.

Dr. O: So that's the EKG the green, the white line is the co2 traces. This monitor is well designed. You can see good contrast between the display and…

OS: You can see trough time

Dr. O: You can see through time, I see from distance. The wave forms are reproduced with high fidelity so that I can interpret them from a pretty good distance away. On the bottom of the right hand side is nothing that makes a good attempt next to is in orange is blood pressure which is the intermittent measurement so its reasonable for the machine to display it like that and then to go after that on the bottom left corner is the gas analysis. That's a pretty good display. The only down side is that it requires standing closer to the patient I have to kind of have to look at the patient and then have to turn back and look at the monitor. Some people in my world are fans of heads up or transparent displays these things understanding about they create a physical device between the patient which would be highly undesirable. If I had a little helmet monitor or glasses mounted display that would be ok. Now on more advanced technologies you get better monitors. For example, their monitor which is not our monitor, this is an anesthesia machine; their monitor would display their patients' vital signs on it to by the right and mirror them over here. So that when they're monitor their patient their blood pressure and their pulse x-ray and their monitoring devices which are all right there that output would be displayed over there. And the advantage is that I could sit outside the room and see their display. They could look up and see their display.

OS: Do you have the ability to control what is shown on the display and which display it is put on and is that easy to do.

Dr. O: It's somewhat easy to do. Not all of these devices as flexible as we would like them to be. This one is pretty good.

OS: Can you configure that display to show information in a certain way.

Dr. O: So for example this is monitor set up and I can set up stream 1 and this is stream 1 and I can look at a way point view so I can go from one ekg to 2 ekg, I can put up pressures if I want, monitor for co2, I have all sorts of things I can put up.

OS: Is it fairly intuitive?

Dr. O: No it's not.

OS: In the way it sets it up?

Dr. O: No its not.

OS: What can be done better?

Dr. O: These inane scroll menus, these buttons that change meaning. It sounds really silly but a larger number of buttons each of which had a more well defined scope of meaning across menus would be very useful.

OS: You can save your personalized modes.

OS: Can you later give me some examples is a poor display and what about is hindering your abilities?

[7] Acknowledgements

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