Advances in Human Aspects of Healthcare

Edited by

Vincent G. Duffy

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Human Aspects
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Preface

This book is concerned with human factors and ergonomics in healthcare. The utility of this area of research is to aid the design of systems and devices for effective and safe healthcare delivery. New approaches are demonstrated for improving healthcare devices such as portable ultrasound systems. Research findings for improved work design, effective communications and systems support are also included. Healthcare informatics for the public and usability for patient users are considered separately but build on results from usability studies for medical personnel.

Quality and safety are emphasized and medical error is considered for risk factors and information transfer in error reduction. Physical, cognitive and organizational aspects are considered in a more integrated manner so as to facilitate a systems approach to implementation. New approaches to digital human healthcare modeling, human factors and ergonomics measurement and model validation are included. Recent research on special populations, collaboration and teams, as well as learning and training allow practitioners to gain a great deal of knowledge overall from this book.

Each of the chapters of the book were either reviewed by the members of Scientific Advisory and Editorial Board or germinated by them. Our sincere thanks and appreciation goes to the Board members listed below for their contribution to the high scientific standard maintained in developing this book.

Explicitly, the book is organized into sections that contain the following subject areas:

I: Assessing Ergonomic Characteristics in Biomedical Technologies
II: Communications, Systems Support and Healthcare Informatics
III: How to Improve Quality of Ergonomics in Healthcare
IV: Physical Aspects and Risk Factors for Patients and Caregivers
V: Patient Care, Patient Safety and Medical Error

VI: Medical User Centered Design
VII: Human Modeling and Patient Users of Medical Devices
VIII: Measures and Validation in Healthcare
IX: Medical Devices and Special Populations
X: Collaboration and Learning in Healthcare Systems
XI: Organizational Aspects in Healthcare

This book would be of special value internationally to those researchers and practitioners involved in various aspects of healthcare delivery.

March 2012

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Section I

Assessing Ergonomic Characteristics in Biomedical Technologies

CHAPTER 1

A Multifactorial Approach and Method for Assessing Ergonomic Characteristics in Biomedical Technologies

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ABSTRACT

The ergonomic assessment of healthcare products is becoming regulatory, but current state of art relies on checklist of end-users interview about general or limited aspects. Ergonomics deals with the human as a whole and as a part of a more complex system; instead the assessment of objects and products is often treated separating the different components of the interaction: physical, sensory, cognitive. This research aims to develop an integrated method and a protocol for qualitative and quantitative evaluation of ergonomic features in healthcare products. The integration of methods for a global and more comprehensive ergonomic assessment can be used in a proactive way in the early stages of development. Basic methodological approaches refer to biomechanics and product usability assessment techniques. The first one is based on the measurement of angular excursions of the joints associated with the implementation of the human motion detectable in dedicated laboratory; the second method rely on direct observations and on site experiments supported by questionnaires/interviews to quantify ease of use and user satisfaction by means of special scales of assessments.

The methodological approach here proposed is aimed to integrate ethnographic analysis, biomechanical analysis, and cognitive usability assessment within a multifactorial approach for the evaluation of ergonomic characteristics.

Keywords: Human behavior analysis, observational methods, quantitative movement analysis, HMI assessment, Ergonomics in Healthcare

INTRODUCTION

Designing for the medical domain is challenging. Health is for everyone a primary, reference, essential and indispensable value. For this reason it is always at the center, at the top of the list of both individual and social goals.

The term HealthCare is proposing a process that provides a clinical service not exclusively addressed to security and provision of treatment to the subject (which is and remains the main point), but which supports the concept of quality of life for the same patient, his/her family and all the health professionals who interact with him/her every day. In a simple word, we have to move from the concept of "cure" to the concept of "Care", term that embeds the philosophy of quality of care or of "taking care" of the whole person. Thus it is to create a new complex and multifactorial process in which technological factors, organizational, and human dimensions must find a balanced mix for a full success. To provide safe and high quality care for patients the healthcare industry requires clinically effective and well-designed medical devices (Martin *et al*., 2008). Medical devices are a diverse group of products that ranges from simple items to complex devices. According to the international definition, and in particular with the one used by the U.S. Food and Drug Administration (FDA), the federal agency responsible for the oversight of medical devices - as well as national and international consensus standards-making bodies – a medical device is “an instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article, including a component part, or accessory which is intended for use in the diagnosis of disease or other conditions, or in the cure, mitigation, treatment, or prevention of disease, in man or other animals, or intended to affect the structure or any function of the body of man or other animals, and which does not achieve any of it's primary intended purposes through chemical action within or on the body of man or other animals and which is not dependent upon being metabolized for the achievement of any of its primary intended purposes” (http://www.fda.gov).

Traditionally, many errors associated with medical devices were blamed on “user error”. Poorly designed medical devices can cause clinicians to make errors that lead to adverse patient outcomes. Even simple tasks such as inadvertently pushing the wrong buttons, loading infusion pump cartridges incorrectly, or misinterpreting onscreen information could be fatal (Wiklund and Wilcox, 2005). With modern advances in sophisticated technology, it is troubling that many medical device user interfaces are poorly designed, fail to adequately support the clinical tasks for which they are intended, and frequently contribute to medical error. Thus the design of devices should take account of the environment in which they are required to function and should support the working patterns of professional users and the lifestyles of patients and carers. In the recent vision of collaborative Health, also the patient and/or his/her own familiars are to be considered "users". Thus, similarly, devices intended for use by patients can similarly foster adverse outcomes if not designed properly to making medical devices safe and effective by involving users in the design process (Martin *et al.*, 2008; Wiklund, Kendler and Strochlic, 2011; Weinger, Wiklund and Gardner-Bonneau, 2011). For this reason, recently, international organizations have adopted specific rules for ergonomic design of medical devices. FDA has mandated that medical device manufacturers use HFE design principles and adhere to standard "Good Manufacturing Practices" (Weinger, Wiklund and Gardner-Bonneau, 2011; U.S. Department of Health and Human Services, 2011]. Similarly other national and international committees are acting (EN 62366, 2008). From now on, most design and manufacturing companies that gave only limited attention to the human factors engineering of medical devices, have to undergo a radical change in developing new devices.

HealthCare Product Design, and in particular the development of bio-electronic device for diagnosis and monitoring, is usually very complex because it concerns many different disciplines (e.g. Medicine, Electronics, Computer Science, Product Design, etc.). Moreover Healthcare products are almost always used by many different actors, for example caregivers, physicians, patients and their relatives. They can be therefore defined as multidisciplinary products. This implies great difficulties during the design and development of new products because it is necessary to consider many different points of view, in particular without forgetting the diverse users' needs (Romero *et al.*, 2010).

Ergonomics may be defined as the application of knowledge about human characteristics and abilities (physical, emotional, and intellectual) to the design of tools, devices, systems, environments, and organizations. The development of usable medical devices requires the adherence to ergonomic principles and processes throughout the entire design cycle, beginning with the earliest concepts and continuing after the device is released for commercial use (Wiklund and Wilcox, 2005).

In the "user-centered design" approach the user is the focus of the design process, and user input and formal user testing starts at the earliest conceptual stages and then continues throughout the design process, thereby facilitating iterative design improvement. In the previous comma, we already discussed how a single medical device can be used by a wide variety of users, from highly educated physicians to patients and caregivers but we could also include also those who unpack, transport, maintain, clean, and test the device, as well as other individuals who are directly affected by the device's use. Therefore, when trying to design the best device possible, it is advantageous to define device users broadly as all individuals who may interact with the device. This means that a wide analysis should be carried out. Here start this process by focusing on the clinical application of medical devices and we will discuss a multidisciplinary approach to collect user information, where user is intend to be both the patient and, above all, the clinician using the device for diagnosis.

METHODS

The idea of merging qualitative and quantitative methods has become increasingly popular, in particular in areas of applied research. Human-Machine-Interaction (HMI) and ergonomics are multifaceted issues so it is important to approach the phenomenon under investigation from diverse sides and to combine data resulting from diverse methods. Based on a previous experience on white goods ergonomic analysis, the proposed method integrates different research methods into a research strategy increasing the quality of final results and to provide a more comprehensive understanding of analyzed phenomena (Andreoni *et al.*, 2010).

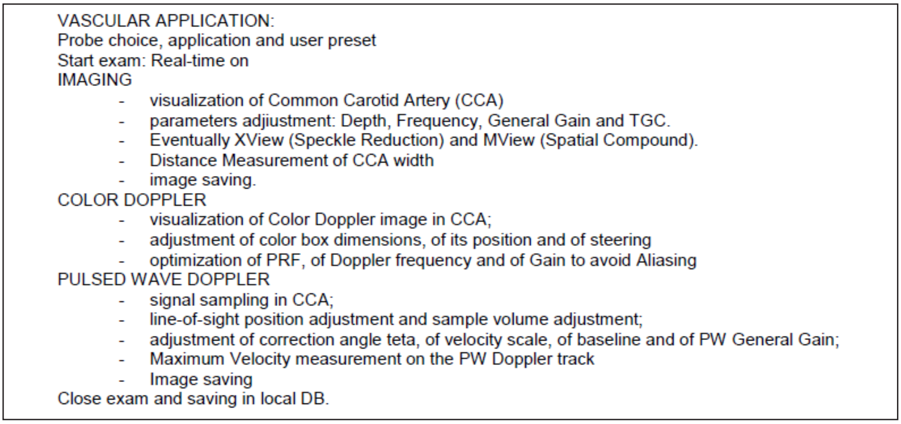
The methodological approach here proposed follows three steps: a preliminary ethnographic analysis have been performed to design and drive the following phases consisting into two in-depth analyses regarding usability and biomechanics of the interaction with Portable Ultrasound system (Figure 1).

Figure 1: The portable ultrasound system used in the methodological set-up of the study.

Ethnographic Analysis

Ethnographic analysis have been performed to design and drive the following phases consisting into two in-depth analyses regarding usability, cognitive and biomechanical interaction with the sonograph which is the test-bed used for this research. Contextual inquiry (Beyer and Holtzblatt, 1997), based on an ethnographic approach was conducted by observing the interaction of expert and unskilled sonographer in clinical laboratory to detect user habits (Amit, 2000) and better define the objectives and procedures of the next analyses. In our case study we observed 5 subjects-sonographers. The ethnographic analysis was carried out through the non-interference principle: we minimized the observer influence thanks to video recording and to avoiding the entrance in the clinical space during the investigation. This allowed us to have the maximum likelihood of the real situation. These tests lead us to identify and isolate the main tasks to be considered in the next biomechanical and cognitive studies.

The outcome of this step was the identification of the two classes of subjects to be analysed (skilled and inexperienced sonographer with respect to the Portable ultrasound system to be investigated in its ergonomic features) and a structured clinical protocol for the investigation of the HMI of the Portable ultrasound device and the sonographers in two standard clinical conditions regarding two applications (vascular and abdominal). An example is reported in Figure 2.



VASCULAR APPLICATION:
Probe choice, application and user preset
Start exam: Real-time on
IMAGING

- visualization of Common Carotid Artery (CCA)
- parameters adjiustment: Depth, Frequency, General Gain and TGC.
- Eventually XView (Speckle Reduction) and MView (Spatial Compound).
- Distance Measurement of CCA width
- image saving.

COLOR DOPPLER

- visualization of Color Doppler image in CCA;
- adjustment of color box dimensions, of its position and of steering
- optimization of PRF, of Doppler frequency and of Gain to avoid Aliasing

PULSED WAVE DOPPLER

- signal sampling in CCA;
- line-of-sight position adjustment and sample volume adjustment;
- adjustment of correction angle teta, of velocity scale, of baseline and of PW General Gain;
- Maximum Velocity measurement on the PW Doppler track
- Image saving

Close exam and saving in local DB.

Figure 2: Example of the single-operation protocol for the analysis of the vascular application.

Biomechanical Analysis

The biomechanical analysis was conducted at the instrumental laboratory of human motion analysis to quantitatively measure by means of an ergonomic index for the measurement of comfort/discomfort of human movement involving a statistically suitable sample of subjects eventually clustered in different categories (e.g. expert or novice as in this case).

Upper-body kinematics was recorded through a six cameras optoelectronic system while the subject performed the clinical examination with the Portable ultrasound system. The cameras were placed so that a volume of about 3 x 2 x 2 m was covered. A set of 32 passive and reflective markers, placed on the subject's body surface, were used for the kinematic computation (Figure 3) (Schmidt *et al.*, 1999). Calibration procedures were carried out before each experimental session. Ergonomic evaluation of postures and tasks was carried out with the MMGA index of discomfort (Table 1) (Andreoni *et al.*, 2010). Also time duration of each task and spatial excursions of the fingertip as end-effector could be extracted and analyzed (Figure 4).

A Body Discomfort Assessment questionnaire combined with a Visual-Analogue Scale was administered too in order to have also a subjective assessment of the perceived discomfort. Subjective scores were re-analyzed in a graphical representation for a better and immediate understanding (Figure 5).

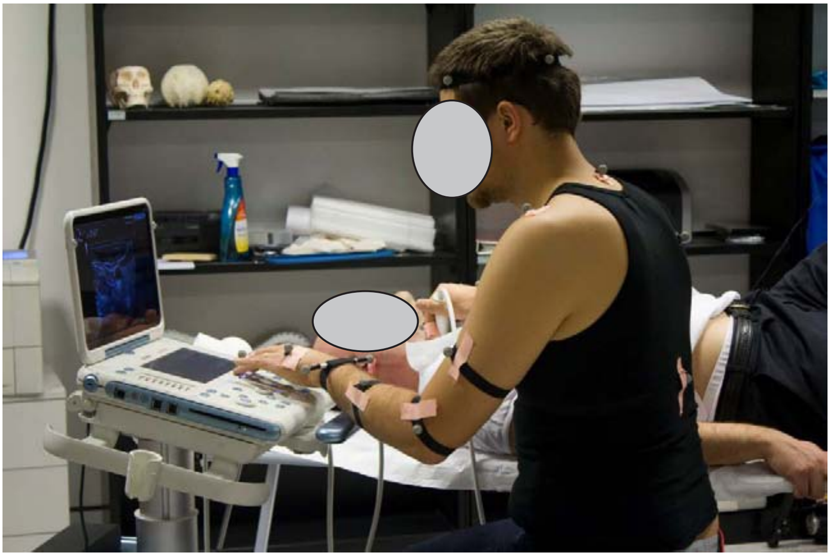


Figure 3: Protocol for the kinematic acquisition of the operator’s postures and movements.

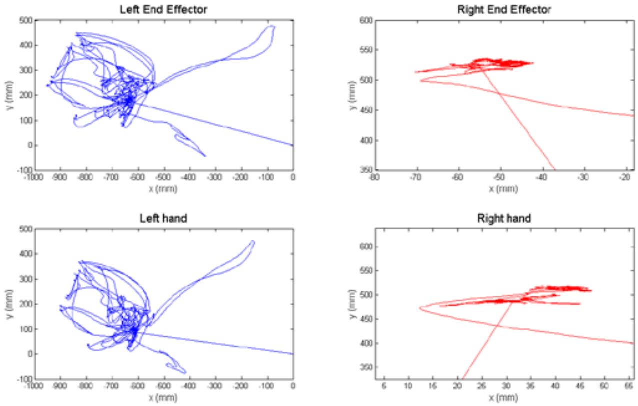


Figure 4: Analysis of end-effector trajectories during the Abdomen Exam.

SUBJ – EXAM	Avg	STD	Min	Max
S1 - ABDOMEN	4,83	0,34	0,93	6,14
S1 - VASCULAR	3,12	0,20	0,93	3,34
S2 – ABDOMEN	3,66	0,56	1,61	4,55
s2 – VASCULAR	2,47	0,13	1,94	3,33

Table 1: MMGA index values in the analyzed conditions

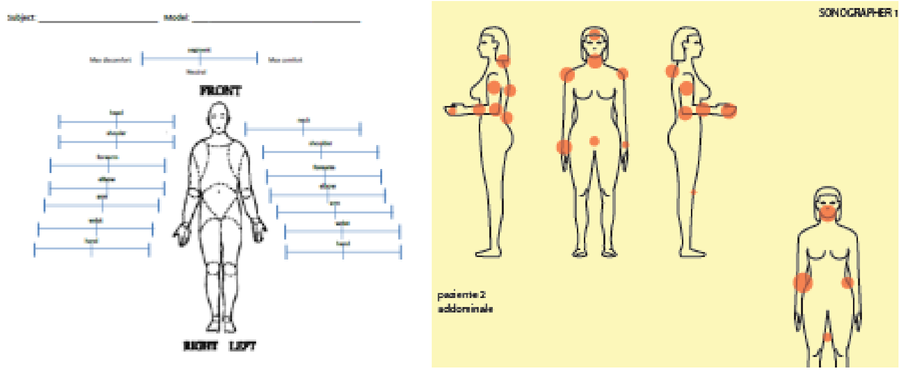


Figure 5: Subjective evaluation of perceived discomfort and the graphical results of the analysis.

Cognitive Usability Assessment

Cognitive usability assessment of communication interfaces (design and flow of operations) is carried out by means of visual, subjective and eye-tracking based techniques according to the desired level of accuracy or needed feedback information to improve HCI design. Eye movements analysis represents a powerful tool in all studies dealing with visual attention and exploration, as in the case of a human-machine interaction (Zambarbieri, 2007). The analysis of subject's eye movements provides quantitative and objective information on where the subject is looking at and for how long. Clear vision of an object is guaranteed only when its image falls within the central part of the retina which is called fovea and remains stable. Therefore, in order to explore a visual scene, the eyes have to move in such a way as to bring the image of an object of interest onto the fovea and to maintain it stable during any relative motion between the scene and the observer.

During visual exploration the eyes make saccades and fixations. Saccades are fast movements of the eyes that rapidly shift the gaze from one position to another. Vision is suppressed, at least partially, during the execution of saccades since the high velocity reached by the eyes (up to 500 deg/sec) would cause blurred vision. Fixation is the time between two successive saccades and it represents the period of time during which visual information can actually be acquired. The two-dimensional movement composed of alternating saccades and fixations that the eyes execute during the exploration of a scene is normally called “scanpath”. Since visual information is acquired by the CNS only during fixations, whereas saccades are used to shift the gaze from one point to another, it is reasonable to infer that the analysis of the scanpath is a powerful tool for the study of exploration strategies and the underlying cognitive processes. Thus, when a subject is exploring visual scene eye movements supply information about the focus of subject's attention.

Among the different techniques currently available to detect the rotation of the eyes in the orbit, video-oculography (VOG) is the one more suited for the purpose of studying subjects' behavior in HMI. VOG makes use of infrared emitting sources to produce corneal reflexes and the measure of eye position is made through the processing of the eye image taken by a video camera. In this way eye movements can be detected simultaneously in two dimensions. There are two types of systems that implement video-oculographic technique: remote systems and wearable systems. In remote systems a camera is usually positioned below the computer display and it records gaze position with respect to the image that is presented on the display. Head movements are tolerated within the limits in which the eye remains in the camera field of view. Wearable systems, also called head-mounted, are placed on the subject's head, for instance by using a bicycle helmet or a baseball cap, or they are worn through a kind of eyeglass frame. A head-mounted device can be equipped with two recording cameras: one for recording the movement of the eyes, the other to detect the scene in front of the subjects that is completely free to move. Specialized software processes the information from the two cameras and produces a video in which a mobile cursor identifies, frame by frame, the point of the visual scene the subject is looking at (Figure 6).

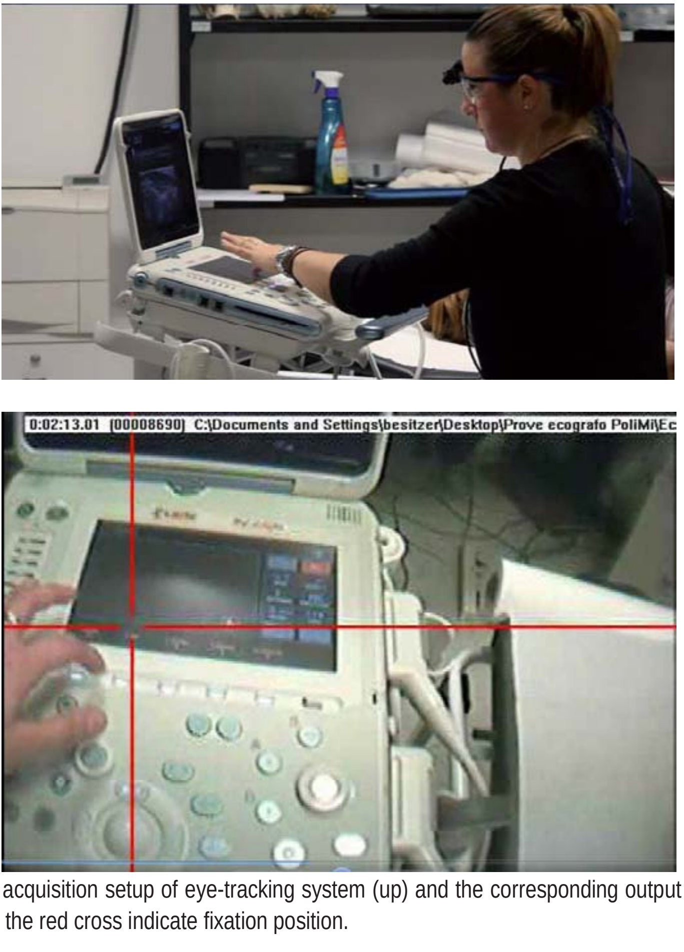


Figure 6: the acquisition setup of eye-tracking system (up) and the corresponding output (below). The center of the red cross indicate fixation position.

The purpose of data analysis is to identify within the recorded video the actions taken by the subject. It is particularly suitable for behavioral studies such as ergonomic assessment in the field of HMI since it allows identifying what the subject was doing at any instant. To achieve that result, the first step of analysis is to define a list of actions and to assign them codes (letters or numbers). Subsequently, by sliding the images of the video, the user has to identify what the subject is doing by assigning the relevant code through the keyboard. Based on these results the information regarding the occurrence of any event can be viewed in terms of duration, and in terms of timeline chart (Figure 7).

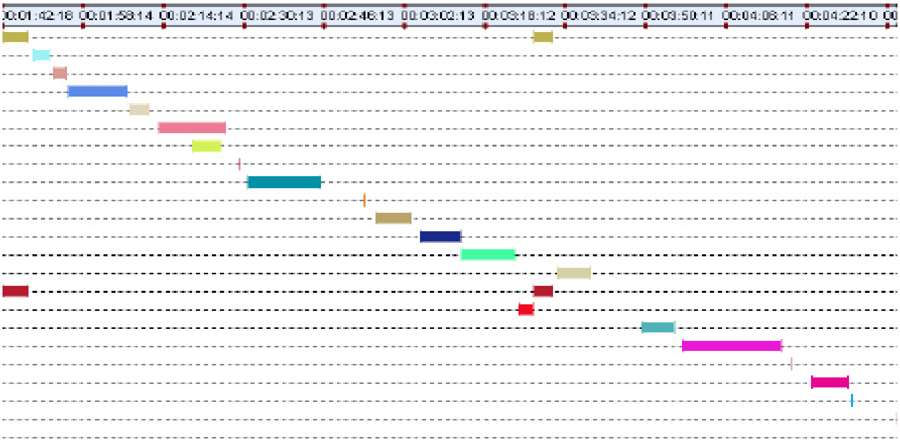


Figure 7: An example of timeline chart derived from eye-tracking analysis.

The first provide a global distribution of actions duration among the different kind of actions, whereas the second represent the evolution during time of subject behavior. In other words results can be described in terms of static or dynamical observation of human behavior.

CONCLUSIONS

Ergonomic and usability testing calls for representative users to perform representative tasks as a means to reveal the interactive strengths and opportunities for improvement of a device. You can think of the activity as pressure testing or debugging the user interface of a device in terms of how it serves the users' needs, a critical need being safe operation. Tests may focus on early design concept models, more advanced prototypes, and even production units (Wiklund, Kendler and Strochlic, 2011). The described protocol represent a feasible, structured approach to collect quantitative user data of physical and cognitive usability of a medical device. The approach has been developed on a ultrasound system but it could be easily applied in any other case, both simpler and more complex. To complete the physical aspects we can add total body kinematics and EMG evaluation to better evidence eventual musculo-skeletal risks. The next step will be a real application with a comparison of the ergonomic features of the current device and the new one that it is still a prototype and will be released next year. This could be though as an example of proactive ergonomics, that is applied early up in the design phase of a new medical device through a real “user-centered-design” approach.

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CHAPTER 2

Case Study of Integrated Ergonomic Assessment of a Portable Ultrasound System

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ABSTRACT

In recent years, the portable ultrasound (PU) systems have worldwide increased their importance both economically (number of systems sold) and clinically. The major task for user interface (UI) designers is represented by the concentration of the necessary controls for advanced technical and clinical features within reduced dimensions. The MyLab30CV (Esaote S.p.A., Firenze, Italy) PU, was evaluated during clinical examination sessions by expert sonographers in different clinical applications. This PU has a typical portable systems graphical user interface (GUI) menu by means of soft keys in the lower part of the monitor with direct controls right under the screen. The outputs of this analysis were the design inputs for the UI of a new PU system, the MyLabAlpha (Esaote S.p.A., Firenze, Italy), characterized by the integration of a high definition touch screen (TS) within the control panel, a reduced number of physical controls, compact dimensions and decreased weight. A detailed description and an evaluation of the new UI and its features are provided.

Keywords: portable ultrasound system, TS, user interface

1 INTRODUCTION

In the last years, the PUs have increased their importance on the worldwide market both regarding number of systems sold per year (56.214 in 2011; InMedica – May 2011) and annual market grow rate (23.4%; InMedica – May 2011).

The number of different products, from diverse manufacturers, available today is increased year after year. Nowadays, the portable ultrasound systems (PU) can be divided, as per the console-based systems, in low, middle and high level, regarding the diagnostic capabilities and technological features. The high level segment is the most interesting from the performances and ergonomics point of view: small systems which are highly transportable (weight under the 12kg) and which need to have clinical performances comparable to the ones of premium level console-based systems. A PU can be also used mounted on its proper cart. In this case it can be intended as a small console-based system with also plugs, holders for echographic gel and probes and supports for peripherals. The PU is nowadays not considered as a second best choice, with respect to a console based system as a main unit, but it is many times the first choice, being the only system available in the imaging lab.

Recently, always more functions and tools were added to the PU systems. The concentration of the necessary controls for the advanced technical and clinical features within the reduced dimensions of the PU control panel has to be properly achieved. At the same time the number/kind of users is increased (also non-sonographers): the same system has to house more “things” and they have to be organized in the easiest and most accessible way possible.

In the design process of any ultrasound (US) system it has to be kept in mind that during the real-time acquisition, the US transducer is a “fixed” interface for the operator, therefore the US system during scanning has to be usable with only one hand, while the other one has to handle the probe.

As console-based system, also the PUs have usually to be shared-service units able to perform examinations in all the main Clinical Applications (i.e. Cardiology - Car, Abdomen - Abd, Vascular - Vas and Obstetrics and Gynecology - Ob-Gyn). PUs are usually characterized by a physical control panel with buttons, toggles, encoders, sliders and a trackball, a qwerty keyboard and a LCD screen. One of the techniques to integrate such a large amount of commands within a compact panel is the use of the direct controls of a GUI menu shown on the lower part of the screen. This menu is re-configurable and usually organized on more levels due to the fact that many controls are needed in any real-time acquisition modality (see Figure 1).

Figure 1: Example of a reconfigurable GUI menu on the lower part of the main screen and buttons and toggles to operate it.

The issue of US systems ergonomics, well known among sonographers (Craig, 1985; Atjak and Gattinella, 1989; Pike *et al.*m 1997; Smith *et al.*, 1997; Gregory, 1998; Schoenfeld, 1998; OHS Update, 1999; Magnavita *et al.*, 1999; Evans, Roll, and Baker, 2009; Sommerich *et al.*, 2011), has been described and treated in many Standards and Guidance Documents from Regulatory Organizations, Healthcare Institutions and Sonographers Associations (Habes and Baron, 1999; Society of Diagnostic Medical Sonography, 2003; DHHS (NIOSH), 2006; The Society of Radiographers, 2007;European Standard EN 62366, 2008). However, today no Industrial Standards are available dedicated to the design of US systems (control panels, GUI and probes). Some recommendations on how the systems need to have certain characteristics (height adjustment, monitor features, size, shape and spacing of controls) are given, but no detailed design and implementation rules and guidelines are available. The lack of detailed UI design rules, missing also for console-based US systems, is even more stringent for the portable units, used by many sonographers even outside the imaging lab, also at the patient bedside (both at the hospital or at home). Hereunder we consider some ergonomics issues analyzed in PU systems and, as an improvement, a new user interface will be presented and analyzed.

2 METHODS

A PU (MyLab30CV, Esaote S.p.A.. Firenze, Italy – see Figure 2), was evaluated during clinical examination sessions by four expert sonographers in the four main clinical applications (Vas, Card, Abd, Ob-Gyn).

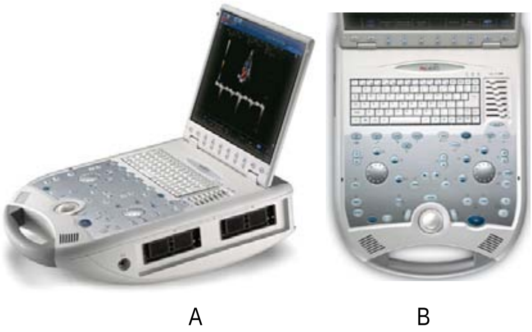

Figure 2: A) MyLab30CV; B) MyLab30CV Control Panel and qwerty keyboard

The MyLab30CV has a typical UI for PU systems: a reconfigurable, multi level, GUI (Soft key) menu is present in the lower part of the monitor with direct controls right under the screen. A physical control panel with encoders for the modality general gain, plus Time Gain Compensation (TGC) controls and modality, measure, annotations, body-marks, saving options and line/update buttons are placed around the trackball. Between the Soft key menu controls and the physical control panel, a qwerty keyboard is present, for Patient ID data entering, free text annotations and Report fulfilling and comments.

The used controls and commands in each of the four clinical applications were counted by an independent observer. Moreover, through an ad hoc interview, the expert sonographer reported the encountered difficulties while performing the examination. For the simulation phases of different possible UIs, a proper portable US system (MyLabOne, Esaote Europe, Maastricht, The Netherlands) with a TS GUI integrated in the same (single) monitor utilized also for the echo image presentation, was used.

3 RESULTS

The MyLab30CV US systems was used by four expert sonographers with different settings according to the specific application (Vas, Abd, Car and OB-Gyn were considered) and to the different body regions to be examined. The different settings called “Presets” were related to the application and the chosen probe. The most used modalities were B-Mode, Color Doppler (CD), Pulsed Wave Doppler (PW) and, only in Cardiology Application, Continuous Wave Doppler (CW) and M-Mode. After the Preset choice, the most used controls and frequent adjustments were:

- In B-Mode: Depth, General Gain, Time Gain Compensation controls;
- In CD modality: General Gain, Region of Interest (ROI) size and position, Pulsed Repetition Frequency (PRF or Scale);
- In PW Doppler modality: PRF, PW line of sight and Sample Volume (SV) position adjustments, Steering (if a linear array probe was used), Doppler Angle Correction (θ) if blood flow velocity measurements were performed.

The subjective analysis with sonographers demonstrated that the highest level of discomfort was reported from the distance between the trackball (which can be considered the center of the US system UI) and the Soft key menu controls. Starting from the user position, the analyzed classical UI has the trackball with the physical control panel, then the qwerty keyboard, then the Soft key controls and finally the main screen with the Soft key menu and the echographic image. The second critical point was the necessity to find the desired command/adjustment within the Soft key menu (organized as a single line), and the presence of controls not intuitively positioned on the panel (many controls for different applications/modalities can be properly positioned for a certain application but not for another: the simplest example is the CW Doppler which is widely used in Cardiology but completely unused in any other Application).

The points reported as utilization discomforts by the sonographer interviews were:

- Soft key menu controls distant from the trackball;
- Qwerty keyboard less frequently used than the Soft key menu controls but positioned closer to the user;

- High number and relative closeness of physical buttons/controls concentrated in a small area (also related to conceptually different functions);
- Necessity to scroll more pages of the Soft key menu (organized in levels) to find the desired control/function.

4 DISCUSSION

The outputs of the conventional PU UI analysis were the input for the design of a new concept of UI for a portable US system, the MyLabAlpha (Esaote S.p.A., Firenze, Italy – see Figure 3).

A B

Figure 3: A) MyLabAlpha; B) MyLabAlpha Control Panel.

A high definition TS is integrated within the physical control panel at a shorter distance from the trackball. A reduced number of well-spaced physical controls (buttons, toggles, sliders and encoders) is available on the panel with the intention to facilitate their detection and use by the operator. Buttons and controls which can be activated (or are already active in a certain system status) are lighted. Some of the most frequently used controls/adjustments are physical in order to be activated/changed while the eyes of the user are focused on the main screen where the echo image is shown: Freeze, General Gain, TGC, Automatic Adjustment of imaging and Doppler traces, line/update, saving options (image/clip/print). The same can be said regarding modality buttons like B-Mode, CD, PW, CW, M-Mode. The level of the UI are three on the MyLab30CV (Physical control panel, qwerty keyboard and Soft key menu controls), on the MyLabAlpha are two (physical control panel and TS), having the Soft key menu controls integrated within the TS, where also other ex-physical buttons/controls are grouped. Moreover, the qwerty keyboard is integrated within the TS and can be activated by touching a proper icon on it.

Multiple possible choices of UI were evaluated and tested prior to the developing phase of the new system. Just to name a few it was discussed the possibility to have the whole controls integrated within a single, wider TS separated from the main screen. That is, no physical controls and buttons at all. The simulation of this scenario was performed using a TS based system (MyLabOne, Esaote Europe, Maastricht, The Netherlands) connected to an external monitor to duplicate the echo image. In the simulation the user had to watch the gain controls while changing them and their effect on the main screen image, alternatively and repeatedly depending on the total amount of increase/decrease needed. The same happened regarding other modality-related controls such as frequency, depth, PRF/scale and angle correction.

Another possible choice would have been to integrate the control panel as a TS input device on the same display of echographic image thus solving the possible limit of eye movements between the main screen and the TS. As a drawback, being the task the integration of a multi-application high level system, the total amount of controls and features would have led to obtaining a multi-level GUI with the controls necessary spread over more windows and tabs. This would have been the only possible choice being a constrain the portability of the system, and therefore having proper specifications for the screen size. On the other hand the echographic image had to be the maximum size possible, this maintaining limited the expandability of the GUI portion on the main screen and forcing to have multiple GUI layers. Those considerations led to the decision to maintain a limited physical control panel with the reconfigurable GUI within a TS separated from the main screen on which the echo image was shown.

The concept of TS is widely used in everyday life within lots of technological gadgets and input devices. Anyway, the US system interface is widely different with respect to the one of the other “consumer electronics” systems. The US device is used, at least during the real-time acquisition, with only one hand (the other has to handle the transducer) with the operator usually not positioned frontally to the US system control panel: therefore, the US UI cannot follow all the same design rules of the everyday life technological gadgets. Additionally, the US system UI has to be designed in order to be used also in situations of low level of illumination (as many imaging labs are) in order to see the echographic image in a better way. The TS as input device is anyway common among console-based US systems: in the last ten years almost all the manufacturers have integrated TSs at least in their high level systems, but it has been introduced only recently among the PU units.

On the MyLabAlpha most of the GUI is present within the TS where direct toggles are used for parameter adjustments. Virtual buttons or functions/controls which can be activated are in dark blue, light blue is for controls/commands already activated and grey for not-available ones The GUI is organized in only two layers maximum for each tab. On the physical control panel controls and commands are more grouped and positioned closer to the trackball.

The ergonomic integration was obtained with no reduction of functionalities with respect to the previous system.

Table 1 presents the direct dimensional comparison between the MyLabAlpha PU (new UI) and a conventional PU UI, here represented by the MyLab30CV system:

Table 1 New UI and conventional PU UI direct dimensional comparison

	New UI	Conventional PU UI	
Control panel dimensions	34 x 36.5cm (1241cm²)	35.5 x 47.5cm (1686,3cm²)	27% smaller control panel
Number of controls present on the panel	44 (27 buttons 6 toggles 3 encoders 8 sliders	59 (41 buttons 9 toggles 2 encoders 7 sliders)	25% reduction in the number of controls present on the physical control panel
Distance trackball – modality gains	13cm	14cm	Trackball closer to the modality gains
Distance trackball GUI controls	19cm (MIN distance 13)	34.5cm (MIN distance 33)	45% reduction
Distance trackball – toggles	11cm (MIN distance) – 15cm (MAX distance)	33cm (MIN) – 34.5cm (MAX)	67% reduction
Distance Trackball – TGC	22cm	27cm	19% reduction
Distance trackball – Qwerty	19cm (Virtual Qwerty keyboard)	23cm	Trackball 17% closer to the Qwerty keyboard

In order to have an initial evaluation of the UI quality of MyLabAlpha, Tests were performed with expert sonographers in the four main clinical applications (Vas, Abd, Car, Ob-Gyn). The sonographer used the MyLabAlpha system in a routine examination without any indication regarding the UI or the functionalities of the PU.

After the use of the system the sonographers were interviewed reporting to be sufficiently confident about the utilization of the system since the first approach regarding the localization and use of the most common real time controls and, after the creation of a proper Preset for the chosen application and probe, they generally needed to operate only on the Basic page of the last selected modality. An independent observer was present during the test confirming the comments of the sonographers.

Some interesting outputs regarding possible future improvements of the GUI came out from the interviews and the reports of the independent observer:

- PW SV when the PW acquisition is active, could be positioned in the Basic page of the PW acquisition TS GUI;
- Sub-windows on the TS with a time defined presence (this point less stringent in case of an already properly set system regarding the chosen probe/application): after a fixed period of time, the sub-window, once activated and not “touched” has to disappear, coming back to the original window on the TS;
- Increment of the font size/readability of the measurement on the main screen and on the black and white prints.

Moreover, the transducers of the new system were designed following the Industry Standards for the Prevention of Musculoskeletal Disorders in Sonography. They are light (100-150gr, for linear and convex probes) and with a dual-possibility hand grip (AppleProbe Design) made available (pinch grip and palmar grip) in order to provide a neutral wrist position (see Figure 4).

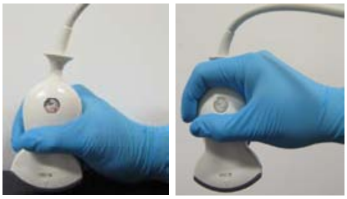
A B

Figure 4: A) palm hold; B) pincer hold

In addition, the novel eTouch concept was implemented on the new PU.

The eTouch represents a tool for the creation of a personalized, user-targeted workflow of the system. It allows the user to record sequences of key mixing functions of the TS and of the control panel. Each recorded sequence (macro) can be named and saved to be available as a customized button in customized TS (eTouch environment). The recording of the macro is performed during the normal use of the system.

Pressing the eTouch button on the physical Control Panel, the user enters in the eTouch environment on the TS (see Figure 5).

A B

Figure 5: A) eTouch button; B) eTouch environment TS page layout.

Examples of eTouch macros can be the following:

- “Freeze-image-print” macro: from Real Time (live), the activation of this macro, drives the system in Freeze, saves an image (the last image of the cine loop) and prints the image (if a printer is connected and active the image will be printed, otherwise, the macro will end with the saving of the image);
- “CFM and line” macro: from Real Time (live), the CFM modality is activated and the Doppler line placed;

- “Annot-measure from live” macro: from Real Time (live), the system is forced in Freeze status, the annotation “tricuspid” is placed on the image and a generic distance measure is activated (the first caliper of the measurement is shown on screen, linked to trackball movements but not fixed).

For any macro the eTouch environment is characterized by the TS encoders’ controls (shown in the lower part of the TS) which are those of the Basic TS page of the last activated mode (B-Mode, CD, PW, etc.).

The eTouch environment is a finite-state machine where the macro has to be recalled while the system is in the same situation when it was when recorded, otherwise the system will perform the exact sequence of tasks, but starting from a different initial condition, which may lead to a different output than the expected one.

5 CONCLUSION

From the analysis of the conventional UI of a PU, performed on the MyLab30CV, the points of not optimized usability were:

- Distance between the trackball (which can be considered the center of the US system UI) and the Soft key menu controls;
- Qwerty keyboard less frequently used than the Soft key menu controls but positioned closer to the user;
- High number and relative closeness of physical buttons/controls concentrated in a compact surface area;
- Necessity to scroll more pages of the Soft key menu levels to find the desired control/function.

The new portable US system MyLabAlpha is intended to offer an easier to be operated UI, a reduced number of controls in order to have a few commands only when needed and only what needed.

A smaller physical control panel allows smaller dimensions to increase portability and it has the aim to lessen hand/arm movements for the user. The reduction in the number of controls present on the physical control panel wants to reduce the learning curve related to the system use. The trackball closer to the modality general gain encoders, TGC sliders and the qwerty keyboard (virtual qwerty keyboard on the MyLabAlpha), the reconfigurable controls (toggles) and reconfigurable GUI (TS) are solutions which go in the direction of less hand/arm movements while performing an examination.

Some interesting outputs regarding a possible improvement of the GUI, which came out from the interviews and the examination of the independent observer, were collected as well. A control panel with reduced dimensions but with well-spaced controls has the aim to increase the readability: the purpose is to reduce the strength and the time-o-flight of the operator hand and arm, reducing the possible erroneous command selection. The use of a high definition TS is intended to concentrate all the main features of the re-configurable GUI in a well defined area close to the trackball. The light transducers designed with a choice between two different grips want to reduce hand, arm and shoulder stress.

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CHAPTER 3

Co-designing Better Work Organization in Healthcare

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ABSTRACT

Hospital care changes in the wake of social and technical developments. When a hospital is renewing buildings, in-house logistics or ICT as an adaption to the changing environment, it is faced with a demand for care that is more human-centered as well as the necessity to save costs In facing these challenges, including hospital staff in the re-design of the work organization has two advantages. First, the staff has valuable experience with everyday care that will help to create a new situation that is workable. Second, the consultation of the staff and serious efforts to co-design a new work organization will increase staff commitment. In this paper we present the application of tools for co-design in a large health-care project. The project is performed in a hospital that will move to a completely new building. It involves the redesign of work organization concepts for nurses with regard to ICT, ward communication, supply logistics, catering and visiting policies for the general wards. Four co-design workshops on different redesign aspects were set up. The center-piece of the workshops are scenario based design games that promote an overview of complete care processes. In this paper the workshops are described and evaluated concerning their applicability to develop work organization concepts, elicit requirements for related products and systems and to be reproduced in future work organization re-design. The chosen set-up enabled participants to generate new situations and walkthrough imaginative work processes and thereby address work organization related problems.

Keywords: co-design, work organization, participatory design, design game

1 INTRODUCTION

Continuous development of new cure possibilities and competition between hospitals force hospitals to reorganize themselves. When a hospital is renewing buildings, in-house logistics or ICT as an adaption to the changing environment, it is faced with a demand for care that is more human-centered as well as the necessity to save costs. Additional challenges are the ageing population and the progressive replacement of treatments with hospitalization by policlinic treatments. In the Netherlands the number of hospitalizations has increased, whereas the average time of hospitalization is decreased (VTV, 2010). These developments result in a higher turnover of patients that stay only a day or two and an older and sicker patient population that remains in the hospital. Therefore, the composition of tasks and work load for nurses changes. In the struggle of reorganization and redesign the ergonomics of new nursing work organization must not be overlooked, as they form the center of day-to day hospital care practice. In the daily nursing work organization, ICT, supply logistics, medication and catering come together and need to leave enough time and space to provide patients with personal attention. Therefore, a good organization of all nursing tasks should form an important point of departure to formulate requirements for hospital renewal.

We present a project that aims to co-design nursing work organization in order to cope with the developments. In the scope of the project, work organization is defined as the way roles, responsibilities, tasks, tools and material resources are distributed over individuals, time and space in an organization. This definition covers four of the five elements of work systems as described in the Balance Theory of job design (Smith and Carayon-Sainfort, 1989); tasks, tools and technologies, physical environment (space) and organization. Redesigning the organization, as an institution with policies, goes beyond the scope of the presented project. Also, the general distribution of space (as in architectural space) will not be covered, because the architectural drawings for the new hospital were already completed, when the project started. Adaptions on a smaller scale are still possible.

The change of work organization implies changes to work ergonomics. A fundamental redesign offers the opportunity to improve ergonomics and thereby health and safety of the staff. However, this is not easily achieved in a top-down approach. In hospitals, ergonomics has a “socially situated practice” (Hignett, 2001), i.e. ergonomics is embedded in the organization in the way staff handles their daily tasks. Beyond the structures that are often defined top-down (schedules, material, tasks), staff do (and should) shape their own tasks in detail. Changing the way work is done can be difficult, as staff does not always see the necessity to change the way they handled things for years. The participation of staff in the design process can help to grow feelings of self-determination (Carayon and Smith, 2000) and enthusiasm for a new situation.

2 CO-DESIGN

Several approaches to redesigning work methods can be found in literature and the participatory approach is a successful one (Vink et al., 2008). Including hospital staff in the re-design of the work organization has two advantages. First, the staff has valuable experience with everyday care that will help to create a new situation that is workable. Second, the consultation of the staff and serious efforts to co-design new work organization will increase staff commitment to a new work situation (Davies, 2004).

Participation in a co-design process is different from participatory ergonomics. In participatory ergonomics typically a group of staff with differing functions get a training in ergonomic principles and then try to use the training to improve the ergonomics of the work situation (Rivilis et al., 2008). In contrast to participatory ergonomics the participation of staff in co-design of the work organization includes not only implementation of ergonomic principles but active designing by the participants, as new ideas are needed to cope with a changing environment. Furthermore co-design of the work organization exceeds ergonomic questions, as participants have to address logistics, styling and experience aspects as well.

2 CO-DESIGN PROJECT

2.1 Project

In this paper we present the application and assessment of co-design tools in a hospital renewal project. The project is performed at the Medisch Spectrum Twente hospital (MST). The MST will move to a newly-built hospital, comprising 620 beds, in 2015. Currently the hospital has 4000 employees, including 250 medical specialist. The migration will entail five important changes that effect the workflow of the nursing staff:

1. in the new building there will only be single-person rooms, while in the current building there are one-, two-, and four-person rooms;
2. medical specialties will not have a pre-defined number of beds in the new wards but will be assigned beds according to demand; hence, their ward unit size and the amount of staff will fluctuate;
3. the hospital management has the ambition to create a paper-free hospital, including digital patient records;
4. the visitor policy will change. Today the hospital works with visiting hours, but single-person rooms offer the possibility to allow visitors to be around 24/7 and for family to stay overnight;
5. the catering will change from a single central kitchen that serves at predefined times to a kitchen on every floor that can serve food continuously and to order.

The new plans mean that the way nurses and ward assistants work, how they organize their shifts and use materials, must change to adapt to the new situation.

To use this change as a chance and create a positive impulse to adapt and improve the work organization, a co-design project was started in cooperation with researchers from the Industrial Design Department of the University of Twente. The co-design project is called project “SWING”, which (in Dutch) stands for "designing work processes for the new building together". It involves the redesign of work organization concepts with regard to ICT, ward communication, supply logistics, catering and visiting policies for the general wards.

2.2 Project organization

Co-design projects need careful management to ensure participants’ commitment and motivation and the implementation of resulting concepts. Success factors for the process are a good project inventory, a steering committee and a step-by step approach (Vink et al., 2006). Swing has a steering committee consisting of an experienced product designer/researcher, experienced in co-design (one of the authors), a business process redesign manager, a building project manager, an ICT advisor, a nurse who is also a member of the nursing advise council, two ward team leaders, a nursing process specialist and a business unit manager. The project is managed by the author and the business process redesign manager, together. Furthermore, there are about 40 SWING workshop participants, mostly nurses, but also nurse practitioners, ward assistants, secretaries and a physiotherapist. These participants come from all over the hospital.

In summer 2011 SWING started with the project inventory by a series of interviews with key information holders in the hospital and a series of visioning workshops, with the goal to inventory concerns and visions for the future of the hospital wards. The next step was a series of design workshops with the goal to look into the re-design of work processes and related products as well as responsibilities and rules. This series consisted of four workshops, each with a dedicated topic, i.e. “ICT & communication”, “catering concept”, “nursing tasks & visitors” and “material logistics”. The ideas resulting from the four dedicated workshops will be elaborated during a third series of workshops. Finally, the project results will be evaluated by means of evaluation workshops as well as a second series of interviews. In this paper we present set-up and results from the second series of workshops.

2.3 Work-shop set-up

The four topics of the second series design workshops were “ICT & communication”, “catering concept”, “nursing tasks & visitors” and “material logistics”. For every design workshop topic about 10 participants were invited. During the workshop the participants were split into groups of five. The workshops took about 3 hours each. The general technique used in all four workshops is a scenario based design game that promotes an overview of complete care processes. The game is a combination of a board game and a task card analysis used by Garde and van der Voort (2009) in earlier projects. The two components strengthen and complement each other and serve as mutual verification tools. The task flow analysis is a way to structure the work processes concerning chronology, time management, staff deployment and information flow. The board game supports participants to imagine the procedure in a realistic setting. By enacting the tasks with board game figures, a developed procedure can be assessed. The chosen workshop set-up has several qualities, that were described earlier by Garde and van der Voort (2009):

1. *it enables the users to invent and design a new procedure,*
2. *it includes all different users at the same time, so that it can be discussed immediately what a change in one user's domain of responsibility means for the domains of others,*
3. *it gives a clear overview of a procedure and the consequences that changes to this procedure have,*
4. *it triggers the participants to empathize the new situation,*
5. *it includes all possible appliances that could be involved in the procedure,*
6. *it is time efficient in view of the limited availability of time medical specialists [and nurses] have.*

Materials used to support the chosen technique in the SWING project were:

- task cards for building the task flow
- a large "game board" consisting of the architectural drawings of a ward in the new building,
- playing figures in different colors representing the different functions of the staff,
- playing figures depicting materials such as trolleys,
- problem cards describing problems that had to be solved with the new work organization.

The general set up of de workshops can be described in three steps:

First participants explored the design of the new hospital building: participants were asked to play out their current nursing work procedure on the game board, i.e. the large architectural plan of the new ward, with the playing figures. This technique (partly also used under the name "living blueprint" by Dalsgaard (2010)), is a way to visualize changes in a future workflow by collating them to the current workflow, and by this means prevents unfit solutions (Jalote-Parmar and Badke-Schaub, 2008); playing out the work procedures, participants encountered problems with the combination of today's work practice and the future ward design (see Fig. 1, left).

Second, the problems found in the first step than had to be solved and the work organization improved. Participants redesigned their work processes and decided upon what kind of technology or materials they want to use in their daily work. Participants used task cards (similar to CUTA (Lafrenière, 1996)) to fixate a task flow proposal (see Fig. 1, right). When creating a task flow, participants could also set-up new rules and assign responsibilities. Doing this, participants created a scenario that had to be tested repeatedly by playing out scenes on the game board.

Third, the designed set-up had to be put through a stress-test. For this purpose, the steering committee had created "problem cards" in advance. These cards contained descriptions of possible problems that were related to the four topics and had to be solvable in the context of the self-created scenario. By this means the new scenario was tested for feasibility and flexibility.

Minor variations on the general workshop set-up were applied in order to dedicate the set-up of each workshop to its specific focus. For the ICT & communication workshop we used additional mock-ups of mobile appliances in real size (e.g. tablets and smart phones) to evaluate what kind of appliances would be useful for what kind of task (e.g. reading, ticking off or writing at different places in the ward) (see Fig. 1, left). The catering concept workshop had a strong accent on responsibilities and therefore we had prepared special “hats” for the playing figures that symbolized responsibilities with respect to diet, feeding, and serving. In addition a number of patient cases with special diet requirements were prepared, that the participants had to deal with. In the nursing tasks & visitors workshop the first emphasis was on the scheduling of nursing tasks over the day. Then, tasks during which visitors were not allowed to be around were marked. Visiting rules and regulatory tasks were discussed and written on special cards. For the material logistics workshop we had prepared lists of materials used at the wards, playing figures of trolleys and cards that had to be assigned to storages (e.g. a trolley, the patient room or on-site storages) and filled in with the materials that should be stocked.

Figure 1 Left: photo from the SWING workshop on ICT & communication, showing the game board, playing figures and appliance mock-ups (October 2011). Right: photo of a task flow scheme, created during SWING workshop on nursing tasks & visitors (October 2011).

3 RESULTS

3.1 Workshop-results

The types of results generated in the four dedicated workshops by eight workshop groups were product requirements, rules, regulatory tasks, assignments of responsibilities, task flows, product requirements, and questions that had to be answered by the building committee. An important overall result was the grow of commitment for the SWING project and engagement with the building process. A few examples for all the types of results will be given.

Product requirements that were generated concerned for the most part ICT solutions. For example, participants wanted all staff members to use a small tablet PC to access and modify information about patients at the patient room. They wanted the application used on the tablets to show a general overview of a patient as first page.

Rules that were generated concerned e.g. the catering concepts stated that there has to be a time-window for ordering food, instead of enabling patients to order food all around the clock. Only then control-moments to check how much everybody has been eating can be created for the ward-assistants.

In every workshop participants created new task flows by placing task cards in chronological order. The existing task flows were altered to adapt to the new situation. For example, single-person rooms require that nursing tasks with one patient are completed before proceeding to a next patient whereas in the former situation, a nurse would first wash all patients in a room and then fill in the measurement scores for all patients. However, a major problem was identified in the task flow for the early shift, i.e. the gross of tasks needs to be accomplished in the first two hours of the shift. The expectation is that the workload will increase beyond acceptable levels due to the longer walking distances and single-person rooms in the new building. A solution, presumably in the form of reorganizing the shift will be explored during the third series of workshops.

The project participants discovered a few problems in the current building plans, e.g. that there was no storage room planned for decubitus matrasses. Questions about such problems were forwarded to the building committee and the SWING participants will be informed on the developments.

A very important result of the workshops was not content related. In the beginning of the project the main tenor of the participants was concerned about the hospital plans and the decisions already made. The project managers were questioning whether the whole project could have a useful outcome at all with this attitude. However, in the second series of workshops people were actively involved in the creation of solutions, which left little room for keeping up an attitude to complain. Since participants felt listened to regarding both their concerns and ideas, the workshops generated commitment for the project, a pro-active attitude of participants, and a more positive view on the developments. This was nicely framed by one participant: *"I think we see a lot of threads at the moment, but I believe that it will all work out in the end".*

3.2 Applicability to develop work organization concepts

The workshop set-up enabled participants to generate new work situations and to walkthrough imaginative work processes. It proved to be suitable for investigating different work organization related problems. It considers both, actions that can be planned (e.g. washing patients) as well as actions that emerge in unplanned situations (e.g. patient calls nurse). Roles and tasks were distributed over individuals, time and space in the created task flows. Responsibilities were assigned and tools and material resources were chosen and tested by use of the playing figures and playing out scenarios. Therefore all aspects of work organization are covered. In addition, product requirements were created. As the chosen technique aims at stimulating creativity, this series of workshops resulted in a rough sketch of the desired work organization. Two sequential workshop series will be organized to detail the work organization and to ensure that all relevant aspects are addressed.

3.3 Reproducibility

The general work-shop set up has proven its power to elicit useful results by each of the eight different groups addressing four different topics. These results confirm the results found in an earlier project that focused on the development of a new treatment procedure by physicians and technicians (Garde and van der Voort, 2009). Therefore, the applied combinatory technique is proven to be successful for the development of a new work organization in combination with relating appliances and ICT solutions. However adaptation of the technique to the specific development situation is a prerequisite (e.g. by creating a game board that reflects the project situation).

Co-design projects regarding work organization often have to deal with political sensitivity. Participants can be afraid to speak out or change the work situation, whereas others have been frustrated with preceding reorganizations or re-design projects. These aspects need to be dealt with carefully. To ensure an open and inspirational environment, transparency and good information management (e.g. keeping participants up-to date about what happens with their input) is of high importance. In the “SWING” project, the first workshop had the function to identify all concerns, discuss them and to jointly formulate visions for the project.

4.3 Follow-up

Sanders et. al. (2010) stated that, in setting up a participatory design method, it is important to keep an eye on the complete experience participants have during a project, and therefore each activity should prepare participants for the next one. The next series of workshops within SWING will build on the outcome of the presented workshops.

The created workflow must be revisited and to achieve this, participants must disconnect even more with their current work-flow and try to think “out of the box”. We believe that, with the second series of workshops the participants have achieved a pro-active and open state, so that the third workshop can force them even more out of their comfort-zone.

In the four workshops, the four topics were addressed isolated. In the progression of the project, these topics must be united, and their interplay and mutual influence need to be explored. In order to generate feasible solutions, emergency scenarios must become part of the project to test the created solutions under extreme circumstances.

5 DISCUSSION

When SWING started, the architectural drawings of the new hospital were already finished. They were created around a vision that contained hospitality amongst other focus points. Therefore, the work organization processes had to be adjusted to the building. An ideal situation with respect to the processes would be, that a building would be built around the processes instead of vice-versa.

A general challenge with co-design is, that on the one-hand participants must be enabled to come up with creative solutions, and on the other they must be restricted by boundaries, to ensure that created solutions are feasible (e.g. financially). It is important to find the appropriate degree of freedom, which does not hinder creativity but still leads to useful results. In the second series of SWING we worked with a set of game-rules to ensure that created concepts would fit to the decisions that had already been made in the building process.

Although, participation of employees in the shaping of their own work situation is mostly assumed to be beneficial for job satisfaction Carayon and Smith (2000) stress that there has to be done more research on the potential negative effect of participation, i.e. increased workload In project SWING participants could participate during working hours, potential additional workload was thereby minimized. However, the different wards faced additional effort to plan the shift schedules. Therefore, some participants did miss a workshop due to being scheduled to work at the ward at the same time and not being able to leave due to intense activity at the ward.

6 CONCLUSIONS

We presented a project that aims to co-design nursing work organization for the wards within a hospital building under development. Four workshops with the topics “ICT & communication”, “catering concept”, “nursing tasks & visitors” and “material logistics” were set-up. As work-shop technique a scenario based design game that promotes an overview of complete care processes has been used. The game is a combination of a board game and a task card analysis. The workshop set-up enabled participants to generate new work situations and to walkthrough imaginative work processes. It proved to be suitable for investigating different work organization related problems. It considers both actions that can be planned (e.g. washing patients) as well as actions that emerge in unplanned situations (e.g. patient calls nurse). Roles and tasks were distributed over individuals, time and space in the created task flows. Responsibilities were assigned and tools and material resources were chosen and tested by playing out scenarios on the game board. The types of results generated in the workshops were product requirements, rules, regulatory tasks, assignment of responsibilities, task flows, and questions that had to be answered by the building committee. An important overall result was the grow of commitment for the SWING project and engagement with the building process.

The applied, combinatory technique is proven to be successful for the development of a new work organization in combination with relating appliances and ICT solutions. However adaptation of the technique to the specific development situation is a prerequisite (e.g. by creating a game board that reflects the project situation).

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CHAPTER 4

A Smart Wearable Prototype for Fetal Monitoring

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ABSTRACT

Fetal monitoring during pregnancy is extremely important to identify risky conditions for the fetus. The standard approach to assess fetal well-being in the uterus is represented by cardiotocography (CTG). Unluckily CTG can only be used in a clinical setting, because it requires expert clinicians and cumbersome equipment to be performed. In order to overcome the disadvantages of CTG, which prevent a close and continuous monitoring during the last weeks of the pregnancy, a new prototype for fetal monitoring is proposed. The device we present is a home wearable fetal monitor. Instead of detecting fetal heartbeats using Doppler Ultrasounds, as CTG does, it is based on the recording of abdominal ECG. The system measures the maternal and fetal ECG by 8 leads embedded in a wearable belt. A custom algorithm was developed for recognition of maternal beats, their subtraction from the whole signal and extraction of fetal heart rate. The algorithm is based on an averaging and subtracting process. Afterwards, the beat-to-beat signal of both mother and fetus is computed. The relevant information extracted from the abdominal recordings is then transmitted to a laptop using a Bluetooth connection. The prototype we have developed will change the way in which fetal monitoring is accomplished, allowing comfortable, close and continuous monitoring of fetal well-being.

Keywords: Fetal monitoring, wearable technologies, fetal ECG