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Expanding the HCI Agenda in Healthcare

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***Abstract*—Designing technology for use in healthcare, and its evaluation in the healthcare setting, deserves special attention because of the nature of the special context of use. Biological hazards and the risk of infection, issues of privacy and security, system response times, as well as human factors and patient safety are identified as areas deserving of special attention. We give examples and quote from clinician interviews for illustration, and we argue that increased focus from the HCI community on these areas will bring tangible benefits of health information systems to healthcare staff, and ultimately improve patient services.**

I. Introduction

In this short paper some special considerations in the design of technology for use in hospital settings are introduced. We identify *biological hazards and risk of infection*, *privacy and security*, *system response times*, and *human factors in patient safety* as topics that deserve special consideration in design, and in evaluation of health information technology.

II. Background

In health care environments, clinicians, nurses, doctors and other allied health professionals are often forced to work under pressure, with patients who have varying levels of dependency. The cognitive state of the staff is in constant flux. They move from periods of intense concentration, stress and watchful observation to relative calm and routine tasks. Although expert in their specialist fields, the work focus for clinical staff is on their patients, rather than on the technology that often mediates, or supplements, in their communication with their patients as well as with fellow staff members.

These large variances in cognitve states and work contexts rarely receive due attention in standardised system design and evaluation methodologies. While laboratory based evaluation and usability inspection methods can successfully identify perhaps the majority of the usability problems of a system [1], clinical work settings are generally not given the special consideration they deserve. Nielsen's "heuristics", for instance, have been used in different contexts and adopted almost uniformly in health information studies to test usability in domains as diverse as web-based EHRs, medical equipment, web design, Internet health tools and services [2]. The assumption of uniformity across such cases seems unwarranted.

Usability has been shown as a major factor in both acceptance and effectiveness of EHR systems in clinical settings [3], [4]. Usability evaluations can be carried out by administering surveys to users who provide explicit feedback. It can be argued that responses are likely influenced by the evaluator's cognitive state at the time. So, if they have been relieved of routine tasks to take part in the evaluation, and are relaxed and happy, the result may be benign. In the real work setting when staff are under stress, overworked and over tired, the system must perform to a higher standard than the laboratory evaluation for user acceptance.

Areas that are deserving of more attention are radiological diagnostic imaging, and digital pathology. Advances in imaging technology are facilitating the development of new specialisms such as the field of intervention radiology and are also making it easier for needle sampling of lesions for pathology, under vision, that previously were only accessible via surgical procedure. Developments in other medical sciences too, such as radiation therapy, orthopaedics and robotic surgery are all highly dependent on accurate visualisation, measurement and volume assessment in image data. Radiological imaging today can reproduce structural location, textural and functional data, and the precision which can be achieved is constantly being refined. Image processing tools aim to generate and manipulate images that enhance the information content for assessment. How people perceive and interact with a visualisation tool can strongly influence their understanding of the image data. For instance the inability to achieve the fine resolution needed in tissue sections, and difficulty in ability to navigate at high magnification are reported as factors limiting diagnostic accuracy in digital pathology [5].

In addition to these issues, which concern the ways in which interfaces are developed, and reliability of user feedback in evaluation, broader sociotechnical factors need to be considered when assessing usability from the perspectives of system acceptance and patient safety. We highlight some of these factors in this paper.

III. Methodology

Our observations reported here come from long-term ethnographic studies in hospital environments. Our studies include observations of medical, nursing and paramedical staff at work in clinical and non-clinical environments. Non-clinical settings include meeting rooms and offices. The clinical settings observed were laboratories, procedure rooms and operating theatres. Altogether over 10 years of observations in the various settings were experienced. Our observations include the implementation of a laboratory information system (LIS)

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Fig. 1. Dirty Keyboards can be a source of infection

from a paper-based system to a fully electronic LIS, and its evaluation before and after implementation. We also refer to a survey we conducted that was prompted by observed confusion among clinical staff while reviewing PET scan videos in the course of our work. A weblink to a PET scan video was circulated on staff and student email lists. There were 368 responses, of whom 53.8% were male, and 44% were under 30 years of age.

Our observations are supplemented with interviews from clinical staff. Over 70 clinicians were interviewed in the past three years about their use of computer technology in the hospital.

IV. Observations

We identify a number of situations in hospital work where special conditions apply for HCI theory, and we will present our observations under the following headings:

- Risk of Infection
- Privacy and Security
- Response time
- Human Factors in Patient Safety

A. Risk of Infection

Healthcare staff wear protective clothing while performing tasks in clinical settings. Where there is a risk of infection by a Category 3 microorganism (or higher) additional precautions are employed to minimise either risk of infection to the patient, or risk for the staff member.

Data entry using traditional keyboard and mouse while using gloves risks contamination of the keyboard and mouse. Indeed keyboards in heavily used areas can often be dirty, and constitute a risk of infection. Local policy can be confused - in some settings all staff may wear gloves while using keyboards, in other settings staff remove their gloves to use the keyboard. For either scenario, unless all staff adhere to the same policy there is a high risk of spread of germs. While many non-pathogenic organisms have been isolated from keyboards, potentially serious organisms have also been reported [6]. Reports of Bacillus spp., meticillin-resistant staphylococcus aureus (MRSA) which can be a very serious problem in some institutions are reasons for concern [7], [8]. New HCI technologies such as touchless interaction [9] may have a positive impact in these work contexts.

The fan mechanism inside as desktop computer has been known to be a source for the spread of microorganisms. It has

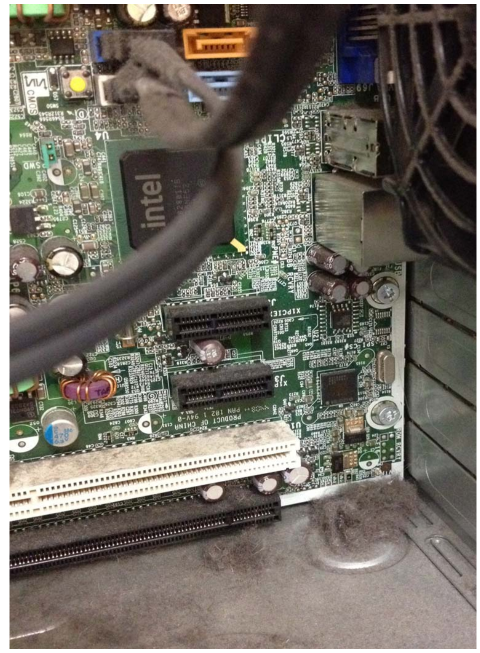

Fig. 2. Dust build-up can harbour germs, that are then dispersed by the fan

been reported that dust gathering inside the computer, can act as a reservoir for bacteria, which are then dispersed into the air through the vent by the cooling fan.

B. Privacy and Security

Patients expect that their data will be protected from unauthorised access. They also expect that it will be protected from external threats including water / flooding, etc.. Implementing privacy protocols can be challenging in healthcare. On one hand restricted access is desired to protect privacy, and on the other hand information must be shared in the interest of patient safety. When limiting access it is not unusual to use short time-out / log-out settings to control access to PC screens in order to protect data in the event of staff leaving a workstation unattended. However these security settings can be frustrating for staff who are working with a patient to gather data. An interviewee reported that:

> *"I meet a patient in one of the Out-Patient consulting rooms. I log into the PC with my ID number and password - that I have to change every so many days . . . and I fill in some detail. Then I turn to the patient to ask about something and when I turn to type that in, the screen has blanked and I have to log in all over again."*

Another claimed

> *"I believe that at any one time there are lots of staff spending time logging into the system. I've calculated that we employ 9 full time staff equivalents just to log in. Think of what we could do if we had 9 extra staff here!".*

C. Response Time

When systems are being evaluated, quite often the evaluation takes place outside of the real world setting where the work activity will be taking place. In the instance reported in [10] a team worked with a development group and the interface was thoroughly evaluated and tested in focus groups and laboratory settings. Yet, when implemented it was found to be unusable because the pace of work, and need for data entry, is so fast, that there is not time to enter the data that was once thought to be 'essential'. Medical work is often fast paced, and the traditional methods of data entry do not facilitate easy use. As one interviewee expressed:

> "*... by the time you take your hand from the keyboard to find the mouse, point it and click or whatever, you've lost too much time ... and the discussion has moved on*"

Lessons from Hart and Staveland's work in aircraft simulation tells us that we need to acknowledge the complexity of the interaction between the task and the mental workload of the subject. They proposed a multi-dimensional rating scale in which information about the magnitude and sources of six workload-related factors are combined to derive a sensitive and reliable estimate of workload [11]. Longo [12] describes an evaluation method informed by the aviation industry work that was successfully applied in a hospital setting. The reported evaluation utilizes a combination of NASA-TLX and Nielsen's heuristics to evaluate an electronic patient record system. It is argued that for complex work settings such as hospitals, evaluation systems need to be better developed that take into account the cognitive load of the user.

D. Human Factors and Patient Safety Time

Intuitively, improved interfaces can be expected to reduce medical errors and improve patient care. However we seem to give little consideration into the possibilities of our interfaces facilitating new errors, and introducing additional risks into patient care.

In our study of how people interact and perceive Positron Emission Tomography (PET) scan images, (reported more fully in [13]), we demonstrate how an individual's perception can strongly influence how the data are visualised. The responses from 368 individuals with respect to the visualisation of the circulated link to the PET scan video are given in Table II. Our results show a range of results: some see the image rotating clockwise, other anti-clockwise, and some see the image in oscillation, or even still. One of those who reported seeing a still image, followed up afterwards to say that when he looked at the image on his phone it was still, but on his computer he could see apparent rotation.

It is at first surprising that this visual illusion believed to be accounted for by the *lack* of depth cues, is sustained in the PET scan video, that demonstrates internal anatomic structures, partial occlusion, semi-transparency and other features one would expect to provide depth cues. However, the lack of shadows, shading, perspective and texture gradients may account for the difficulty in perceiving depth in the figure, as these features have been shown to allow perception of opaque volumetric objects [14], [15].

TABLE I
REPORTED MOVEMENT OF PET SCAN VIDEO

Movement	Frequency	%
Clockwise	148	40.2
Anti-Clockwise	42	11.4
Both directions - Equally	51	13.9
Both directions, Clockwise dominant	76	20.7
Both directions, Anti-Clockwise dominant	50	13.6
Stationary	1	0.3
Total	368	100

Observers sounded puzzled when reporting their observations. One observer reported that *"... depending on which part of the body I focus on the direction of rotation appears to change"*. Another noted that *"without the heart as a reference point it can appear to be going either way"*. One non-medical observer reported that *"If I focus on the body it seems that he oscillates from one side to the other, always facing forward ... even though the heart changes sides ... "*. Another reported: *"(he) seems to rotate from one side to the other and back, always facing me"*, while another said he moves *"from right to left and back again"*. This apparent oscillation has been recorded in the hollow mask illusion, another class of bistable illusion that is associated with a bias to perceive convexity in a face [16].

That such variation in observation should be reported is a cause of concern and warrants further investigation. Given that many errors in medicine can be attributable to miscommunication of information, and the central role of radiological imaging in medical work, it is a natural question to ask if such visual illusions may be underlying some mislabelling of patient laterality [17] and contribute to errors.

Accuracy of diagnosis, and ultimately the efficacy of diagnostic radiology, depends on the conditions under which patient images are viewed [18]. The interpretation of medical images, mediated by computer, is an area that has been gaining attention but remains to be fully explored with respect to human-computer interaction [14].

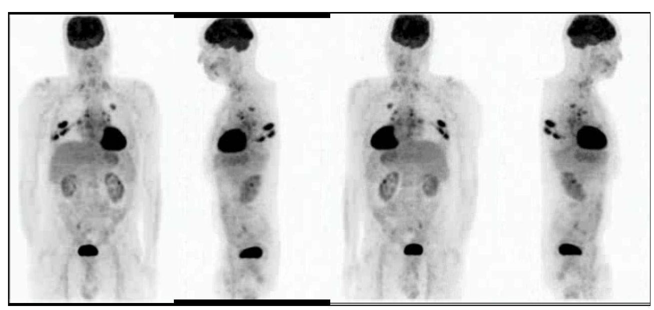

Fig. 3. Images from PET scan video. Depending on one's perception, the figure appears to be turning clockwise, anti-clockwise, or in both directions.

There is growing recognition that more attention should be paid to users who must view and manipulate the data, because how humans perceive, think about and interact with images will affect their understanding of information presented visually. The strong need to study human factors as a basis for medical visualisation design is further emphasised by the rapid advances in graphics hardware devices for 3D visualisation in this field [19]. It is critical that any HCI issues that may influence the interpretation of image data must be fully understood and measures put in place to minimise any detrimental effects introduced by the system, or tool.

We examined our data for differences in perception by gender, and also by left or right handedness. Table II gives the breakdown of

TABLE II
FREQUENCY IN OBSERVATIONS BY GENDER AND HANDEDNESS (% FREQUENCY)

	Still	Clockwise	Anti-Clockwise	Equally	Moves in Both Directions Clockwise dominates	Anti-Clockwise dominates	TOTAL
Gender							
Male	-	85 (42.9)	24 (12)	27 (13.6)	41 (20.7)	21 (10.6)	198 (54)
Female	1 (.6)	62 (36.9)	18 (10.7)	23 (13.7)	35 (20.8)	29 (17.3)	168 (46)
Unknown	-	1	-	1			2 (1)
TOTAL							368
Handedness							
Right	1 (0.3)	130 (42)	37 (12)	39 (12.6)	62 (20.1)	40 (13)	309 (84)
Left	-	15 (34.9)	5 (11.6)	4 (9.3)	11 (25.6)	8 (18.6)	43 (12)
Ambidextrous	-	-	-	5 (62.5)	2 (25)	1 (12.5)	8 (2)
Unknown	-	3	-	3	1	1	8
TOTAL							368

our results. There is little difference between men and women in this study, but we have demonstrated a small but significant difference between left handedness and right handedness.

E. Introducing Errors

Ash [20] and others report many instances in which healthcare applications seem to foster errors rather than reduce their likelihood. Koppel's study [3] found that the errors prevented in wrongly interpreted handwriting were replaced by errors generated through interaction with the interface in an electronic prescribing system. The system often facilitated medication error risks, with many errors reported to occur frequently. Although 'error prevention' is listed as one of Jakob Nielsen's 10 heuristics, issues of errors generated through badly designed interfaces are often overlooked in evaluations. There is a great need for the development of techniques that can generate data to predict the technology *in use* in healthcare settings, and contribute to real improvements in patient safety.

V. CONCLUSION

As methods continue to evolve to evaluate the use of technology in healthcare, we argue that evaluation methods should take account of actual use, or how the tasks are performed, in real settings. Appreciating the healthcare work environment can be hazardous, and that the tasks are often carried out in difficult circumstances, our IT systems should be robust enough to withstand the conditions. Furthermore IT systems should enhance the work environment and reduce the complexity of the tasks, as well as the mental workload of the users.

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