Finger Instead of Mouse: Touch Screens as a Means of Enhancing Universal Access

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Abstract. Touch-Screen Technology is the most natural of all input devices - even children can easily learn how to operate them. But this simple interaction proved also to be ideal for people who are not overly familiar with computers including elderly and/or disabled patients in a hospital. A pilot system of an interactive Patient Communications System (PACOSY) has been developed in a User Centered Design (UCD) process. Patients were enabled to retrieve and enter information interactively via various touch screen systems connected to the Hospital Intranet. This paper concentrates primarily on experimental experiences with touch technology and the technological requirements for a touch based Patient Information System (PATIS) serving as Point of Information (POI) for patients within a hospital or a future Point of Consultation (POC). People with low or no computer literacy found using touch screens easy and motivating. Together with a cheap, simple and user friendly interface design, such systems can enhance universal access within an information society for all.

"Each Pointing concept has its enthusiasts and detractors, motivated by commercial interests, by personal preference and increasingly by empirical evidence" (Ben Shneiderman, 1998, p.323 [1])."

1 Introduction

A pilot system of an interactive patient communications system (PACOSY) was developed at the Institute for Medical Informatics, Statistics and Documentation (IMI) using an User Centered Design (UCD) Process. The System was tested with and developed for elderly and partially impaired patients at the clinical department of Oncology at the Medical University Hospital in Graz (Test group). This 2.300 bed hospital is amongst the biggest in Europe and serves, together with 21 County hospitals, a population of more than 1,6 million people living in Styria (Austria). The aim of this paper is primarily to report experiences, with the focus on appropriate hardware, and secondarily to raise awareness and thereby stimulate extensive further research.

Experience with the focus on the User Centered Design (UCD) was presented at the 8th International Conference on Computers Helping People with Special Needs from 15-20 July 2002 at the University of Linz, Austria [2].

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2 Aims and Goals: Simple, Cheap, Easy to Use

According to Stephanidis & Savidis (2001), [3] simple, cheap and easy to use solutions in information technology (IT) can be a step towards an information society where everyone can have access to relevant information, which is considered of paramount importance for its success [4]. The author is of the firm opinion that this project with patients in public hospitals is a start at achieving this ambitious objective.

The test group began with little to no computer literacy. According to McMillan (1996), [5] literacy is defined as the ability to process information using text. Thus, computer literacy may be defined as the ability to process information by using an information device. By using such systems this population can be made familiar with computers generally and the computer anxiety can be reduced [6]. It is interesting to note that, according to Robertson & Hix (2002), [7], most research on the use of computers by mentally (as apposed to physically) retarded people falls into two general categories:

- Computer science literature discusses advanced assistive technologies (e.g. speech synthesizers) but rarely addresses the usability of commonly available devices;
- Educational and psychological literature describes the use of computer technology in special educational settings, focusing on teaching techniques, but rarely addresses the usability of commonly available devices.

3 A Vision: Computers for Patient Education

Since almost every hospital bed has a television set, why not a computer?

According to Lewis (1999), [8], patient education has recently emerged as a component of health promotion and disease management programs in response to increased pressure to provide more relevant and concrete information at lower cost. Lewis (1999) further suggests that the use of information technology to increase patient knowledge and their involvement in health care decisions also leads to better health results and reports that several studies described that elderly patients, with very little prior computer experience, had reported satisfaction with computer based learning technologies and successfully acquired information about health and disease related self care (see also for example [9], [10], [11]).

According to Jones (2001), [12], particularly cancer patients tend to lack information regarding their illness and are often dissatisfied with the information and support they receive. In response, educators and health care professionals are developing better ways to inform patients and their families about their medical condition, possible treatment and self-care.

According to Ellis (1987), [13], or Bental et.al. (1999), [14] computers have been used generally in patient education for many years. Without being a replacement for personal contact with professionals, there is evidence that they complement this, providing the patient with easy access to both specialist and general health topics. Bental et al. (1999) discovered that patients, given a suitably designed interface, find accessing computer information acceptable and often less embarrassing than asking apparently trivial questions of health professionals. Direct access may not be neccessary, computers could be used to produce personalized leaflets and letters automatically, or dictate personalized spoken information over the telephone.

Adapting Information to Patients Needs

One potential advantage of computer based resources is the possibility of automatically adapting the material to the particular needs of individuals and organizations accessing the information. The material can be selected and presented according to rules supplied by the programmer. This *can* be as simple as inserting the patient's name to personalize the information. Bental et al. (1999) considers tailoring the content of the material or the way that the content is presented to fit the needs of the individual.

Electronic Questionnaires

It is obvious that paper usage can be reduced and information processing can be enhanced by using computer supported questionnaires (see for example [15]). These can either be on local POIs or more conveniently on mobile devices (e.g. a workpad solution).

4 POI, PATIS, and POC

Point of Information (POI)

In commerce, a multimedia kiosk is generally used as a Point Of Information (POI). If the kiosk includes a transaction component to buy goods and to pay for them by credit card it becomes a Point Of Purchase (POP) or a Point Of Sales (POS), similar to vending machines.

Patient Information System (PATIS)

PATISes are increasingly popular although, according to van't Riet, Berg, Hiddema and Sol (2001) [16], there are not many documented success stories: A core issue for such systems is their usability. This must include the extent to which the system takes the actual needs and capacities of the patients into account. Van't Ried et.al. recommends [17] for a review of PATIS.

Point of Consultancy (POC)

A point of consultancy could provide specific information on demand. The type and presentation manner of this information is a matter for further research.

5 The Patient Communication System PACOSY

A compulsory prerequisite of the design was to provide a stable system, which returned to a defined initial state on exit, however, no special precautions were taken to avoid deliberate vandalism.

At first the solution for a specific clinical task stood in the foreground: An interactive questionnaire, replacing the written questionnaire, is completed by the oncology patients immediately on arrival, and particularly asks about their state of mind. From the viewpoint of the departmental psychologist in charge the objective is a screening: on the basis of the responses he is able to build an opinion as to the necessity of immediate support etc. Comparisons between conventional usage of written and computerized questionnaires (e.g. from Peterson & Johannsson (1996), [18]) showed that computerized versions could be advantageous. An automatic alert is being considered, either over the network and/or in the form of a screen output and/or on the mobile phone of the psychologist in charge and will be implemented in a later version. Although anonymity is not considered advantageous, confidentiality is necessary to inspire trust. Special concern was given to navigation through the questionnaire (refer e.g. to Nielsen (1990), [19]) and the simplicity of the user interface.

A cheap, scalable, standard solution within the hospitals Internet with extensive use of the hospitals standard equipment (PCs, Microsoft-Windows, MS server) was aimed at. The same software supports touch screen and mouse alternatively. In the future this solution should be adaptable to other clinics with a minimum of expenditure and supplementary programming. The most important objective was maintainability of the content by clinic personnel (secretary etc.).

The system was constructed to act as a client server system defined by HTTP. The client connects, using a standard browser to a server within the Intranet via TCP/IP and requests the Webpage. This is sent in the form of an HTML page, which is correspondingly interpreted by the browser and displayed graphically [2].

6 The Finger as Natural Input

Since touch screens literally put the fingers in touch with what is on your computer screen, this technology is considered as the most natural of all input devices. The most obvious advantage of touch screens is that the input device is also the output device [20]. Being able to touch, feel and manipulate objects on a computer screen, in addition to seeing and hearing them, provides a sense of immersion [21].

Thus it is most commonly and effectively used for simple applications where any person can easily use without prior experience or instructions. Since touch screens do not need any added accessories such as keyboard and mouse, it also saves working space. On the other hand, they are not ideal for users who need to point accurately to a small area on the screen, for widespread searches or for handling significant amounts of data entry. Neither are they optimal for implementing complex tasks.

7 Experimental Setting and Methods Used

Twelve patients took part in specific experiments (also including the User Centered Design). The participants were tested individually. Each participant was first interviewed to gather demographic data; age, gender, preferred hand, visual and physical limitations, and computer literacy. All of them had absolutely no computing experience. Besides other inquiring techniques, video and audio recording was running and written notes were made (refer also to [2]).

8 Findings and Discussion

One of the main objectives of the first experiments was choosing the most appropriate hardware technology. At first we divided Touch Systems into two sections:

- Touch Screen Technology (resistive, capacitive, acoustic, infrared); and
- Casing types (kiosk, panel, webpad)

Almost all touch screen companies sell integrated systems as well as components to convert monitors into touch screens. The latter possibility was rejected. Each touch screen system includes three components that can be configured in various ways: 1. The sensor touch screen which serves as the user interface; 2. The controller, which processes the signals from the sensor screen and passes the event data to the computer; and 3. The driver software, which makes the touch screen compatible with the local operating system.

General Touch Advantages and Limitations

Although touch screens proved to be an intuitive interface, however it was recognized that they were unsuitable for entering large quantities of data.

Touch Screen Technology

There are several different types of technology employed by touch screens currently on the market: resistive, capacitive, surface acoustic wave and infrared light.
Only the first three types were examined and the following results obtained:
1. General

The technical constraints that limit the design and deployment of these touch screens are very specific to each type. In general, these deal with factors such as the clarity of display, the specifics of interaction, and the maintenance of the touch screen equipment. Due to such constraints, touch screen deployment is limited to certain environments and specific tasks [22], [23]:

2. Resistive Touch Screens

A mechanical pressure on this type of screen closes an electrical contact between two conductive layers. Since the pressure only sets up a connection between the two layers, the resistive touch screen can be activated by any solid object: a gloved finger, a pencil etc. This technology is used for Personal Digital Assistants (PDAs) e.g. the Psion and Palm. Advantages include no necessity of alignment (justifying), exact positioning and the possible use with gloves, i.e. in the medical field.

2. Capacitive Touch Screens

A pane of glass coated with ultra-thin metal lies over the actual screen of this type. From the corners of the display, a low voltage of alternating current, which creates a weak electrical field, is applied to the electrode grid of the conducting layer. When the user touches the screen they simulate a form of condenser electrode and "ground" the area (field). From the (low) electricity, which is diverted around the user's finger, the touch controller determines the respective coordinates of the contact point. Correspondingly, capacitive touch screens only respond to the touch with a conductive object (special metal pen, finger etc.). Advantages include higher resolution, higher light efficiency, not influenced by surrounding light; Disadvantages include the necessity of calibration and sensitivity to errors from exterior influences.

3. Acoustic Touch Screens: Surface Acoustic Wave (SAW) Technology

SAW-Technology is based on sound waves. The edges of the screen are equipped with ultra sound transmitters with reflectors at each opposite edge and a piezoelectric receiver in one corner. Ultra sound waves are continuously being sent across this reflector system. As long as this field is undisturbed the waves arrive without obstruction at the receiver. However, if the field is disturbed, through a finger, pen or similar, then the position of this object is determined from the missing wave course within this field.

The following table shows briefly the obtained results.

Table 1. Comparison of touch technology

	Touch Resolution	Luminance	Response time	Calibration
Resistive	high	< 160 cd/sqm	< 15 ms	once
Capacitive	high	200 cd/sqm	20 ms	regularly
Acoustic (SAW)	medium	> 250 cd/sqm	> 20 ms	once

Luminance

Luminance was the most critical parameter and finally the selection factor for the choice of touch screen. In principle it is the luminous intensity per unit area. The SI unit is candela per square meter (cd/sqm). The luminance can be measured by spectroradiometer. Typical Cathode Ray Tube (CRT) screens have a luminance of approximately 300 cd/sqm [22].

The resistive technology was not suitable due to the disadvantages: unfocused, low brightness - determined by the number of layers applied - and a less durable monitor.

Taking a normal LCD monitor with a brightness of 200 cd/m² and an LCD monitor with surface wave technology and 185 cd/sqm as the optimum parameters, it can be seen that a five-wire resistance touch screen, which proved to average less than 150 cd/sqm and a capacitive touch screen with more than 200 cd/m^2 were unsatisfactory.

Finally, the (SAW) technology proved to be the most usable for our purposes, due to its single glass panel and highest clarity. Its drawback was that it is relatively easily affected by contaminants on the screen, which absorb the waves and cause dead zones. Also it is not very flexible; in order for an acoustic wave to be sent, the screen must always be touched with a finger; something hard like a pen did not work.

Casing Types

Three types of casing types were examined: Kiosk systems, panels and webpads. Kiosk: An abundance of different Kiosk Systems were examined and tested, but proved to be unsuitable. Webpads: Currently available Webpads did not meet our specific demands. Future Webpads, if commercially available, could be advantageous but must be further tested.

Based on the results of our examinations we decided to rely on a Panel solution and excluded whole Kiosk Systems due to the fact that they are too heavy and unwieldy. The best experiences were made with Panel PC's which can be mechanically used in three different ways:

- mounted on a desk
- mounted on a wall (swivel arm) and
- used as a mobile panel

For bedside use we suggest a panel mounted on swivel arms. These are in use with television sets but not available to date with touch computers. The following table briefly shows the results of the examinations of the three types:

Table 2. The three categories of touch systems

		Weight	moveability	sturdiness	comment
Kiosk		> 100 kg	none	very high	robust, but not suitable for our specific task due to immobility and no adjustable viewing angle
Panel-PC		12 kg	good	medium	most suitable, chosen for further experiments
Webpad		< 1 kg	very good	low	could be suitable in the future, when better pads are available

Hand/Eye Coordination and Time for Pointing

The patients reported that they found the operation of our system easy. This was mainly due to the use of direct hand/eye co-ordination. Fitts' Law was taken into consideration during the design. According to Fitts (1954), [24], the average duration of responses is directly proportional to the minimum average amount of information per response. Also the time to move the hand into contact with a visually presented object (button) is a function of both the size of object and its distance from the hand. The time for pointing *tp* is a function of both the distance *d* of the reach and the width *w* of the target object. This relationship can be expressed in the following formula where *a* and *b* are empirical constants and vary depending the used device [25]:

$$tp = a + b * \log 2\ (2d/w)$$

The expression log2 (2d/w) is, according to Shneiderman (1998), [1] also called "index of difficulty". Understanding how manipulations of *d* and *w* affect the time *tp* is of considerable importance in developing efficient touch screen interfaces. Within certain parameters (including the dimensions of the screen) we had control over the size of target objects and the distance of the user from the screen (figure 1).

Fig. 1. An example for the used buttons

Measurements of time used for the selection of the touch bottoms showed similar results to the original experiments by Fitts (1954): We measured the time from the point where the participant's intention to touch the screen was recognizable to the actual triggering of the touch button. The results were as follows:

Minimum t = 2s
Maximum t = 10s
Average t = 3,3s

It was noticeable that run-aways to the above border were reduced with increasing examination time. The values oscillated more and more towards the average.

Viewing Angle

The Viewing Angle (refer to Schultz et.al. (1998), [26] for theoretical details) proved to be highly important and differences caused adaptations (i.e. we had to set the angle in dependence of the patient size), which were very disturbing during the experiment. In this case a Webpad could be a better solution.

9 Future Outlook

At the beginning the main concern was the thorough examination of useable touch screen technology and the comparison of different casing systems (Kiosk versus Panels).

The first stage was the implementation of a specific clinical task (questionnaire for screening) using an User Centered Design (UCD) involving patients and clinic personal. For further details refer to Holzinger (2002) [2].

At a further stage, the implementation of a generally usable Software/Hardware solution for patients on a variety of different terminals is planned. A possible application could run both in the Graz University Hospital and in all Styrian County Hospitals. Central research question could include:

- What demands on information do in-patients have?
- What demands on information do out-patients have?
- What must be considered in the information design?

It is possible to examine how different patient groups from different hospital departments (e.g. childrens department, eye-clinic, etc.) work with such systems and how these systems must be ideally designed (User Centered Design). As a benefit the departments gain a fully working global PACOSY with POIs in different locations and with bedside PACOSY.

The range of information intended for the patients could include:

- departmental information (about medical doctors, nurses, etc.)
- administrative information (insurance information, services, etc.)
- information about their illness (prevention, treatment and therapies)
- information about their surroundings (orientation, maps, views and floor plans).

The range of interaction for the patients could include:

- on-line questionnaires (e.g. screening, contentment, feedback, etc.)
- ordering menus (including diet consultancy)
- interactive medical and/or psychotherapeutic consultancy (in the sense of a on-line point of consultancy - POC)
- even surfing on the Internet could be possible on demand

Studies as to the kind of information relevant and helpful to patients, the type of interfaces which could be most beneficial and experiments with talking interfaces [27] would be interesting. Especially spoken language technology could be of real benefit to the targeted audience [28].

These aims are in close compliance with the research agenda of the European sixth framework program where the topic Human-Computer Interaction gains a steadily increasing importance [29] and these topics could be a focus within an future European Research Project.

10 Conclusion

Although the first sample population was small, the experiments showed results, which are in accordance with existing literature: Most of the patients reported that they "liked this kind of computer" and all found the touch interface simple to use. A Panel PC proved to be best suitable in connection with a simple interface design. The limits of such an approach are in speed and in the level of information, the depth of commands and arm fatigue. Thus, every interaction element must be carefully considered.

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