Bridging Technical and HCI Research: Creating Usable Ubiquitous Computing

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Abstract

This paper describes methods used to support collaboration and communication between practitioners, designers and engineers when designing ubiquitous computing systems. We tested methods such as "Wizard of Oz" and design games in a real domain, the dental surgery, in an attempt to create a system that is: affordable; minimally disruptive of the natural flow of work; and improves human-computer interaction. In doing so we found that such activities allowed the practitioners to be on a 'level playing ground' with designers and engineers. The findings we present suggest that dentists are willing to engage in detailed exploration and constructive critique of technical design possibilities if the design ideas and prototypes are presented in the context of their work practice and are of a resolution and relevance that allow them to jointly explore and question with the design time. This paper is an extension of a short paper submitted to the Participatory Design Conference, 2004.

Keywords

Human-centered design, participatory design, interaction design, design games, ubiquitous computing, multimodal interfaces.

INTRODUCTION

It has been more than a decade since Mark Weiser's (1991) seminal article "The Computer of the 21st Century" defined a vision for the now familiar term "ubiquitous computing". Although computers have achieved ubiquity in the form of wired and wireless devices such as mobile phones, PDAs, screens, and embedded microprocessors, in many cases they have not blended into the background to seamlessly support human activity in the way envisioned by Weiser. Some practitioners have successfully adopted stand alone items like PDAs, modifying their practices in order to take advantage of new technology and sometimes integrating them with other devices.

However, the leap from adoption of single machines to adoption of multiple machines operating as a ubiquitous computing environment is often less than ideal. As Weiser pointed out, the problem of designing ubiquitous computing is not due to technical challenges alone but demands the "very difficult integration of human factors, computer science, engineering, and social sciences." These problems are manifest in infrastructure costs, deployment difficulties, practitioner training needs and uptake difficulties (due to systems being designed from a technical vision, rather than designed to meet the needs of particular work practices). In order to explore these issues for ubiquitous computing, it is necessary to consider both the practitioner interactions, practices and capabilities (such as the ability of practitioners to integrate devices into their practices), and the characteristics of technology and its underlying infrastructure. This suggests that rather than develop a complete concept for a ubiquitous computing environment and then build a research prototype that is removed from a work practice context, a participatory bootstrapping approach is needed. In such an approach designers reveal the capabilities and characteristics of technology and technical infrastructure to practitioners in intelligible ways (practitioners often find the details of infrastructure both mundane and baffling) and practitioners try out and explore the possibilities for such technologies to enhance their practices in the context of their work environments.

This paper attempts to provide insights into different approaches to the design process that allow more effective communication in design. The first section of this paper examines some existing ubiquitous computing design approaches and potential alternative approaches. The following section discusses our attempts at putting our design methodologies into practice in the domain of a dental surgery and the resulting design outcomes. The final section summarises the principles learned and explains future events planned for further refinement of the design.

DESIGNING TECHNOLOGY

There are many examples of ubiquitous computing systems that demonstrate potentially useful technologies but that lack a sense of practitioner involvement and have generally not explored how they will be embedded into practice. Use scenarios are often impoverished. While such research is useful for testing new technology, it does not necessarily provide new perspectives on design or push the boundaries of how we conceive of the possibilities for these systems. We began to look at how to have conversations with practitioners in their context of use about ubiquitous technology through "Wizard of Oz" techniques and low-fidelity prototypes that represent key interaction abilities or core technologies, a common currency of language and understanding between practitioners, designers and engineers can be found.

Augmented offices

Work carried out by the Xerox Research Centre Europe imagined what a future office may be like (Andreoli et al. 2003). Their aim was to create an "affordable enabling infrastructure", with a basic assumption that technology in their scenarios would be both inexpensive and readily available. While this assumption may hold true, it would be instructive to explore the scenario from the point of view of the end practitioner through participatory design. An example scenario given by the researchers describes a practitioner attempting to print a document. RFID tags embedded into the paper would allow the practitioner to locate their document quickly and efficiently. If a practitioner attempted to print a document when a large file was already being printed, the option to initiate a negotiation of printer priority would be available. The printer would initiate a phone call to the owner of the large print job to facilitate this.

A participatory design approach might explore business practitioners impressions and experiences in locating a job by RFID tags, examine what expense was considered worthwhile, reveal what other things they might do with technology such as RFID tags, examine the logistics of tagging each piece of paper with an RFID tag, examine practitioner privacy issues, examine under what circumstances office workers would be happy to be interrupted from their work to negotiate time on the printer and so on.

Networked surfaces

A recurring theme in ubiquitous computing research is the idea of networked surfaces. Research into this field has investigated using the surface of everyday furniture such as desks, note-boards, etc, as a means of communicating between sensors and other machines. This allows the devices to both receive power and to communicate without requiring bulky components within their own package to facilitate this independently.

Conceptually, this fits nicely with ubiquitous computing's ideals. However many examples given by the Pin&Play project (Laerhoven et al. 2002) use the surface only as a source of power and not communication. Lifton and Paradiso's (2002) Pushpins have a range of only approximately ten centimetres. Thus there are several factors that could be explored through participatory design. For example, by engaging participants one could examine the context in which such surfaces would be used, which items use the surface for communication, which simply need it for power, how other technologies such as wireless technologies compare, how communication range issues affect usability, other imagined use of the surfaces, costs, etc.

Interactive rooms

There have been a number of projects that aim to empower entire rooms with computing abilities. By embedding these computers into most of the furniture and walls, computing abilities are argued to be ready-at-hand. For example, the i-LAND project (Streitz et al. 1999) makes use of tables as scanners, desks as collaborative spaces and walls as computer screens. While this technology has made the transition to a commercial product, it comes at significant cost. Having been built as a specific technological platform and product for a generally perceived use, its users must either find specific problems that fit the technological product or adapt the technology to meet user practices and contexts. In order to accommodate a specific technology configuration that is not designed with their work practice in mind, users typically need to undertake large shifts in work practice. While this may be considered desirable, the alternative work practices are untried and unknown.

Atelier Project

Binder and Warren (2003) describe research where architectural students were given both barcodes and RFID transceivers to use in their designs. In their project they used a participatory design approach and utilised simple and off-the-shelf technology. They found that barcodes and their associated readers were more easily appropriated as tools for interaction than the RFID transceivers and readers. The suggested cause was that while barcodes and barcode readers have a place in every day lives (and therefore a common understanding of their use), the technology of RFID does not suggest uses for its interaction. Its mere lack of familiarity restricted its use. This highlights the need for effective communication of technological ideas, allowing a more informed design in a participative process.

CREATING COMMUNICATION IN DESIGN

We have attempted to create effective communication channels between practitioners, designers and engineers through a series of design activities. These activities were modelled around the use of games and role-playing. Games have been used in design since Habraken and Gross (1987) used 'concept design games' to explore interactions in the design process. These games lack the element of competition found in most everyday games, and when using games in our design process, the definition of a game blurred further. Our games had rules, a task to complete and multiple participants working together towards a common "fun" goal. They did not make use of board game metaphors used by other designers but had more of a sense of 'play'. For example, students were asked to solve a particular problem of interaction in the surgery with one student role-playing as a dentist completing a check up, while the other acted out the new method of interaction.

Games and role-playing are vehicles for physical and visual interaction (rather than abstract discussions of design) while also provoking thought about and discussion of potential designs. Furthermore, practitioners can offer only limited time to design, and games provide an organised framework for concentrated design sessions (Pedersen and Buur, 2000). Given the demanding schedule of dentists, we found short participatory activities useful for both increasing involvement and to structure our design activities for the short amount of time that we had.

The basic concept behind the activities we used is to allow practitioners to reveal details of their work practice in conjunction with the designers revealing technological potential. Low-fi prototypes allow the practitioner to imagine possible uses. Instead of the technology 'declaring' how it should be used or what it is capable of, the practitioner is instead able to imagine ways to modify or adapt it. The ambiguity of mock up or simple prototypes is key to allowing this kind of flexibility.

In-situ activities are useful for designers. They reveal how the participant interacts with devices within their actual work environment, and the designers are informed of problems or potentials in the design. Furthermore, the practitioners are in their everyday domain. This means they are familiar and comfortable with the design environment. In this way, games place all parties on a level playing field.

Our aim in our research was to try out these techniques in a specific domain in order to see what they revealed.[1]

The dental surgery

Our research has focussed on studying the domain of a dental surgery. This environment exhibits a rich combination of both human interaction and instrument use within a complex social environment. Dentists are turning to computers to help manage patient records, to assist during procedures, for patient education and to display digital x-rays and pictures taken by intra-oral cameras. The majority of dentists in Australia have a computer in the surgery. However, during a procedure, a dentist must adhere to infection control standards. Primarily, the dentist must remain clean[2] by wearing gloves. These gloves are then removed in order to use things like a keyboard and mouse which are not easy to disinfect or sterilise. The dentist also works closely with the patient in a dental chair, which makes access to a computer physically awkward. Placement of the keyboard, mouse and monitor to fit in with the traditional dentist-assistant-patient layout is difficult. All of these factors combine to make the use of a traditional computer interface disruptive (figure 1).

[1] In this paper we use the terms participatory design and where we adopt the word "user" we do so with caution; whereas we aspire to technology that integrates into all aspects of work practice, the term "user" is often coupled with functions and goals and a tendency toward instrumentalist solutions. We aim to consider social, informational, physical and spatial aspects of work as well as the embodied skills of participants. We take the approach of participatory design in order to learn about all aspects of participant work practice and as a result we think of this research as belonging to a field of human-centred design.

[2] In dentistry, there is a distinction between clean and sterile. Instruments only remain sterile while they are within sterile packaging. Once removed, they are considered 'clean' instead, until they are placed in the patient's mouth. Likewise, benches and other equipment are considered clean, not sterile. Anything that comes into contact with the patient is considered dirty.

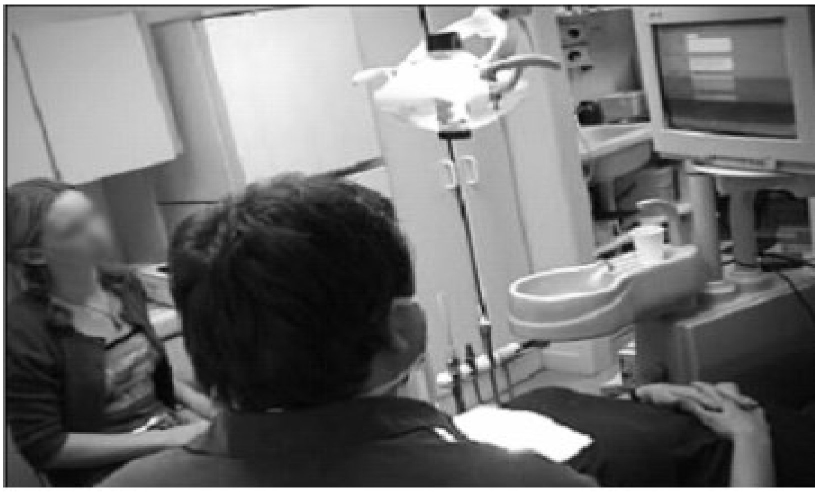


Figure 1: A typical layout with computers in a dental surgery

During our research, we collaborated with both dentists within private practice and students and staff at a dental school. These different groups provided slightly different viewpoints on their interaction within the surgery. Dentists within a private practice are used to 'four-handed dentistry', while the students are more independent as they share their assistant with other students.

The dental school

We undertook an ethnographic study at the dental school which lasted two months and consisted of seven visits. It was during this time that we gained an insight into how the school functioned and of the work practices of the students and staff. We used both contextual and informal interviews in order to familiarise ourselves with dental practice and as a springboard for organising design events and creating prototypes. We identified potential technologies for facilitating information work in dental surgeries, such as a digital pen, multimodal interfaces and 'smart' instruments with an associated 'sensing' table.

The digital pen

Through our ethnographic studies, we gained a sense of the existing work practice. At the dental school there are a large number of students working concurrently. In addition to this, the chairs are shared across sessions, so a single chair may be used by up to four different students in a single day. Although the dental school plans to completely convert to digital records, the number of chairs and the sharing of equipment make this a slow transition.

During our study, we discussed how information was handled using existing procedures with the students, lecturers and the secretarial staff. Notes regarding the procedure completed by the student are written on a piece of paper while the student is still 'dirty'. These notes are then transcribed at the end of the procedure to the official record and returned to secretarial staff. The staff are then required to transcribe the codes for tasks completed and equipment used during the procedure to a computer based record. The students were unhappy with the system as when they were in a hurry (as they often were), transcribing at the end of a procedure was both tedious and time-consuming. The secretarial staff also found difficulties with the system. Although part of the patient record was stored on computers, they had no simple method of sharing the record between departments. It took a lot of time to photocopy records for other sections or to organise the transfer of the files.

Since many other surgeries use computers, use of a computer based system was discussed, however issues such as high costs, restricted physical space, existing computer infrastructure and the need for additional training of students in dental software meant the response was lukewarm. These discussions generally took place immediately after a procedure with a patient and after using their existing system. We also had informal interviews when the lecturer or students had time free. However, we had to be careful when discussing their needs and the technological possibilities; we tried to provide our expertise in technology while still collaborating with the practitioners, and not guiding the design by ourselves.

These interviews found that many of the students were not interested in using computers in the surgery because of the infection control issue. As with the architects discussed by Binder and Warren (2003), they were accustomed to the keyboard and mouse paradigm of computing. However, once an array of different technologies were shown, explained and 'played' with by them, not only did students begin thinking of new ways to incorporate computing into their dental procedures, but they also began informing other students of the technologies shown.

We found similar results with both the lecturer and a member of the secretarial staff when we approached with the idea of a digital pen. We thought a digital pen has potential within the dental surgery and as such prepared a prototype that allowed the pen to be used with the dental record in the surgery. We organised a meeting with the lecturer of the dental school and allowed her to use the pen with the record and to see how this translated to a digital representation, and how this representation could be further manipulated. A transcript is presented below of a conversation that followed this activity:

> Researcher: "So I think it's just downloading."
>
> Lecturer: "Is that cleanable or sterilisable or what?"
>
> Researcher: "Well yeah, that's one thing I wanted to talk to you about. Because when they use pens in the surgery, don't they just wrap them in glad wrap?"
>
> Lecturer: "Yes, they do."
>
> Researcher: "So would that be alright for that?"
>
> Lecturer: "Yes, that could be alright because they wouldn't be touching… touching the tool. So that could be wrapped in glad wrap, and probably wiped down with disinfectant afterwards, would that affect anything?"
>
> Researcher: "No, it's sufficiently packaged so you can wipe it down."
>
> Lecturer: "Isn't that neat? Isn't that cute?"
>
> Researcher: "So, do you see benefits in that system…or?"
>
> Lecturer: "Yes, I think so actually. Again, you'd have to have a clinic which is completely set up for it, but I can see that… you see [the secretary] has to transcribe it – I didn't put item numbers and things like that, that's what she needs to transcribe to the other records – so she needs, you know, to save her searching through everything."
>
> Researcher: "So, I was just thinking in terms of impact on a surgery, for example, here, no one uses computers. But if you just had a little cradle thing put in at each desk, and then when you put the pen in it sent all the pages over to the office then you could keep all your existing work practices, and just make life a bit easier for [the secretary] I guess."
>
> Lecturer: "Yes, I think it's an interesting concept actually, it's very neat. Very impressive. How much does that cost?"

Before this demonstration the lecturer was not enthusiastic regarding digital writing technology. As seen in the transcript, through the demonstration, the lecturer becomes interested in the technology as it appears to meet their needs. During our earlier discussions and interviews with the lecturer, there seemed to be an almost definable turning point of interest in the technology. However, it was not until she had the ability to play with the technology and discuss its technical properties and functionality that the lecturer started imagining future usage scenarios and possible usage constraints. After the demonstration she showed the pen to other members of staff.

At the end of the above discussion, the first question she asked was "*how much does it cost?*". Sometimes cost is a secondary consideration in the deployment of new technology, but in many cases it is a key factor in technology acquisition.

A similar conversation also took place with a member of the secretarial staff. While discussing the possibility of new ways of recording the patient record, she found it easier to imagine the information transfer at first conforming to existing systems, but then began imagining new possibilities. For example, at first we discussed the use of handwriting recognition for automatically converting the codes of a procedure and feeding them to the existing database software. When the functionality of the pen was explained she began to imagine new possibilities as discussed below.

The pen itself is the size of a large ballpoint pen (figure 2) and writes normally with ink. However, when used in conjunction with digital paper[3], all strokes of the pen are recorded individually, available for download to a computer. These can be stored as an image file, a word processor formatted file, or be processed by recognition software to output digital text. Given this information, the secretary imagined a system that recorded the dental record simply as it was, viewable on a screen. Instead of having an individual machine at each chair, having

[3] The paper is obviously physical rather than digital; however it is imprinted with a fine grid of dots that reflect infrared light. The pen uses a camera to track its position using the dots on the page, and records the path traced along the page to internal memory. This is then sent to a computer through a USB cable, although wireless Bluetooth models of digital pens also exist.

docking stations instead would allow a central computer to receive all records and catalogue them. If other departments required a copy of the record, it could be printed out or electronically sent to them.

Figure 2: Logitech io digital pen (Logitech 2003)

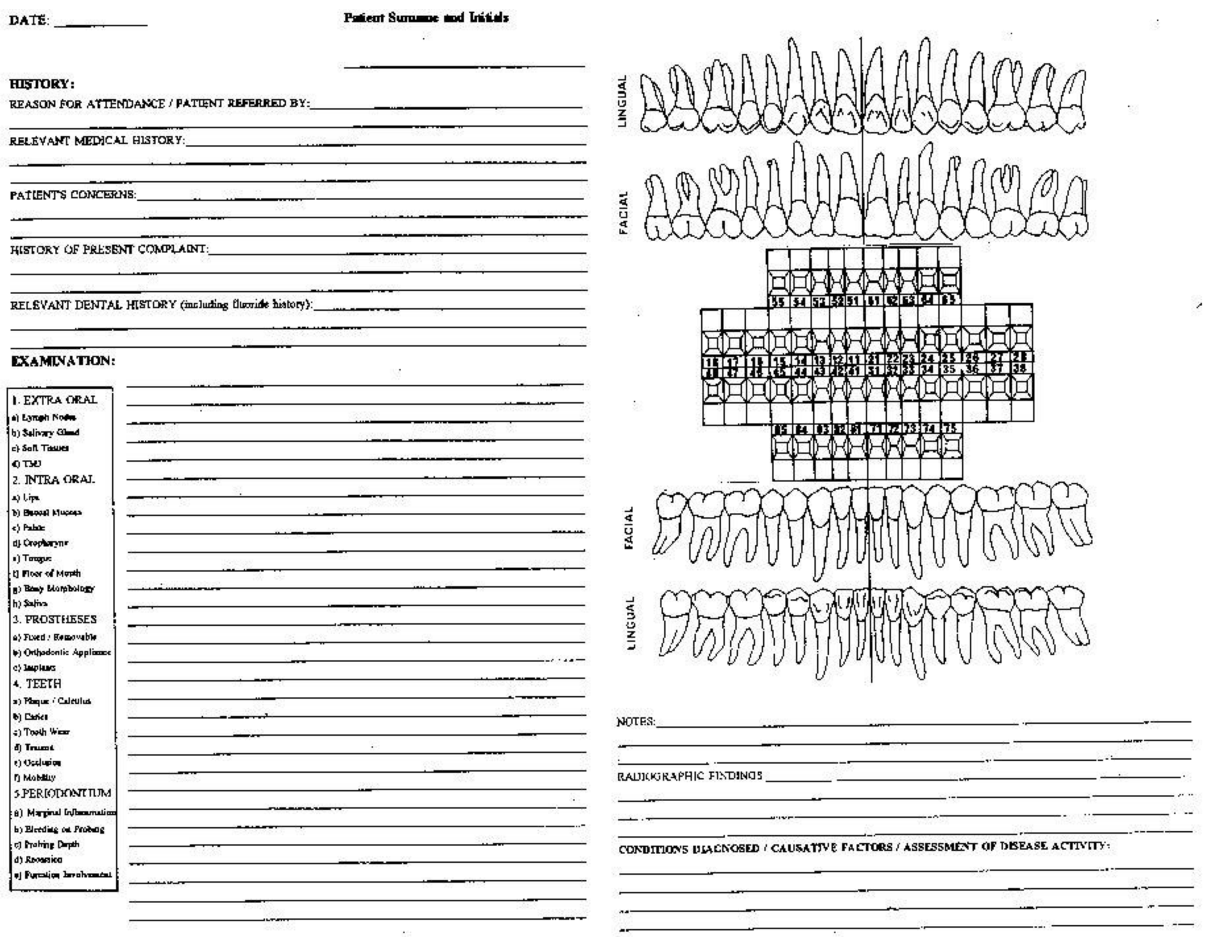
Conversations with the dentist around the prototype revealed that there are several aspects of their current work practice that could potentially be improved by such a system. Participants described how removing the need to transcribe information at the end of a procedure by using a “write once” system would save time and effort. However, they also pointed out problems with the system, such as the need for docking stations.

The ability to preserve many of their existing work practices was also discussed. For example, the need to take notes from a procedure to a supervisor for assessment and to be signed off would be kept. However they also noted that introduction of a pen based computer record keeping system would likely still require changes in course structure and student training.

Another aspect of the system discussed was that using a pen (as opposed to a keyboard and mouse) takes into account infection control procedures. As discussed in the transcript, it was observed that students would take a normal pen, swab it with alcohol and then wrap it in glad wrap. The digital pen used is sufficiently packaged to allow cleaning. These types of discussions were useful for helping explore a possible system design. To allow further exploration and feedback, we obtained a digital pen and created a digital paper version of the dental record (figure 3). This looked identical to the record with which they were familiar, so when we trialled it with them they knew the location of data entry points and used it without difficulty.

The prototype was selected even though it used off-the-shelf hardware because it is simple technology for the practitioner. Pens are easy-to-use, familiar objects. This embraces the goals of ubiquitous computing where the technology is invisible. There is no time spent thinking about how to use the device; its function is obvious and simple. The fact that it is possible to buy a digital pen commercially also means it can be modified or replaced quickly and easily without spending time developing a prototype from scratch.

Through using a basic prototype, immediate constraints of a complete system became apparent. For example, we identified to the staff the ability to edit the record and adjust individual pen strokes after downloading it. The lecturer pointed out the legal requirements that void this as a feature. Knowing this changes our system design: it is more important to have the record easily transferable to the computer than the ability to edit the digital copy. Implementing the ability to edit would both increase development time and be unsuitable for practitioners.



DATE: ____________ **Patient Surname and Initials**

HISTORY:

REASON FOR ATTENDANCE / PATIENT REFERRED BY:

RELEVANT MEDICAL HISTORY:

PATIENTS CONCERNS:

HISTORY OF PRESENT COMPLAINT:

RELEVANT DENTAL HISTORY (including fluoride history):

EXAMINATION:

1. EXTRA ORAL
a) Lymph Nodes
b) Salivary Gland
c) Soft Tissues
d) TMJ
2. INTRA ORAL
a) Lips
b) Buccal Mucosa
c) Palate
d) Oropharynx
e) Tongue
f) Floor of Mouth
g) Bony Morphology
h) Saliva
3. PROSTHESES
a) Fixed / Removable
b) Orthodontic Appliance
c) Implants
4. TEETH
a) Plaque / Calculus
b) Caries
c) Tooth Wear
d) Trauma
e) Occlusion
f) Mobility
5 PERIODONTIUM
a) Marginal Inflammation
b) Bleeding on Probing
c) Probing Depth
d) Recession
e) Furcation Involvement

LINGUAL

FACIAL

55 54 53 52 51 61 62 63 64 65

18 17 16 15 14 13 12 11 21 22 23 24 25 26 27 28

48 47 46 45 44 43 42 41 31 32 33 34 35 36 37 38

85 84 83 82 81 71 72 73 74 75

FACIAL

LINGUAL

NOTES:

RADIOGRAPHIC FINDINGS

CONDITIONS DIAGNOSED / CAUSATIVE FACTORS / ASSESSMENT OF DISEASE ACTIVITY:

Figure 3: The dental record used

While this process of design yielded satisfactory results so far, this system is simply a step towards exploring better work practice in a dental surgery. It is not possible to understand shifts in work practice that result from technology until technology is fully implemented and tested in every day work contexts. What this approach does provide is an open feedback loop, where the system is flexible and less time is spent backtracking because it has failed to meet participants' needs.

Similar approaches are possible with low fidelity prototypes in order to explore new technologies that are not already packaged in a predetermined form and available off-the shelf.

Multimodal interfaces

In a separate investigation (Campbell et al. 2003), we identified the possibility for a multimodal interface (e.g. speech, gesture) to the computer to facilitate interactions with a computer based record, whilst reducing the amount of time required to drive the interface and the workarounds needed to maintain infection control standards. To explore the design of this interface, we ran a design activity[4], with two dental students. This activity aimed to help identify promising ways that information can be represented and accessed. Our aim was to gain an understanding of which representations and modalities worked well and why.

We asked one student to simulate the computer interface, while the other completed an examination on one of the research team members. This approach gave the practitioners a familiar procedure to complete but in such a way that it suggested new possibilities for interaction. It also allowed us to see what the effects of speech and gesture might be without investing time and money in prototypes by using "Wizard of Oz" techniques. By varying the way that information is made available and is input to the system, we hoped to identify effective attributes of new interface modalities.

It is important to keep practitioners involved in the selection of technology. For example, when testing the use of speech and gesture with two of the students, the following conversation took place:

[4] We referred to such events as design activities when advertising them to potential participants due to queries over how games could be used for 'meaningful' research. However, we devised them with games in mind.

> Student 1: “One more question – is she meant to be telling me where she wants me to write? Usually we just listen to them talk and write.”
>
> Student 2: “It’s easier for me to just say… ‘Medical history – nil sig’ so the heading, where I want to write it, and what I want written I suppose.”
>
> Student 1: “Cause see how she’s talking to him, saying do you use fluoride toothpaste, do you do this, do you do that, and then turning to me and going ‘fluoride toothpaste, this’ [Student 1 gestures while she’s saying this]. Usually while she’s saying that I’d be doing that anyway.”
>
> Researcher: “Okay, so have you guys done that before, where you’re filling out the patient record for someone else?”
>
> Student 2: “Yeah, yeah, if we’ve got a spare session then we always do it for someone else.”
>
> Student 1: “All the time.”
>
> Student 2: “The only difference is if someone like a dental assistant or someone is assisting you, like I said, they sort of automatically know where to put it approximately, so there’s no repeating any information or anything like that.”
>
> Student 1: “Say [Student 2] will be looking the mouth, she’ll go through and say ‘Yep, quadrant 1 is fine, there’s this here’, and she’ll just say it as she’s going and I’ll just write it wherever it should go.”

Without actually having the practitioners test a possible interface first, we would not have realised they are accustomed to dictating to others for their records, as it was never observed during our study. Furthermore it showed us the most efficient method (in their current work practice) of collecting the data as they know the layout of the record and they know the order the procedure should run. A possible approach might be using speech recognition and contextual cues from the dentist’s speech or activities to confirm where the information is placed in the record. The idea of utilising context might be attractive, however actually detecting it in these dynamic social interactions is highly problematic and needs to be explored further.

From interviewing dentists in private practices we discovered that almost all existing dentist-oriented speech recognition programs relied on training and could only be used by a person who had trained with the program. This type of recognition was used for converting raw speech to text. However, what was found through the activities with the students was that many abbreviations were used. In addition, there was implied knowledge that whoever was filling out the form would know that something would need to be written. For example, “intra oral, nil sig” would mean to ignore all entries under intra oral as there were no problems in that area.

This may explain why comparatively few dentists currently use speech recognition. In addition, there is also a lack of understanding as to what speech recognition can actually offer as detailed in the following conversation:

> Lecturer 1: “So presumably at some stage, I mean we’ll end up with voice activated computers so you can actually dictate your treatment plan.”
>
> Researcher 1: “Yeah.”
>
> Lecturer 1: “But does it, does it respond to any voice? I don’t know much about this at all, or is it specific voice activated?”
>
> Researcher 1: “Do you mean a particular voice, or a particular phrase?”
>
> Lecturer 1: “Particular voice.”
>
> Researcher 1: “The voice recognition we’ve been playing with works with anyone, but you can only say really specific phrases, you can’t just talk regularly and have the computer understand you. If you want to do that you have to train for a particular person, so there’s a trade off there, and the training takes pretty much a day.”
>
> Lecturer 1: “So the reality is to voice chart, is not to provide a whole series of charting as you heard the students do when they have a new patient and go through every tooth, that would be more complicated than just a phrase, like “examination” or ‘periochart’.”
>
> Researcher 1: “Yeah, exactly.”

We imagine that further testing will need to address problems of finer granularity that pertain to the type of technology we choose. We will need to explore things such as the accuracy required for the speech and gesture recognition, and how to account for and adapt to deficiencies in the new modalities (for example, what might be the verbal or gestural equivalent of a backspace key?). These issues will present themselves through further collaboration.

In summary

The key aspect of our research for improving the design process was to find ways of supporting common communication. This communication in the participatory design approach allowed us to understand the dentists' work practice and to offer our knowledge of technical devices and possibilities to the dentists in their work context. By revealing the technology, first in props and scenarios, and then with actual devices for participants to experiment with and test, we reached a prototype system that has been tested with positive feedback about its use.

FUTURE WORK

The activities we have completed so far have not told a full story. It is necessary to take what we have learned from these initial design sessions and apply it towards exploring the methods of interaction and representation of information further.

While the first activity seemed to identify speech as the most essential modality, this may simply be because of the affordances of the paper patient record. Future activities will allow the record to be completed by selecting written phrases through gesture. This is a technique used by some existing dental software, but so far there has been little research into the trade-offs of each method and their various combinations. During our activities, the students used minimal amounts of gesture which consisted only of pointing. We aim to identify whether this is because gestures are not a viable interface or if it is because they are not afforded by their current information representation.

There were also occasional "awkward" moments with participants. For example, in the most recent set of activities, some participants did not see the value in using "Wizard of Oz" and hesitated in their involvement. In future we will attempt to brief participants more carefully as to the types of activities and their purpose. Another time a participant did not understand how a particular technology was used and therefore was unreceptive to ideas being discussed. In this case we had not briefed the participant properly and in future should be careful to spend time exploring technical capabilities before discussing design possibilities incorporating them.

It is hard to say precisely where the design will proceed after this activity. Details that reveal themselves during these activities have the potential to change the course of the design. However, through undertaking a sufficient number of participatory activities and framing the design problem from several different perspectives, the better combination of modalities will emerge.

Workshops that explore the constraints and possibilities of specific interface technologies and infrastructure technologies are also planned. For example, if the interface is wireless, a spatial model of the surgery will be used to help map out 'hot' and 'cold' zones, range, privacy issues, etc, in order to illustrate issues in wireless design to the dentists and to reveal issues from the dentists' perspective. Other workshops that explore technical deficiencies and how to balance them, such as the accuracy of recognition will also be required.

CONCLUSION

This paper has described a participatory design approach to exploring and prototyping new methods of patient record keeping in a dental surgery by taking advantage of ubiquitous computing technologies. It demonstrates that research in ubiquitous computing should pay attention to design communication. Our activities have supported a better understanding of the context of use for the designers and engineers while the practitioners acquire a knowledge of how new systems will impact their workplace. Through using participatory design methods, researchers are able to explore practitioner needs in authentic work contexts and to communicate technical possibilities through use of contextually embedded prototypes.

HCI already has a tradition of using low-fi prototypes and "Wizard of Oz", in order to explore the broad emphasis of a design with users and to get this right before proceeding to detailed design. We are trying to show the kinds of conversations possible with professional practitioners in their context of use by using such methods. Furthermore we have shown that even technical issues (such as the merits of bar codes versus RFID) can be explored with practitioners using these low-fi prototypes and "Wizard of Oz" techniques. Because ubiquitous computing so intricately embeds human and technical issues, it is important to get into the use context with practitioners early in order to push the boundaries of how we conceive of the possibilities for ubiquitous computing.

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