A Participatory Design Agenda for Ubiquitous Computing and Multimodal Interaction: A Case Study of Dental Practice

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ABSTRACT

This paper reflects upon our attempts to bring a participatory design approach to design research into interfaces that better support dental practice. The project brought together design researchers, general and specialist dental practitioners, the CEO of a dental software company and, to a limited extent, dental patients. We explored the potential for deployment of speech and gesture technologies in the challenging and authentic context of dental practices. The paper describes the various motivations behind the project, the negotiation of access and the development of the participant relationships as seen from the researchers' perspectives. Conducting participatory design sessions with busy professionals demands preparation, improvisation, and clarity of purpose. The paper describes how we identified what went well and when to shift tactics. The contribution of the paper is in its description of what we learned in bringing participatory design principles to a project that spanned technical research interests, commercial objectives and placing demands upon the time of skilled professionals.

Author Keywords

User-centred design, participatory design, interaction design, ubiquitous computing, speech recognition, gesture recognition, multimodal interfaces, busy professionals.

ACM Classification Keywords

H5.2. Information interfaces and presentation: User Interfaces – Evaluation/methodology, input devices and strategies, prototyping, user-centred design.

INTRODUCTION

The research described within this paper takes a participatory design approach to understanding how ubiquitous computing and multimodal interfaces might support the work practice within a dental surgery. Our interest in ubiquitous computing originated in the philosophical underpinnings of Weiser's research [17], of developing "invisible" and "calm" computing that allows a practitioner to focus on their work, rather than driving the computer interface.

Coupled with this notion of ubiquitous computing comes the realization that if any new form of interface or computational appliance is to fit "invisibly" into a work practice, it must fit with the work and rely upon the skill of the practitioner to adapt and appropriate it into their existing material environment and set of practices. This often unacknowledged form of work in adapting and appropriating tools and methods is referred to as articulation work [15]. The designer then must find ways to work closely with the practitioner in order to understand their practice, and to find a way together with the practitioner to design. Suchman [15], among others, points out that design does not finish, but that practitioners continually design as they adapt and develop their work practice with new devices.

Design or systems development should then be seen as an "entry into the networks of relations – including both contests and alliances – that make technical systems possible" [op cit 15 pg 92]. This necessitates replacing the "designer/user opposition", wherein designers design and users use, test, or are probed, with a different kind of designer/practitioner relationship which embraces more mutual learning and richer layers of engagement in the traditions of participatory design. Although Weiser recognised that designing ubiquitous computing demands the "very difficult integration of human factors, computer science, engineering, and social sciences" [16 pg 1], research in the field is instead dominated by technical explorations that are removed from the context of real practice [3].

In our project with dentists we set out to explore ubiquitous computing from within the demands of a particular work practice: dental practice.

Participatory design has its roots in the Scandinavian tradition [7, 13], which sought to empower the worker and allow for democratic expression in the design process. The

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essence of participatory design is to develop mutual trust and respect and effective communication and collaboration between all parties involved in and or affected by the design efforts, so that resulting designs best support users and use.

We chose to explore dental practice for several reasons. In early exploratory work in gestural interfaces, where we examined a variety of work contexts, dentists expressed interest in the possibility of hands free operation of computers due to difficulties associated with infection control practices.

We were in turn interested in dental practices because they involved a combination of information work, rich physical manipulations and social interaction between dentist, assistant and patient. The dental surgery is replete with artefacts, instruments and information displays. Given the wide variety of actions and interactions, it seemed a fertile ground for exploring theories and practices of interaction design.

The design sessions described in this paper are part of an ongoing project to better design information environments for dentists.

We began our research in this area with ethnographic studies of local dentists and a dental school. These both provided contrasting insights into work practice, terminology and our understanding of the practitioner's requirements. We also made use of design events with both groups (separately), using techniques such as low fidelity prototypes, design games, and role-playing [2, 3, 4].

Over the course of three years we have developed good relationships with two practising dentists and with the CEO of a dental software company. This has led to further introductions to a variety of users of dental technology who participated in the work described in this paper.

We attempted to focus design work and prototype development on areas of practice identified by dentists as needing design attention. We have also attempted to keep development scope and costs realistic. Our early studies indicated, in some ways contrary to expectations, that speech based interfaces could be effective in some dental procedures.

In this work we describe how we have attempted to complete a speech based prototype to allow multimodal interaction for dentists, so that they can update computer based patient records more easily during dental procedures. The application of speech was a promising starting point, with other kinds of ubiquitous computing technologies being of potential use. We focussed on speech in order to develop a single technology to a satisfactory level of maturity for trialling in patient examinations.

We ran three design sessions, each with a different dentist from a different dental specialty and surgery, whom we were introduced to by the dental software company CEO. In each case, we had no prior contact with the dentists until the design sessions began. The prototype developed from these sessions was then discussed and trialled with a fourth dentist, Scott*[1], who had prior involvement with the research project.

This paper presents the results of the design activities and a prototype trial, including lessons for design and reflections on the activities.

PREVIOUS WORK

Research Domain

Dentists use 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 by wearing gloves. These gloves are then removed in order to interact with a computer using 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 (see Figure 1). All of these factors combine to make the use of a traditional computer interface disruptive.

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

Methodology Background

During the research all design activities were situated at the practitioner's domain. In the same vein as Buur and Pedersen's research [10], by taking design tools, such as laptops, prototypes and design representations (as discussed in [2]) to the workplace, a sense of demystifying the design process was achieved. This also assisted with intelligibly explaining technology to the users to assist their contributions to the design [4]. By understanding the designer's limitations and expertise, the user is able to contribute in more meaningful ways.

Our work builds upon other early attempts to improve technical understanding during participatory design of

[1] Name has been changed for anonymity.

ubiquitous computing, such as Good's work with a portable torque feedback device [6]. While technical expertise is necessary, but not sufficient for design (the practitioner's perspective and other design skills are also needed), one important challenge was representing technical knowledge in design conversations in such a way that it educates and informs practitioners and gives them access to the nature of technical decisions involved.

Furthermore, design changes had to be carefully considered and grounded within the practitioner's environment, due to the complex interweaving of social interactions with information work and dental work. In-situ activities reveal how the participant interacts with devices in their actual work environment, and the designers are informed immediately of problems or potential in the design. Additionally, when practitioners are in their everyday domain, they are familiar and comfortable with the design environment, helping to place all parties on a level playing field.

There were also practical considerations to be made. Our access to the practitioners was given freely by them, and they received no form of remuneration for their time. By centring activities at their workplace, maximum use could be made of their time, and inconvenience was minimised.

Existing Prototype

The most advanced of a series of low-fidelity prototypes developed for our project was a speech recognition engine coupled to a common dental application package.

The prototype used basic grammar-based recognition (provided by the Microsoft Speech API) to provide input to the dental software that most of the dentists we had studied used. A more complete description of the final prototype is described later in the paper.

While we recognised (and adapted to) the technical problems in speech recognition, it was chosen as it was one of the best received prototypes and it showed the potential to be trialled during a procedure. However, adding contextual triggers to the dental application required the assistance of the company who developed the software. As a result, the CEO of the company (a former software engineer) became closely involved with the prototype development. It was through this relationship with the CEO that we were able to gain access to a wide variety of dentists who used the software and were interested in testing new versions.

Configuring and applying the speech recognition engine was problematic. As noted by Kraal, speech recognition is not a "one-size fits all solution to any problem" [9 pg 1]. While speech is a modality that is both natural and frequently used for communication, this does not mean it automatically lends itself to human computer interfaces. Although the input of speech is relatively simple, editing and correcting errors is difficult and can in turn produce more errors that need to be fixed, leading to error cascading. Errors occur because there is more variation in tone, inflection, speed and intonation in human speech than the acoustic computer model can accommodate [op cit 9]. The tendency of people to hyper-articulate words that have been misunderstood can lead to further recognition difficulties. Thus when speech technology is used it tends to require a lot of appropriation and articulation work on the part of practitioners.

It is interesting to note that many of the successful applications of speech recognition occur where it is deemed clunky or inappropriate [9]. It is often simply a more efficient method for entering text than other alternatives despite its shortcomings.

In designing for speech recognition applications it is critical to understand the context in which speech recognition is to be used, what kinds of things are to be said, and how they might be said. Each application will be unique, even though, as Kraal points out, much of the research into speech recognition usually overlooks this. It is clear then that the only route to successfully incorporating speech driven interfaces into practice is through participatory design work with practitioners. This is necessary in order to understand the context of use, and to cooperatively design aspects of editing, choice of commands and so on.

Given that there is a broad corpus of research in speech recognition, our aim was not to improve the technology behind speech recognition, but rather to use participatory design to more effectively design speech recognition applications to suit their context of use.

DESIGNING FOR DENTISTS

Finding Participants

We approached John*, the CEO of the dental software company, for assistance with adding additional functionality to the dental software used by dentists already involved in our research. As part of his new role within his company he was interested in exploring new design ideas for his software. He offered to set up access for us with three separate "technology-interested" dentists to help provide feedback on the prototypes. These dentists were typical dentists from a variety of backgrounds, but who had previously expressed interest in reviewing new features. This was beneficial from John's point of view as it would also allow him to see what new features in his software dentists would be interested in, while for us, potentially one of the biggest problems in participatory design is identifying practitioners willing to participate. Good [6] spent five months finding interested practitioners within a company that had *requested* the design work.

While we were based in Australia, the dentists' practices were located throughout New Zealand. However, we were able to organise a timetable whereby both John and the dentists were available over a period of two days, allowing us to organise design activities that involved them.

The three dentists held quite different attitudes to new technology. The first dentist disliked using new technology (such as speech recognition) and did not believe it would be useful in a dental surgery. The second dentist had transitioned to a completely paperless office and had up-to-date, practical equipment. The third dentist was an early adopter who used new equipment as a marketing tool.

As an example of this contrast, while one dentist used tablet PCs for the patient to fill out their record, and a high degree of automation for charting, another dentist had the patient fill out their personal information with his secretary on a piece of paper, before transferring it to a digital form later on.

All we knew of the practitioners before the activities was that they had an interest in new versions of the dental software. We wanted to make our limited time with them as productive as possible by getting feedback on designs generated from discussions and ethnographic studies with other dentists, while also finding out about their practice, particular ways of working and design ideas. Therefore, we decided to plan fairly general activities that introduced different ways of interacting with the dental software. We sent a list of the activities to John so he could pass it on to the dentists, and so we could gain any feedback from him regarding our proposed approach.

While we had plenty of prior experience in dental surgeries, and thus at least we were able to participate in an informed way [14], it is critical that the user has a level of trust and openness in order to create communication in design. Although we had managed to gain access to a useful number of dentists who were open to donating their time to our design discussions, it concerned us that we did not have the time to establish working relationships with them.

Planned Outcomes

As a result of the design sessions we hoped to progress towards a speech technology based interface that a dentist could use during a patient consultation. We were aiming to support a procedure called a periodontal exam[2] with the dentist Scott, who had previously contributed to our work.

METHODS

Planning

The methods we used depended on several factors. Firstly, we used our experience in participatory design, particularly with dentists [2, 3, 4], to inform the choice of activities that would be effective. While we had previously found activities such as games and role-playing useful for ourselves as researchers, we decided that these were not appropriate intervention methods, since these shift the power in the relationship to the facilitator who decides the ground rules and frames the debate. We also felt that it was important to ground our design activities and discussions in their work practice. Furthermore, we had to design the activities based on the fact that the dentists were not familiar with our work, and also probably unfamiliar with participatory design. The final consideration was the limited time that we could expect from our professional dentist volunteers. The activities we planned were as follows. We first wanted to show prototypes we have been working on, and also have the dentist show us their surgery and equipment. We then planned to explore how gestures and speech are used by the dentists and to discuss how multimodal interaction might be used with their dental software for charting or a periodontal exam. Finally, we wanted to brainstorm different approaches to implementing gesture interfaces and to explore the distinctiveness of different gestures.

We based the activities on the broad aims of our research (to understand how to develop speech and gesture prototypes that fit with work practice), and on our design environment (an unknown dental surgery, with the only certainty being that they used the dental software John sold). We took laptops with the dental software installed, and the necessary equipment with us to demonstrate prototypes, knowing that the dentists would be familiar with the software interface.

We very carefully considered the order in which we would run the activities and took the view that we would rely on improvisation in order to maintain a good discussion, rather than steadfastly following the original plan. Our main concern was to understand the practitioners' work and concerns and to give them a voice, while getting realistic feedback on our prototypes.

While showing them prototypes first could have potentially biased their feedback, or moved their focus away from their work practice and concerns, we felt it was necessary to show what we had already done in order to explain why we were there. Our original inclination was to ask for a tour, and to have a general discussion, before explaining the design work to date. This was largely so as not to seem self-focussed and so as not to show naïve designs to someone whose work practice might have no call for such designs. However, by way of politeness it seemed we should explain ourselves and why we were there, and the best way to do this was through the artefacts of the design endeavours to date. Ultimately we decided to offer to demonstrate first, but also to offer the choice to the hosting practitioner.

Such were our musings in order to plan for the most revealing design conversation that we could have. In a previous design activity, when asked to explain how he used technology in his surgery, the dentist talked about his

[2] A periodontal exam uses a probe to measure pocket depths of a person's gums. It is generally an invasive, slow procedure that ties up both the dentist and the attending nurse who must record a large amount of information (the measured depths). It has been repeatedly highlighted to us as a very good test procedure for an improved system of interaction due to its complexity and current difficulties.

Linux server and the hardware configuration of the individual machines, seemingly because he was talking with someone who was interested in the 'nuts and bolts' of the technology. Conversations sometimes took us deep into interests and into issues of configuration as well as into immediate use.

We were concerned to manage expectations. We did not want the practitioners to think they were trialling complete systems, nor to assume we were developing from scratch. This was addressed by demonstrating our technology and setting the tone for the follow up activities from the outset. This is not to say we did not have open ended discussions regarding technology, nor did we expect to only keep the demonstrated prototypes in mind. Our aim was simply to frame and contextualise the interaction.

Finally, there was the issue of practitioner availability. Although our ideal plan was for three hours, John advised that we would only be able to realistically get about two hours with each dentist. To adjust for this we considerably shortened our time spent demonstrating the prototypes and viewing their surgeries, instead choosing to concentrate on exploring the design problem.

Situated Design

Given that participatory design is about building trust and relationships leading to fruitful collaboration, there can be no set of procedures that will be followed to the letter. However, it is important to have a plan as a guiding point and to help keep the activities focussed. Knowing that the situated action would be different to what we had planned, we tried to keep in mind our three main objectives:

1. To improve our understanding of the dentists' instruments and technologies (particularly those new and unknown), in addition to sufficiently informing the dentists of our work to date, especially existing prototypes (and the underlying technical understanding).
2. To examine the methods of interaction used by the dentists, and explore ways of incorporating these or intervening to improve human computer interaction.
3. To develop concrete design ideas for our prototype to move it from low-fidelity prototype to a usable device that we could trial in a dental surgery.

It was important to us that the dentists were engaged and able to work with us the best way they could. To do this we had to adapt our plan to each dentist during the activities. In doing so our three design sessions were quite different from each other due to local improvisation.

The Practitioners

The first dentist, Peter*, ran a practice by himself, and although he used a computer for his record keeping, he was not particularly interested in alternative methods of interaction. We began by demonstrating medium-fidelity prototypes, which he was not very enthusiastic about. At this point John interrupted and attempted to explain our work in a way that was compelling to Peter. After piquing his interest in this way, Peter began brainstorming new methods for interaction that suited his work practice. This spontaneous brainstorming was very interesting, but used up half our time with him. We decided at this point to shorten the remaining activities. We asked him to run through the basic steps of a periodontal procedure on one of the researchers while attempting to integrate the gesture prototype. It was obvious to us by this stage that Peter was most interested in concrete examples that could relate to him, so we continued to brainstorm with him in the vein of "realistic" product ideas, which helped us understand what was important to him.

Next we met with David*. David was an endodontist[3] who spends most of his time using a microscope to assist his work. He made extensive use of new technology, such as tablet PCs and pen based interfaces to his record system, but had little computer interaction during a procedure, instead relying on his memory. We found that once we met up with David, he was running late and so we were unable to run through a scenario with him. Instead, we spent our time demonstrating and discussing prototypes as well as being shown his equipment and how he used it. David was interesting because he had already successfully integrated a lot of new technology into his work practice and discussing how he integrated this into his traditional methods of work was very informative to us.

Finally we met with Jason*, a general dentist with a large practice. In addition to owning and running two practices, he also maintained the new equipment and IT setup, and so knew a great deal about cutting edge equipment in dentistry as well as being very open minded to new interaction possibilities. Jason had more time than planned and so we were able to complete our timeline in full.

FINDINGS

These sessions enabled us to modify and extend our speech based prototype for interaction with a patient record while undertaking a periodontal procedure in a dental surgery. By later observing Scott using the prototype and discussing its benefits and shortfalls, we were able to identify where the design process was successful and where it was problematic. The activities also informed our understanding of dentists' work practice and gave us new insights into our design techniques.

Prototype Description

The finalised prototype consisted of a speech engine which provided navigation and data input for a periodontal

[3] Endodontists are concerned with tooth pulp or dentine complex. The most common procedure performed by them is a root-canal.

charting application. The application used was a popular dental software suite, and the existing periodontal recording section of the software, shown in figure 2, was used as a basis for the prototype. The speech engine used grammar-based speech recognition[4], and had been specifically developed for use in noisy environments and used an off-the-shelf Bluetooth wireless microphone that attached to the dentist's glasses, or could be kept clipped to their chest. The microphone also worked whether the dentist was or wasn't wearing a mask.

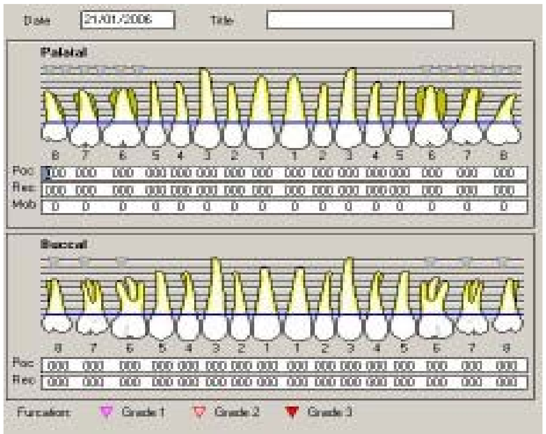

Figure 2: The periodontal charting interface

The prototype also kept track of how the dentist was working (for example, if they were looking at x-rays, or the patient's chart), and the location in the mouth for data entry when using the periodontal application. It accepted both direct tooth selection, or if a tooth had finished having data entered it would automatically move to the next most convenient data entry point that the dentist would be likely to use. The prototype also allowed the dentist to customise the order that data was recorded around the tooth. Previously, the next entry point would need to be selected manually by the dentist after each entry was made (figure 2). All aspects of periodontal charting were supported using the speech interface, including furcation grading and pocket depth measurements, as well as incidental requirements such as bringing up x-rays.

Efforts were made towards using gesture for navigation control, but the hardware was not sufficiently mature for use during a procedure. The software remains adaptable to any type of modality input, relying on action commands to control the interface, rather than hard-coded interaction with the particular modality. The emphasis remained on adapting the technology available to ourselves and the dentist into a more usable system.

[4] Constrained grammar speech recognition can be configured for a general group of speakers rather than requiring individual training. Usually it is for a particular region, but with a small dictionary space, is generally successful in providing recognition without training.

Trial

Our prototype was trialled by Scott during an actual periodontal procedure with a volunteer, but without a nursing assistant, under an approved ethical clearance protocol. It was important to us that the practitioner used the prototype, once sufficiently mature, while examining an actual person. Subtle nuances in the way people work in an authentic situation can have large effects how they perceive and react to the prototype.

The trial was simple – Scott was asked to undertake a periodontal examination with a research colleague volunteer as the patient, and a researcher on hand for any questions or problems with the speech prototype. After a quick run through of the navigational commands and a description of how the software worked, Scott attached a wireless microphone to his protective glasses and began the procedure. The charting was completed in approximately 15 minutes. Time was then spent discussing the prototype with the dentist and acquiring feedback. Below is an example of the trial with Scott. Bold type indicates a speech error.

Dentist: "set one" "set seven" "set one" "go to recession" "go to last tooth" [Pauses to check location because of lack of feedback] "**set one**" "set one" "set two" "set three" "set speech off"

Engineer: It's kind of annoying with the recognition rates sometimes…

Dentist: But not too bad. I think I need feedback for when I'm going to recession and when I'm going to pocketing, so I know I've switched between them.

Engineer: Yeah I noticed that yeah.

Dentist: That's probably the biggest thing. And it feels a little bit strange sometimes if you go through a series of determining pocket depths for a tooth and it jumps to the next tooth [computer beeps to say speech is back on] and you want to go back and record the recession. "Wasn't talking to you" …and you want to record recession for the same tooth.

Our main concern was the problem of error correction. In particular, we aimed to avoid errors that cascade into other errors and disrupt the flow of work. As identified by Karat et al [8], cascade errors account for the majority of time spent correcting misinterpreted speech recognition, particularly for novices. One method identified for reducing errors is the use of multimodal input [8]. However, this was not a possibility for us, given the problems involved in using a keyboard and mouse and lack of a mature gesture interface. It can be seen in the example transcript that while there were recognition errors, the system did not create cascade errors.

We were concerned that the reduced accuracy of a prototype might be sufficient to disrupt the workflow and irritate the dentist. However, as exemplified in the transcript, the errors that occurred were tolerable, at least for a prototype. The dentist could identify errors in recognition easily and fix them simply. There was unintended triggering of the speech system during conversation with the researcher, but the dentist was unmoved, quipped back to the speech engine and then continued in conversation. While these errors would be annoying in practice, they did not noticeably disturb the procedure or the participatory design conversation. The dentist became comfortable with the speech interface in a short amount of time and soon began charting at his normal work pace.

There were issues with regard to feedback and contextual navigation, which are also seen in the transcript. Some of the audio feedback, having been deemed too distracting, had been removed from the prototype. Because Scott was unable to see the screen, on occasion he was unsure of whether the computer had heard his command. Furthermore, automatic navigation driven by the context of the procedure (as requested by several dentists) interfered with the way Scott worked, and became a nuisance when an error was made.

In our case, we realised with our context-dependent navigation that we had overlooked a possibility about how dentists chart around the tooth. Our design was based on the explanations of practice by Scott and Jason and limited ethnographic observation. In the course of the procedure we found that the dentist did not always want to chart all points of a tooth, leading to a subsequent prototype modification. Although we tried to eke out all possible variations in our discussions with the dentists, later trials in authentic contexts naturally found things we had overlooked.

There were some potential problems in the prototype that we simply dealt with up front. Using an off-the-shelf speech recognition engine from the United States meant that some Australian pronunciations weren't recognised. When a speech interface doesn't respond, the natural tendency of the user is to hyper-articulate. This does not help the speech engine decode the speech. For certain words, "eight" in particular, we had to point out to the dentists that it was necessary to pronounce "ayyt", instead of "aayt" as it might be pronounced in Australia or New Zealand. Thus we needed our dentists to slightly modify their speech for the prototype, just as handwriting must be slightly modified for accurate detection on some screen based interfaces. By making such technical problems or quirks transparent prior to the prototype use, the dentist readily accepted the modified way of accenting some words. This seemed to be an effective way of bringing an early prototype into a professional use situation in order to have a participatory design conversation.

The trial also demonstrated that it is important to have a technical team member who is able to ground technical discussions, provide layperson explanations and fix problems in the prototype. This was particularly true during the trial itself, where there were issues with wireless connections, and minor bugs in the code. It also allowed for in-situ technical development with the three dentists during the design activities, allowing a shorter development period before trialling in another authentic scenario.

As discussed in our previous findings [4], it is not possible to understand shifts in work practice that result from technology until technology is fully implemented and used in every day work contexts; such is the contingent nature of true work. Overall however, it showed that the democratising process of participatory design allowed the designer and the practitioner to make useful contributions towards a prototype, as illustrated below in the section on creating communication in design.

Lessons for Design

Our reflections upon the entire process led us to conclude the following lessons:

Designing with Busy Professionals

Overwhelmingly within our project, one of the most difficult issues to deal with was the need to develop effective interactions with busy professionals. We wanted to gain detailed insights into how they viewed the new technology, their existing technology and their work practice, rather than elicit only superficial feedback. Practitioners such as dentists have tight schedules and donating their time also effectively means losing money for their business. This means finding ways to compensate for short access periods, long gaps between availability and a dearth of willing participants.

For the activities discussed in this paper, we were lucky to have the relationship with John, who was a skilled practitioner and CEO, both knowledgeable about dentistry and dental technology and also having significant contacts within the industry. This provided us with a range of much needed participants. John was also instrumental in allowing the activities to be useful without the prior contact required for effective design.

Initially John was to be merely an observer, but from the outset was extremely helpful in garnering trust with the dentists and hugely assisted in making efficient use of the time. Having a mediator such as John creates a bridge between unfamiliar groups and to assist in ensuring effective communication between them. In this case, we were simply lucky – his involvement in the actual sessions was not planned but ultimately made the sessions a success.

Staging events is also an efficient means of propelling the design. As discussed by Binder et al [1], they are an effective way of concentrating activity and focussing the design process. For their events, Binder et al also favour conversational design, for the reason Schön noted that “development work is propelled by the dialogic engagement of stakeholders and object worlds” [12]. Staging events allowed us to gain concentrated access to the dentists and also for them to feel they achieved something by participating.

Finally we found it was necessary to improvise effectively to make most efficient use of the time. As detailed earlier in the paper, unexpected time constraints or reactions from the dentists forced us to adapt so that we could make the best use of our time with them. To achieve this, our main approach was to always improvise activities in order to generate and maintain a good design discussion and to ensure the practitioners were being heard.

Creating Communication in Design

Effective participatory design rests upon effective communication between all participants. We see effective communication happening when both designers and practitioners are able to frame and shift the debate, contribute without fear of embarrassment, take initiative in offering examples, ask rudimentary questions, seek to fully understand and clarify and remain engaged. Sometimes it is necessary to adapt your approach to design to allow this. This is something that became clear to us in our early studies and we have strived to improve this with each design activity. This is not a new discovery by any means. During the design of a multimedia educational application, Robertson noted that:

> “Cooperative design of the product was enabled and achieved by the work that the designers did communicating with each other” [11 pg 1]

What is interesting is both the types of participants that help this communication, and the ways of improving it. For example, involving one of the software engineers of the dental software in our activities allowed for explanations of the underlying structure of the code. This in turn provided realistic avenues for brainstorming and more efficient decisions for generating prototypes.

An important consideration is how to tell when you are having effective communication. Researchers may have a “gut feeling” that a discussion or activity is proceeding smoothly, but through examining videotape we were able to identify what contributed to creating communication and what indicated it was not happening. Signs of useful communication are obvious attempts at sharing understandings, such as offering clarifying information or finishing a statement. This indicates an interest and confirms to the other party that there is common ground. In doing so, it may also expose new opportunities in the design. For example, while John and David were discussing the use of accelerometers in a gesture recognition device, David was able to suggest new gestures based on his new shared understanding of the technical details. Further evidence of effective communication comes when the practitioner moves from thinking about how they work, to how similar practitioners might work. For example, Jason began describing problems with a potential interaction technique because “from dentist to dentist, it’s going to vary again”, and proceeded to demonstrate the different ways other practitioners worked in the same situation. It also indicates the practitioners are engaged when they spontaneously give examples of practice.

Spontaneous brainstorming indicates a level of comprehension that acts as a platform for new ideas. This is assisted particularly by designing in the practitioner’s domain. It allows the practitioner to posit new ideas for interaction within their domain and draw inspiration from their existing work practice.

While respect for ideas is expected during formal brainstorming, new ideas may occur at any point of the interaction between the designer and the practitioner. When spontaneous brainstorming occurs, ideas should be met openly by the designer during all stages of the design process. It is also an indication of a level playing field and the level of trust when this is reciprocated by the practitioner.

The following is what we believe to be a good example of effective communication in design. It is interesting because in the process of suggesting a new interaction technique, the practitioner gives an example which in turn leads to further brainstorming and realisations about why the interaction may be useful.

Designer: What if you tap the tooth you’re working on and then said a number – would that feel less natural than writing it?

Dentist: Oh that’d be alright.

Engineer: So you might be able to use the probe for navigation, like what surface you’re on and then entry say…

Dentist: …and then say four…

Engineer: Four, two, three…

Dentist: I do that with the nurse already.

Designer: So it’d definitely be more natural?

Dentist: Yeah, yeah, that would. Speaking would be more natural, also from a communication point of view, because what I normally tell the patient is that twos to threes are quite normal, when I start getting to fours, fives and more, we’re in real trouble then. So what happens is the patient is there going “oh I hope it’s not a four, oh great it’s a two, it’s a three”. We’re going along well, and then all of a sudden, “Oh no, it’s a six”. So it’s driving home the point that gum disease is there, and then if you get a whole range of issues, that are there, you can tell them well look you have a whole range across here, the disease is quite general. If you only call out those numbers a few times, you can say it's localised at a few areas, and they've got their communication by the fact you've talked about those numbers.

Engineer: And when you're saying it, you're just reinforcing…

Dentist: Reinforcing, that's right. So you're plying them with education.

Engineer: So saying it out loud is quite an advantage.

Dentist: Yeah, a big advantage than being silent. Because quite often we've been silent and they're going, "oh I wonder what he thinks".

Initially the dentist is not that interested – "Oh that'd be alright" – when asked about using speech instead of writing information on the teeth (another interaction possibility). However, once he begins thinking about it and drawing an example from experience, he relays that saying numbers out loud would help educate the patient, and becomes quite interested in this method of interaction.

The example is also interesting because just as communicative resources are important in design, they are important in dental practice. Practitioners recognise a need to communicate to their patients and to educate their patients in dental care. One of the best ways to do this is during the conduct of the visit itself. Dentists also recognise that service sells and justifies the bill.

Accountability and Design

The above interaction led to an interface design which made the dental procedure understandable to both patient and dental nurse, as well as dental practitioner and designer. It emerged through the process of participatory design in which both practitioner and engineering designer sought to understand each other's work. Accountability from an ethnomethodological perspective refers to the fact that parties to an interaction have access to and can report on the action taking place. Eriksén [5] discusses accountability in design from an ethnomethodological perspective, from a political perspective (from the point of view of adequately considering issues important to all stakeholders) and from a technical perspective (in terms of transparency of the workings of the technology underlying the interface). The above example is a nice demonstration of how in seeking to make the interaction intelligible in the natural course of conversation (accountability in the ethnomethodological sense), the interaction leads to a design that at least partially addresses issues important to stakeholders in the political sense – knowledge of how the procedure is going is made available to the patient. Both patient and dentist have access to and can report on the action taking place.

In the transcript below, the dentist reflects on speaking the procedure out loud to the patient and the importance of patient education:

Dentist: So yeah, calling out numbers is a big advantage, because just from treatment wise, periodontal disease is hard to sell to clients, because they have no pain, there's issues going on, so what if the gum's bleeding? It's no biggie. They stop. And it's one of those things where you've really got to get on top of it, and if you can use those numbers and that's one of the reasons I like the lines on that, is that it really starts to point out things… What I say to them is that, okay, these lines represent the level of bone and you've only got two spaces left, there ain't much there, and they can relate to that because they can see it on the computer. The computer doesn't lie. Graphing is actually really important, charting is really important to reinforce it. The voice side of it is good, if the dentist uses it in the correct manner. We've got to start educating them why we're charting and what we're looking for and then it actually works in their favour in getting that treatment accepted.

The existing periocharting application for dentists has what was criticised by the dentists as a poor interface for data entry. However, as data is entered into the application, it draws a corresponding graph of the patient's gum-line and the bone structure beneath (referred to as "the lines" in the transcript). Due to the assistance to patient education and the associated benefits, a dentist reported that many other dentists find a work-around for entering the data just so that part of the application can be used.

While in this case the dentist suggests what they are willing to share with the patient, it is often not practical for dentists to share everything. Nonetheless, this kind of interaction serves as a promising start for exploring what could be shared, and under what circumstances, leading to more possibility for opening up the medical (and perhaps billing view) to the patient, where the patient so desires.

The Nature of Participatory Design with Busy Professionals

We embarked upon this research in order to understand and to demonstrate how designing multimodal interfaces and ubiquitous computing could be done differently by collaborating with practitioners in authentic work domains through participatory design. Our research has led us to engage with different practitioners at different stages of the research as our design interests progressed from early explorations with general dental practitioners, to meeting the CEO of a dental software company, to meeting dentists who were interested in the development of dental software. This may give the reader a sense that we were simply engaged in user testing rather than participatory design.

Rather than engaging dentists as users in order to test our ideas, we have always conducted the research in the spirit of understanding the dentist, giving them as full access as possible to technical knowledge and choices, and giving the dentist a voice. We have strived to develop relationships of trust where we report back to the dentists on what we found and invite further input. We have struggled with the need to fit within the limited time we can glean from busy professionals, but believe this makes the endeavour no less participatory. It is worth pointing out that although we explain our approach of participatory design to our collaborating practitioners, we cannot assume that our practitioner colleagues adopt the view that they too are participatory designers. Nonetheless, we have always endeavoured to *design with* dentists, rather than *design for* dentists or *test our designs on* dentists.

FURTHER WORK

The activities and trial described within this paper are part of a larger arc of investigating the creation of a multimodal based interaction system for dentists through a participatory design approach.

CONCLUSION

A participatory design approach has been brought to the design of multimodal interaction and ubiquitous computing. Such an approach recognises the articulation work done by the practitioner in adapting and appropriating ubiquitous computing technologies into their cultural practices and material environments and seeks to engage the practitioner in design by building relationships of trust and mutual exchange. The paper describes how relationships were developed with a dental software provider and dental practitioners, sufficient to lead to the design of a useful prototype, even though the dental practitioners could only offer limited time to the design endeavour. The design effort focussed on creating and maintaining fruitful exploratory design discussions with practitioners, facilitated by development of a series of low fidelity prototypes that both explored and demonstrated technical choices in lay terms and allowed contingent use of technology in context to be revealed. A speech recognition based prototype was developed that makes the periodontal examination results available to the patient as they are recorded by the dentist. Issues of accountability and the extent to which this was participatory or user-centred design are discussed.

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