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Implications for the design of a digital stethoscope for anaesthetic preadmission consultations

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RESEARCH

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Abstract

Background
This research addresses the development of a digital stethoscope for use with a telehealth communications network to allow doctors to examine patients remotely (a digital telehealth stethoscope). A telehealth stethoscope would allow remote auscultation of patients who do not live near a major hospital. Travelling from remote areas to major hospitals is expensive for patients and a telehealth stethoscope could result in significant cost savings. Using a stethoscope requires great skill. To design a telehealth stethoscope that meets doctors' expectations, the use of existing stethoscopes in clinical contexts must be examined.

Method
Observations were conducted of 30 anaesthetic preadmission consultations. The observations were video-taped. Interaction between doctor, patient and non-human elements in the consultation were "coded" to transform the video into data. The data were analysed to reveal essential aspects of the interactions.

Results
The analysis has shown that the doctor controls the interaction during auscultation. The conduct of auscultation draws heavily on the doctor's tacit knowledge, allowing the doctor to treat the acoustic stethoscope as infrastructure – that is, the stethoscope sinks into the background and becomes completely transparent in use.

Conclusion
Two important, and related, implications for the design of a telehealth stethoscope have arisen from this research. First, as a telehealth stethoscope will be a shared device, doctors will not be able to make use of their existing expertise in using their own stethoscopes. Very simply, a telehealth stethoscope will sound different to a doctor's own stethoscope. Second, the collaborative interaction required to use a telehealth stethoscope will have to be invented and refined. A telehealth stethoscope will need to be carefully designed to address these issues and result in successful use.

This research challenges the concept of a telehealth stethoscope by raising questions about the ease and confidence with which doctors could use such a device.

Key Words
Design, digital stethoscope, qualitative research

Background
In Australia, people who require surgery and live in rural areas outside of the major capital cities must travel vast distances in order to receive pre-surgical care, which can be extremely expensive. An important pre-surgical service is a consultation with an anaesthetist who assesses the patient's suitability for anaesthesia. The pre-surgical consultation with an anaesthetist consists of an interview to obtain and review the patient's medical history and a physical examination by the anaesthetist. During the examination, the anaesthetist observes the patient's airway and examines their heart and lungs by using a stethoscope.

In order to reduce the need for patients to travel for pre-admission consultations, some health services use a video conferencing system to allow doctors to see patients remotely. In the Queensland health system a state-wide "telehealth" service is provided that can connect any hospital in the state to any other. In a remote consultation, the anaesthetist is at the main hospital and the patient is at their local hospital, typically two to three hundred kilometres away. A nurse is with the patient at the remote location to assist with the telehealth system and to provide other services to the patient at the end of the consultation.

The only component of the pre-admission consultation that cannot be completed by the remote anaesthetist is the

auscultation step. In some cases, the pre-surgical interview may be sufficient to ascertain the patient's general health and suitability for anaesthesia; however, in some cases, it is necessary for the doctor to listen to the patient's heart; for example, if they have a pre-existing condition which may affect their heart such as angina, previous heart attack or a heart murmur, or if the patient is "high-risk" in other ways. In these cases, it is necessary for the patient to travel to the main hospital for assessment, return home and then return again for surgery in two to four weeks. This travel is expensive and time-consuming. Conducting pre-surgery auscultation remotely could offer significant benefits to patients in remote and rural areas by eliminating this unnecessary travel before surgery.

This research aims to develop a digital stethoscope for use with a telehealth communications network in order to allow doctors to examine patients remotely. In order to create a digital stethoscope that is readily accepted by the doctors and meets performance requirements, we are collecting data about the use of existing stethoscopes in anaesthetic pre-admission clinics. We have observed both face-to-face and videoconference clinics.

Until recently, acoustic stethoscopes were the only type of stethoscope available. Now, however, there are electronic stethoscopes which offer diagnostic power similar to that provide by acoustic stethoscopes. There are measurable differences in the sound capture and transmission properties of different acoustic (1) and digital (2) stethoscopes. However, while different stethoscopes have measurably different sound reproduction, it is not clear whether those differences are perceptible or even diagnostically significant. For example, some sounds that are very low (below 50Hz) contain potentially valuable diagnostic information, yet many people are unable to hear these sounds with a conventional acoustic stethoscope (2).

There is great skill in using a stethoscope effectively and in interpreting the sounds that are obtained through the stethoscope (3-5). We have tried to investigate the ways that anaesthetists use a stethoscope as an example of tacit knowledge. Tacit knowledge is knowledge that is used by experts, in this case doctors, and is not able to be easily expressed as it is the result of long practice and reflection. A doctor's tacit knowledge about using their stethoscope allows them to use the instrument fluidly and in a way that makes the stethoscope, from the doctor's perspective, an extension of their practice as a doctor. While the stethoscope mediates auscultation, it is not the focus of auscultation. This is why a doctor says they "listen to your chest" not "use a stethoscope to listen to your chest". This tacit use of a stethoscope must be understood in order to design new devices that can function as stethoscopes.

Doctors generally agree that the use of stethoscopes should be encouraged (3-5). While some doctors seem to be cautious about the increasing role electronic technology plays in what was formerly a process with seemingly little technological mediation (6), Murphy (5) notes that recent advances in computer science and signal processing have meant that greatly increased objectivity in the analysis of breath sounds is possible. This integration of new signal processing technology with the established process of auscultation points towards a renewed role for the stethoscope as a diagnostic tool for nurses (7) and doctors in remote medicine.

There is some existing medical research on the use of digital stethoscopes for face-to-face and remote auscultation. Existing digital stethoscopes have been found to be useful in certain situations, such as in verifying the health of a patient's heart post-operatively (8). However, the criticisms made of the devices are that they lack sound quality (8, 9), and remote interaction with the devices is problematic (8, 9). This indicates that the design and use of remote digital stethoscopes are areas where a significant research gap exists. In a study which was performed "to determine whether the use of an electronic, sensor based stethoscope affects the cardiac auscultation skills of undergraduate medical students" it was found that students trained on the electronic stethoscope had no significant differences in diagnostic ability to students trained on the acoustic stethoscope (10). This indicates that it is the remote and collaborative aspects of the interaction that are problematic, not the difference in the form of the device. The generally positive results (8, 9) and cautious optimism (11) reported in field studies of remote auscultation indicate that a digital stethoscope for use in telemedicine would be valuable. The concerns expressed in the previous studies of digital stethoscopes in telehealth relate particularly to: the new skills that must be learned by the doctor and nurse, the "lack of visual cues" (8) and the difficulty of remotely directing the placement of a stethoscope head (9). This indicates that this is an area that needs in-depth research that focuses on remote interactions and users' experiences with stethoscopes.

Method

Thirty preadmission consultations between doctors and patients were observed, consisting of 27 face-to-face consultations and three telehealth consultations. Currently, no stethoscope is used in a telehealth consultation. As the research was intended to document how stethoscopes are used in face-to-face consultations, the telehealth consultations were observed to ascertain the context into which the telehealth stethoscope would be inserted. The small number of observed telehealth consultations provided adequate information about the telehealth context for the purposes of this study. Participants were selected opportunistically over a period of several months. That is, patients who were waiting in the pre-admission clinic waiting area were approached for their consent to participate in the study. Remote patients were approached and consented via teleconference before being seen by the doctor. This selection method was employed as the purpose of the study was to obtain a qualitative view of everyday interactions in pre-admission consultations. It is possible that as a result of the opportunistic selection of participants some particular types of doctor-patient interaction were

not observed or were not sufficiently observed. As a consequence, the results of this research are indicative only. However, the sample size reported here is relatively high for qualitative research of this type. No incentive was provided to participants. No screening questionnaire was used. Doctors were approached and consented before the clinic time started. All participants, doctors and patients, signed informed consent forms.

Each observation began, once consent was obtained, when the patient entered the consultation room and finished when the patient left the room. The observation was recorded on video. Patient participants were given the option of the researcher leaving the room during the consultation though this was rarely requested. The video captured the full interaction between doctor and patient.

Analysis of the video is done by creating "codes" which are applied to the video to delineate segments of time that are of interest. Codes describe behaviours, or sequences of behaviour, actions or parts of actions, or any other aspect of interest. We use The Observer software (12) to aid our analysis. Table 1 shows the codes used in this analysis.

Table 1: Observation Coding Scheme

Code	Description
Examination	Conducting a physical examination of the patient
Medical Record	Doctor's attention is on the patient's medical record
Computer	Doctor's attention is directed at the computer
Writing	Doctor's attention is directed at writing
Patient Conversation	Doctor's attention is directed at the patient

The coding scheme used in this analysis describes the activities performed by the doctor in a typical pre-admission consultation. The coding scheme does not, indeed can not, describe all the activities that occur in a consultation. Instead, the coding scheme captures activities that are of interest. In this case the coding scheme is focussed on the organisation of work during a consultation. The coding scheme was developed over the course of the analysis and, once it became stable, was applied consistently to all observations. The examination code was used when the doctor physically examined the patient, including auscultation. Stethoscope use was not coded in detail because only broad positioning information could be seen in the video data, which did not contribute to understanding the doctor's activities in the consultation. Second, the relevant information obtained through auscultation is heard only by the doctor, interpreted and is then written on the patient's admission paperwork and/or medical record. It is this larger act that is relevant for this research and it is captured in the interaction between the examination, medical record and writing codes. The medical record code indicated when the doctor was using the patient's existing medical record, which was contained in a paper file. The computer code was used when the doctor used the computer on the consulting-room table. The writing code was used when the doctor wrote notes on the pre-admission consultation paperwork. The patient conversation code was used when the doctor and patient spoke to each other. If the patient was speaking but the doctor's attention was directed elsewhere, for example towards the computer, then the other relevant code was used.

Results

Two findings arise from our analysis. First, it is clear that the stethoscope mediates interaction between doctor and patient during the physical examination. The doctor's actions during the physical examination draw so strongly on tacit knowledge that they simply use it as a way to gain access to the sounds inside a patient's chest. It is this finding that most significantly impacts on the design of a future digital remote stethoscope. A digital remote stethoscope will require doctor, nurse and potentially patient to work together in a way that requires high use of explicit knowledge rather than the tacit knowledge that the doctors access in order to use their existing stethoscope.

The second finding is that pre-admission consultations are mediated by the administrative aspects of the consultation and that the stethoscope plays a subsidiary role and is not even the primary tool used in the consultation. It is for this reason that it is currently possible for some preadmission consultations to take place via teleconference even though there is no facility for doctors to conduct remote auscultation.

Both of these findings arise from our application of the coding scheme to the video data. In the analysis here, the medical record, computer and writing codes (Table 1) have been combined as "administration". Figure 1 shows that, considered in this way, administration makes up the largest block of time during a consultation with an average time of 00:06:05 minutes, followed by conversing with the patient, 00:05:17 minutes, followed by the short time spent on the physical examination, 00:01:15 minutes. That is, the physical examination of the patient is subsidiary to working with the administrative aspects of the consultation. The examination is very quick and the auscultation time within the examination even shorter. The activity times do not convey the fluidity with which the doctors conducted the examination and auscultation, which is apparent in the videos.

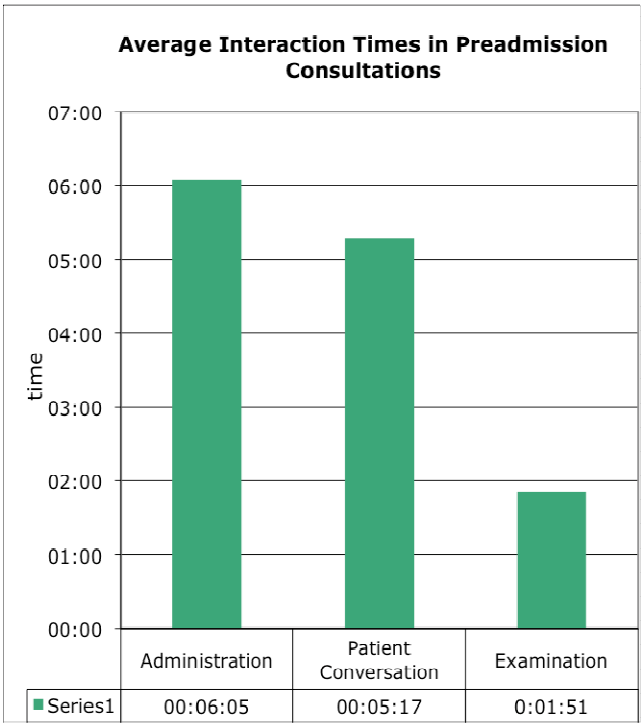

Figure 1: Average interaction times in observed preadmission consultations.

While the medical record always has a strong role in the consultation the stethoscope acts as a tool that is brought into use by the doctor as needed. Patients who are generally healthy receive a brief auscultation. Patients who are infirm or who have potentially dangerous existing conditions receive a similar length auscultation to low risk patients but a longer physical examination. The similar length of auscultation suggests that the skill of auscultation is in the interpretation of the sounds from the stethoscope and that very similar techniques are used to obtain the required sounds, regardless of the patient. The observations have shown that the doctors are able to use their stethoscope as it suits them and they use it with great fluidity, demonstrating high level of expertise. Doctors would often say to the patient, "I'll listen to your chest now" and then give the patient some instructions, such as "lift your shirt", or "hold your breath", however there was no time when any of the doctors observed demonstrated any behaviours that indicated anything less than complete mastery of their stethoscope. The doctors were observed to demonstrate fluent performance applying the stethoscope on the patient's chest, back, sides and occasionally neck without shifting their focus (13, 14). This fluent behaviour is consistent with existing expertise research and demonstrates the doctors' high familiarity level with their stethoscopes, the process of auscultation and auscultation's role in the pre-admission clinic.

The fluent, intuitive, way that the doctors use the stethoscope and the subsidiary role the stethoscope plays in a consultation has several implications for the design of a telehealth stethoscope.

Discussion and implications for design

The results of this study, and our previous analysis (13, 14), suggest that a good telehealth stethoscope must be as similar to existing acoustic stethoscopes as possible. This implication means that a telehealth stethoscope must sound like existing acoustic stethoscopes and the practice of using it must be as similar as possible to existing acoustic stethoscopes.

A difficulty in sounding like existing stethoscopes arises because all stethoscopes have slightly different frequency response – that is, they all sound measurably different. Different stethoscopes sound measurably different (1, 2). This is problematic for a telehealth stethoscope as doctors' tacit knowledge about their stethoscope and practice of auscultation is based on familiarity with their own stethoscope's sound. A telehealth stethoscope will certainly sound different from a doctor's own. It is unclear whether differences between stethoscopes result in less accurate diagnoses by doctors or even if the differences, while measurable, cause the doctors difficulties.

The most relevant finding is the high level of expertise with which doctors use their stethoscope. One reason that the doctors have been able to acquire such a high level of expertise with their stethoscope is that it is consistent. An acoustic stethoscope is a relatively simple artefact with very few parts. The consistency in response of the stethoscope allows the doctor to treat it as being transparent. Rather than focussing on using the stethoscope, a doctor can focus on listening to the patient's chest. If the transparency of the stethoscope were broken or changed in some way, the stethoscope would cease to act as "invisible" and would become a thing to deal with in and of itself. An effective telehealth stethoscope must therefore allow a doctor to make use of their tacit knowledge about listening to a patient's chest.

Treating a telehealth stethoscope as largely invisible will be more difficult as it will be a system of physical artefacts and software. All elements of the telehealth stethoscope must work correctly to allow a doctor to use it tacitly. In order that an acoustic stethoscope functions correctly it must simply be in good repair with no cracks in the tubing and have a diaphragm that is intact. In contrast, a telehealth stethoscope places a large number of artefacts and systems between the doctor and patient and will require new working relationships between people in order for auscultation to take place.

Unlike a face-to-face pre-admission consultation, in which a doctor and patient sit opposite each other, in a telehealth consultation doctor and patient view each other on a television screen. A nurse sits with the patient at the remote end of the consultation. In order for the doctor to listen to the patient's chest, the doctor and the nurse will have to work collaboratively to apply the head of the telehealth stethoscope to the patient's chest. Each time the doctor wants to shift the head of the telehealth stethoscope, or even to subtly adjust the positioning of the head of the device, communication will have to occur between doctor and nurse. The additional interaction

between doctor and nurse and the collaboration that will be required to obtain good chest sounds will be a new practice. This will have to be learned in order to make a telehealth stethoscope useful. The collaborative work of using a telehealth stethoscope will need to become part of the practice of using the system in order to make the system work and this collaborative practice, as well as the actual device, will also need to be designed.

Conclusion

This research has led to a significant implication for the design of a successful telehealth stethoscope: a telehealth stethoscope will be a shared device, not a personal one. As all acoustic stethoscopes reproduce the sounds of the chest slightly differently, doctors build their auscultation expertise through their personal stethoscopes. A telehealth stethoscope will sound different to a doctor's own stethoscope and this may have an impact on their diagnostic and interpretative ability. Using a telehealth stethoscope will be much more complex than using an acoustic stethoscope because of the collaborative interaction required in order to make use of it. While some systems, such as the telehealth infrastructure, exist already, other systems and social protocols, such as how doctors, nurses and patients will interact, are yet to be created.

These preliminary findings are significant because they provide new knowledge about the factors influencing the adoption of telehealth stethoscopes for remote patient assessment. If the systems that will support the use of a telehealth stethoscope are not adequate, then the telehealth stethoscope will not be able to be used. These findings allow a deeper understanding of what a successful telehealth stethoscope should be and will ultimately lead to the production of an advanced telehealth stethoscope that will enhance the ability of doctors and nurses to conduct remote auscultation assessments.

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CONFLICTS OF INTEREST

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