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Introducing vocal modality into electronic anaesthesia record systems: possible effects on work practices in the operating room

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ABSTRACT
The work reported in this paper is part of a project aiming at introducing vocal modality into the electronic anaesthesia record in Denmark. The purpose of the paper is to offer a basis for comprehending the use of anaesthesia records in work practice, to list the current main issues and possible improvements, and finally to foresee the impact of the addition of a new voice interface. The present paper is the result of a collaboration between an engineer, involved in making prototypes of the system described above, and a socio-ergonomist. The analysis is based on a literature review, interviews and direct observations.

Keywords
Anaesthesia, electronic records, patient, voice, speech

INTRODUCTION
Problems in the way paper based and electronic anaesthesia records are filled during anaesthesia have been observed, such as anachronisms, temporal defects and lacking entries. In response, it has been suggested that a way to surmount these deficiencies is to offer anaesthesiologists a voice-based input modality to an electronic record (Schmitz, 2004). Some attempts have been made (Jungk *et al.*, 2000; Sanjo *et al.*, 1999), and are calling for more research, on identifying precise subtasks where voice input can be beneficial, on the specific human-computer interaction, such as feedbacks, and on the trade-off between vigilance and visual contact with the patient. Some studies have demonstrated the usefulness of activity modelling in anaesthesia interfaces (Beuscart-Zéphir *et al.*, 2001), but they focussed on the pre-operative consultation. On top of technical difficulties, other issues and a number of research questions need to be considered, such as the different roles of the anaesthesia record, and the prediction of possible impacts of the new technology on the activity. A detailed analysis of the activity should allow us to extract some guidelines to be used in future experimentations of the new tool. The implications of the modification of tools on work practices are also taken into account.

FOCUS OF THIS PAPER
We leave aside a first set of questions, which has to do with the underlying assumption behind the problem as defined above, and raises the issue of whether a "good" anaesthesia record is a one that is fully and correctly filled. To say a word about this, we often take for granted that increasing the amount of information in the record, and allowing this information to be filled synchronously to the operational reality is a good objective. However, interviews have shown the difficulty to differentiate between important and unimportant information in electronic anaesthesia records that were 'fully' filled, while in hand-written records, that were visibly incomplete, important information was easier to identify. Moreover, while extending the file, anaesthesiologists do not focus on the patient. This area of issues around the question of what a "good" record is thus raises a set of questions, like the roles of record, during an operation or outside the operating room, and the interests of anaesthesia doctors in filling the records 'fully'.

A second set of issues concerns the changes that the new technology will have on work practices, both in the operating room and outside. For instance, in the operation room, we can expect that the new modality might affect the existing communication schemes. In order to start comprehending these issues, we need to have a reasonably complete picture of the activity of the anaesthesia doctor, and the role of the record, at least in the activity around the patient.

The present conference article will focus on the second set of questions. The aim of the present work is to describe the activity of the anaesthesia doctor and of the roles of the anaesthesia record in this activity. In fact, while we believe that the first set of questions (the one left aside) is central when seeking to validate the new technology in relation to patient safety (Gauthereau, 2004), we also believe that we first need to comprehend the activity itself, if we ever wish to understand the mechanisms behind its evolution over time (Lave Jean, 1993).

ELECTRONIC ANAESTHESIA RECORDS (EAR)

Introduction to anaesthesia

Anaesthesia is a medical act aimed at reducing the pain and consciousness of a patient, in order for him to receive a medical act such as surgery. There are various kinds of anaesthesia; some of them are only targeting an area of the body, with the patient still awake. In this paper, we will mainly focus on general anaesthesia, which is applied to the whole body and keeps the patient asleep using various kinds of drugs administration, such as induction agents to produce unconsciousness, analgesics to reduce pain, muscle relaxants, inhalation agents to keep the unconsciousness, etc. In many countries, general anaesthesia can only be conducted by a specialist doctor. In some other countries however, nurse anaesthesiologists may deliver anaesthetics, normally under the supervision of a specialist doctor. In this paper, "anaesthesiologist" refers to the practitioner, doctor or nurse, directly in charge of the patient. During anaesthesia, many choices have to be made by the practitioner, based on knowledge, monitor trends as well as direct observations. This activity is reported in the anaesthesia record (AR).

Importance of the anaesthesia record (AR)

During anaesthesia, the main task is to take care of the patient, so the AR is a secondary task. This means that anaesthesiologists do not necessarily have much time to do it. They may be stressed or not fully concentrated on the record keeping; they sometimes postpone it after the operation and have to rely on their memory. But the AR is important, not only because it is a legal document, but also because it is used during operations to communicate and make available what has occurred previously, especially to support a quick oral briefing if someone joins the team. Indeed, at the organisational level, some hospitals base their incidents recuperation strategy on experienced anaesthesiologists joining the medical team in a minute (de Keyser & Nyssen, 1993).

An analysis has shown that 70% of reported anaesthesia incidents were related to human errors (Chopra *et al.*, 1992), and a study of some accidents shows a lack of functional communication in the medical team (de Keyser & Nyssen, 1993).

The fact that the document is an indispensable source of information during the operation is the main reason for maintaining a real-time system: the information entered into the anaesthesia record cannot be just recorded (audio/video) and eventually transcribed. It is also used as a verification mechanism; for example, some anaesthesiologists believe that it is better to fill the anaesthesia record before transfusing some blood to the patient, in order to ensure that the codes are checked correctly before any critical administration (de Keyser & Nyssen, 1993).

What is actually recorded in the AR and how, reflects local customs, but the AR must at least contain the main vital signs (*e.g.*: heart rate), time, techniques, route and dose of the administrated drugs, as well as the main events (*e.g.*: surgery started).

From paper templates to electronic systems

In operation rooms, registration of anaesthesia records during anaesthesia has been done manually on paper for a long time. However, it is well-known that hand-written documents in the medical domain are a common source of communication mistakes. A survey yielded the following result: "46% of medication errors occur on admission or discharge from a clinical unit/hospital when patient orders are written, and they drop by 90% when they are electronic" (Pronovost, 2003). Moreover, handwriting is quite time consuming and forces the practitioner to leave the current task to use pen and paper. Therefore, especially during busy and perhaps emergency phases, staff will sometimes defer writing down the information in the anaesthesia record. In turn, this may lead to the risk that practitioners might forget or misremember data, which will produce misleading information with potential impact on subsequent phases of the anaesthesia.

Furthermore, in contrast to electronic systems, paper-based recording does not provide much barrier to ensure that the provided data is consistent; it is filled and used in various ways by the different practitioners, creating inconsistencies, and there is a lack of space to write the remarks or some other precisions.

As a result, it seems that a substantial percentage of anaesthesia paper-based records are incomplete or contain errors (Hamilton, 1990). This is in agreement with a rapid small-scale analysis we did in June 2004 at Herlev University Hospital (DK), which uses paper-based recording. 55 records were randomly chosen and computerised without correction by a highly skilled anaesthesia nurse. As examples, only 7 (13%) specified the ASA (American Society of Anesthesiologists) physical status classification, which is recognised to be important, and 14 (8%) did not provide any information about the time when the operation or the anaesthesia ended. We then focused on obesity, as it is easy to establish inconsistencies automatically. Out of 55 files, 42 (76%) contained valid weight of the patient, which is a required information. 15 files (27%) provided additional information about height, which allowed us to calculate the body mass index (BMI). When BMI >= 30, it is likely a sign of obesity; this was the case for 9 files, and out of them, 8 (89%) had not checked the obesity field, as they should have done.

Finally, the sometimes hard-to-read handwriting presents additional problems that are not always trivial. This makes those files difficult to use, especially when they have to be transmitted to another department or hospital. Some observers have therefore argued that there is a need for a complete electronic "patient data management system" (PDMS) (Schmitz, 2004). Today, some anaesthesia departments have switched to electronic systems, including an electronic anaesthesia records.

We did a survey in October 2004 on almost all the anaesthesia departments in Denmark. Among the 35 responding departments, 13 (37%) did not use any form of electronic system, 14 (40%) used a complete electronic system, and the 8 (23%) left used a partially electronic system.

DESCRIPTION OF THE PROBLEM

Current problems with EAR

While electronic anaesthesia records (EAR) seek to solve most of the issues encountered with paper-based recording, there is still room for improvement. The comments, in particular, are not described as precisely as they could be, partly due to the use of a keyboard, not convenient in such an environment. When doctors and nurses are busy and maybe stressed, the registration process is often delayed, which can lead to omissions, uncertainty, inaccuracy, resulting in anachronisms. There are some events that do not require precision, and five minutes precision is fine for most cases, but that can be difficult to achieve with the current interface.

Moreover, observations in 3 other hospitals in Denmark (Køge, Frederiksberg, Bispebjerg) have shown that the touch-screen used in the current interface is often placed behind the anaesthesiologist, which is not especially convenient, as it makes difficult seeing the record and the patient at the same time (see Figure 1). In addition, no alternative pointing device has been observed, in case the touch-screen would fail, even though difficulties with the touch-screen have been noted, like when using menus. In addition, the small font size forces some users to change glasses to read or fill the record.

What to improve in the records?

Today, electronic patient data such as heart rate, blood pressure, etc. are automatically recorded. However, other information, such as patient current skin colour, is equally important to the anaesthesiologist. Furthermore, validating, labelling and commenting the data automatically recorded could be very useful for later interpretation. Even if this is already possible in the observed systems, it is rarely done. Improving the quality of the data being recorded during the operation should support different functions in which the records are being used during this operation.

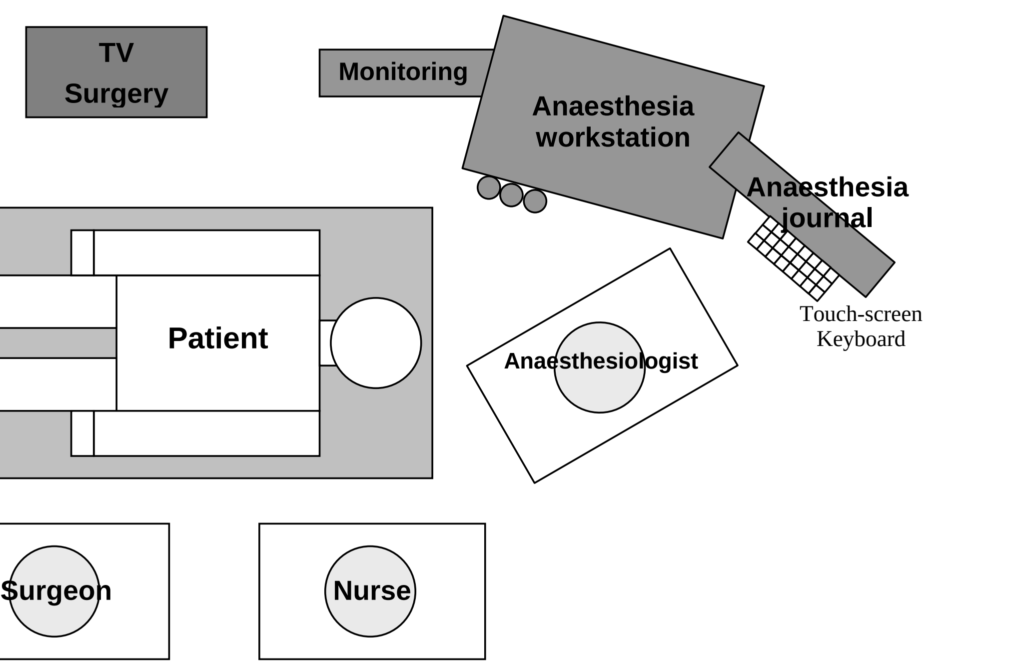
Support for decisions

Anaesthesiologists like to see the parallelism between the vital signs and actions undertaken. While this is already true and efficient today, it could be improved with a more complete and accurate timeline of simultaneous actions and comments. Also, considering future possible developments, we can see that some efforts have been made to make anaesthesia monitors and alarms more "intelligent", in order to provide more concise information; but those systems are limited by the lack of relevant data: "not all information can be given by the monitors, and the anaesthesiologist is too busy" (de Graaf *et al.*, 1997).

Support for memory

The AR is often used as a memory support, especially during long or difficult operations. Since gathering relevant information is laborious, it is important to improve the way it is recorded; otherwise, especially when workload is high, the anaesthesiologist will tend to rely only on memory, which can be a source of errors or time delays.

Figure 1: Anaesthesia theatre



Support for communication

The AR is used as a support for verbal communication between the different actors involved in the anaesthesia. Observations have shown that they point to precise areas on the record while talking and explaining things. Insuring that the EAR is up to date is therefore crucial.

Why introducing vocal modality in EAR?

It has been thought that vocal modality could improve the way EAR is being filled out (Schmitz, 2004). If it can provide a faster interface, it would be especially useful for short anaesthesias, like abortion or appendicitis, when the time spent to feed the record is sometimes longer than the operation itself. We believe voice input would be especially suitable to standard commands and remarks like "Intubation". Other important benefits would be gained if voice can avoid postponing the registration, which creates a loss of precision, takes extra time and resources.

Voice recognition in the medical domain

Improvements in voice recognition have allowed successful project in the medical domain (Devine *et al.*, 2000), such as voice commands to assist surgery at Hvidovre hospital (DK, 2004) (in English). With speech engines available in Danish, some systems have been put into daily use, such as diagnosis dictation at the radiology department of Vejle Hospital (DK, 2003) and are rapidly spreading to other departments: anaesthesia in October 2005 (Philips/Max Manus voice technology). However, most existing applications are targeted at non-real-time environments: doctors provide dictation, perhaps in an office, where input and subsequent reviewing may be made in batch mode.

Consequently, there is little literature about real-time speech input during operations or anaesthesias, when voice recognition is not the primary task and where there is a need of processing, interpreting and validating more complex speech in order to react, to do precise actions or verifications, to write in the correct fields and to move between them (Smith *et al.*, 1990).

Differences with existing medical voice interfaces

Current voice recognition systems in daily use in the medical domain, such as for X-ray diagnosis in Vejle hospital, provide an efficient way to enter plain text into the system. However, this kind of application differs from the EAR in two respects.

First, as described before, the anaesthesia record is not the main task of the practitioner, while it can be considered as the main one for X-ray diagnosis. This situation creates additional difficulties for voice recognition with a noisy environment, possibly with other people speaking, and with variations in the speaker's voice because of stress, a mask covering the mouth, body movements and postures.

The second point is that in current systems, recognition is made in a free speech mode, which means that the user does not have many constraints in the way sentences are formulated. In return, the system delivers a block of plain text with no interpretation (the computer does not know what to do with the data), no verification (ranges, units) and almost anything could be said. When this method is perfectly adapted for writing a typical 15-line summary, it is not directly suitable for filling an anaesthesia record. Since the anaesthesia record is composed of several areas with fields that are meant to contain various kind of information, the voice recognition system has to be able to determine where to store the data, in order to use the correct format and to limit the range of what is acceptable (numbers, units, medications, etc.).

For filling in the anaesthesia record by voice, the anaesthesiologist will have to use a set of commands – based on keywords – to quickly navigate in the form, like moving between the fields. This phraseology (the way to speak to the system) can be extended with high-level sentences dedicated to the main events that occur during anaesthesia, such as "intubations" for example, for the anaesthesiologist not to have each time to explicitly specify the targeted field. Those commands and high-level sentences can be recognised by the voice recognition system and associated to a meaning.

Relying on a precise phraseology to address the system, the voice recognition engine is not only able to return some plain text, but also to react, to do precise actions or verifications, to write in the correct fields and to move between them.

MODIFYING WORK TOOLS AND ITS IMPLICATIONS ON WORK PRACTICES

As we are modifying work tools, it is crucial to be aware of their important role in human activity. In accordance with the activity-theory research tradition, we understand activity as basically mediated. That is to say, in order for a subject to perform an activity, there is always use of a mediator. This mediator can be either a physical artifact, or a symbolic one, or both simultaneously. The physical environment has structuring properties fundamental to cognition, as do artifacts whose structures are the products of a more or less long social-cultural process (Nardi, 1996).

Given the complexity of tools usage in human activity, predicting all the implications of a technical change on work practice is almost impossible. Tools are used on different levels (instrumental or semiotic) and support different cognitive mechanisms. Moreover, their usage highly depends on the level of expertise of the user. While some implications of technological changes can be predicted, not all of them can. Validation of new technology while in need of in-depth studies of the actual activity, thus needs a stage during which the new technology will be introduced in a practice in order to study its actual effects on work practice.

Activity-analysis can support innovation but should not be used too much as a brake: not being able to predict all the implications of a technological change should not be used as a reason to stop the innovating process.

USE OF ELECTRONIC RECORDS IN THE ACTIVITY

In order to highlight consequences of modifying anaesthesia work tools and to achieve a well functioning solution, we need to test prototypes in simulated environment. A good starting point is to test the principle of the new tool in "Wizard of Oz" experiments in which a perfect version of the tool will be simulated by humans. In order to prepare this set of experiments, we should have assumptions about the impacts that can be observed. The first step is thus to understand the current practice (Gravenstein, 1989).

In this section, we are going to describe the activity of anaesthesia linked to surgery in an operating room. The main objective of anaesthesia in relation with surgical operation is to enable a situation that allows surgery: it is a facilitator's role. However, while this is the assigned objective, anaesthesiologists have another main goal: to maintain the patient as close to consciousness as possible. It is thus a situation in which anaesthesiologists are dynamically controlling the level of consciousness of the patient in order to limit as much as possible the depth of anaesthesia while at the same time enabling the surgeon to perform his task on a patient that is non-reactive.

We can identify 6 mains phases in an operation with anaesthesia: a pre-operative phase, a pre-anaesthesia phase, an induction phase, a regulation phase, a post-surgical phase and a post-operative phase (*cf.* Table 1).

Pre-operative Phase

The main goal of this phase, which can be performed some days before the operation, is to establish the profile of the patient during an interview.

At that moment, the anaesthesiologist prepares the case, taking forth the patients data, in order to establish a risk level for each patient. This risk-level (ASA class) influences the procedures that will be in use during the operation. For planned operations, this evaluation is done through an interview of the patient, which is the occasion to establish the general health profile of the patient, current medications, etc.

Today, in Denmark, even when electronic records are in use, doctors generally use paper-based documents and will have to re-enter the information in the computer system. This appears to be mainly due to financial considerations and lack of interoperability among systems, and should be solved soon.

Pre-anaesthesia Phase

This phase usually takes place in the operating room itself, or in a preparation room in which everything will be settled and then moved all together in the operating room. The main goal is to prepare the anaesthesia: the patient, the equipment, the monitors, the drugs, etc. This phase begins a while before the arrival of the patient, to start preparing the drug, and the equipment. For instance, the drugs are put forth and labelled. Once the patient arrives, the anaesthesiologist will first check the patient identity, and the kind of operation expected. During this phase, the anaesthesia record starts to be filled with information about the patient and the anaesthesia team. Sensors used to record the patient's vital signs are connected to the monitors and to the patient. The anaesthesiologist also explains to the patient what is going to happen. At this stage, the anaesthesiologist is typically assisted by another one.

Induction Phase

The induction phase starts with the administration of the first drugs. The anaesthesiologist is very active and needs to manage several tasks simultaneously, monitoring the consciousness level of the patient in order to intubate when it is appropriated.

During that phase, the anaesthesiologist needs to carefully follow the patient vital signs, both from the monitors and from the sight of the patient, while at the same time, more anaesthesia drugs must be administrated. Once the patient is intubated, the anaesthesiologist can rely a bit more on the artificial breathing system. Until then, the anaesthesiologist actually needs to support the natural breathing function of the patient using a manual breathing system.

In the observed situations in Denmark, two anaesthesiologists are present during this phase, mainly communicating by looking at each other's actions, without much talking. The main events are reported in the EAR as soon as one of the anaesthesiologists has time to do it. Most likely, the one monitoring the patient and in charge of intubating the patient is not the one that will fill up the record. This step is quite short, as it lasts for about 5 minutes.

The next step is the intubation itself, and once the patient's state is stable, the surgery can start. This takes another few minutes. At this early stage that follows the intubation, the anaesthesiologists tend to verbalise quite much to the nurses. With time, this will decrease to the benefit of verbalisation to surgeon. Focus is then more on the monitors and less on the patient.

Maintenance Phase

When surgery has started, there is typically only one anaesthesiologist left, who constantly takes care of the patient, and administers drugs that will keep this one in an unconscious state. The anaesthesiologist carefully monitors the patient's health because of drugs side effects and surgery, like impact on blood pressure, heart rate and breathing.

During this phase, when surgery has started, the anaesthesiologist must be especially vigilant about vital signs of these basic functions. Since blood pressure and

Table 1

<table>
<tr><td colspan="6">Anaesthesia process</td></tr>
<tr><td rowspan="2">Pre-operative</td><td colspan="4">Peri-operative</td><td rowspan="2">Post-operative</td></tr>
<tr><td>Pre-anaesthesia</td><td>Induction</td><td>Maintenance</td><td>Recovery</td></tr>
</table>

heart rate are not only impacted by the anaesthesia drugs, but also by the surgical act in itself, the anaesthesiologist needs, once changes in these vital signs are detected, to identify the specific cause behind these perturbations. The identification might, on the one hand, help the surgeon to detect an error (such as a cut of a wrong blood vessel), and on the other hand, alert the anaesthesiologist about a dangerous reaction of the patient to the drugs.

In order to monitor the patient's status, the anaesthesiologist looks at the monitors providing vital signs, but also at the patient (colour of the face, muscles' relaxation, hydratation level, pupil dilatation). Electroencephalogram (ECG) can sometimes be used, as they can help anaesthesiologists by providing data regarding the consciousness level of the patient.

Since this phase has normally a lower workload than induction and recovery, the anaesthesiologist usually takes time to complement the record for the previous phase. Today, when vital signs are automatically recorded, the anaesthesiologist must pay attention to the validity of this data, and also needs to enter data regarding the drugs used (changes in concentrations, injections, etc), and main data regarding the surgical act (at least start/end of surgery).

This phase is a lonely one for the anaesthesiologist. In case there was some help during the induction phase, the second anaesthesiologist has left the operation room shortly after the maintenance has started. Moreover, other nurses are usually more concerned by the surgical act than by the anaesthesia.

The vigilance and activity level of the anaesthesiologist may vary, during the different phases of the surgical act, but also from one patient to another one. For critical cases (i.e.: high ASA classes), the anaesthesiologist will anticipate more on what could go wrong. In general, one could say that there is a constant need of anticipation, for example: the inertia of the body's reaction to drugs requires proper temporal model. The anaesthesiologist also needs to follow the surgical act, as this information will be used in order to anticipate the beginning of the recovery phase (de Keyser & Nyssen, 1993).

Recovery Phase

At this stage, surgery is about to be finished and a secondary anaesthesiologist has often joined the team. Anaesthetic gases have already been stopped, by anticipation. When recovery can actually start, the antidotes will be injected, especially in order to reverse the effects of muscle relaxants. By the end of the recovery phase – the patient still being unconscious –, the anaesthesiologist extubates the patient just before this one wakes-up. The main preoccupation of the anaesthesiologist at this moment is that the breathing function becomes natural again.

This transitory phase is complex for different reasons. Firstly, as we said, the patient needs to breathe on his own again. Secondly, the surgery being over, nurses will start cleaning up the patient, for instance by taking away compression points. In fact, since this is a more complex task with more simultaneous things to be done, the anaesthesiologist is often assisted, as in the first two stages. The division of tasks follows a traditional schema, so both the anaesthesiologist and the assistant know in advance who will do what. Normally, the anaesthesiologist and the assistant only discuss about sharing tasks when there is a need to modify the traditional division of labour, for instance when one of them wants to practice specific actions.

Here once again, the anaesthesiologist needs to enter data in the record, typically restricted to factual data like time of extubation, injections, etc. Thanks to the anticipation of the anaesthesiologist, this recovery phase lasts approximately 10 minutes. It is the responsibility of the anaesthesiologist to decide when the patient is conscious enough – *e.g.* to reply orally – and can thus actually leave the operation room, to be handed over to the recovery room.

Post-Operative Phase

After a general anaesthesia, vital signs will continue to be monitored and reported in the AR. Together with the patient, the anaesthesia record is transferred to the recovery room. So far, the patient record contains both preoperative data as well as the AR with a description of what happened during the operation. Furthermore, the anaesthesiologist has put some specific comments into the AR, which will be used by the nurse in the recovery room to know how to handle the patient.

The case of crisis situations

In the previous description, we have not discussed the case of crises that may occur under a planned operation. Even if we have not yet observed such crisis situations, we know from interviews that under those circumstances, filling up the record has a low priority to the eyes of the anaesthesiologist. Even though this level of prioritisation decreases, a well-informed record is, in these cases, even more important. Indeed, these abnormal situations are the most interesting ones to analyse and comprehend. From that particular standpoint, records that are properly filled out are important. Not only it is interesting afterwards, but during the operation itself, crises are very demanding: the anaesthesiologist needs to take complex decisions that require good supports. In such a case, it is especially important to clearly see the relations between the vital signs, the drugs administrations and other undertaken actions. Being able to link these two sets of data should enable better decisions to be made.

A FOCUS ON TIMELY CONSTRAINED PHASES

Returning now to the study of the implication of the new tools, we can easily identify two major categories of impact. The first category is directly linked to the new modality: how does the use of this new modality influence the concurrent activities? The second category is linked to the product one wishes to obtain thanks to this modality: how can a better-filled record affect the upcoming activities. In order to analyse the potential impacts of the new interface, we assume that the vocal modality is used as intended, that is to say, data is recorded more or less in real-time.

Implications on concurrent activities

On the anaesthesiologist himself

During the induction phases, but also during recovery, the anaesthesiologist is quite active physically, and to record data by talking is yet another simultaneous task. On the one hand, one could argue that this could increase the workload of the anaesthesiologist, but the new task actually consists of verbalising current activities, that is to say, no new task is created that would be independent from the existing ones. On the other hand, the anaesthesiologist's self-consciousness might be improved.

During the maintenance, which does not require a lot of physical activity, the vocal modality is less needed. Regarding the impacts of the new technology on the anaesthesiologist himself, differences with induction and recovery phases are minor, at least qualitatively.

On the interactions with other medical staff

During high-activity phases, the anaesthesiologist's audio channel might be less receptive to others. There is thus a potential impact on the communication from other staff to the anaesthesiologist. During these phases, the most probable person to interact with, is the second anaesthesiologist. Nevertheless, oral communication between these two persons is kept low, at least under normal circumstances.

The other potential negative impact is on how others pay attention to the anaesthesiologist's talk. And we have two alternative hypotheses: either people will not listen anymore, or in the contrary they will listen to everything said, even what is not of interest for them. It is also important to pay attention to the impact on the work of other medical staff. Choosing an appropriate microphone can reduce the negative impact.

Implications of verbalisation

According to Ericsson & Simon (1984), three levels of verbalisation can be identified.

The first level refers to situations where it is a matter of saying loud something without transformation, such as numbers or words displayed on monitors. This kind of verbalisation is very reliable and increases the cognitive load very slightly.

The second level requires creating dedicated sentences, such as a description of the patient's skin, or what basic action has been done. This is considered reliable, even if it increases a little the workload.

The third level, which is considered less accurate, implies additional cognitive processing, as it is about giving opinions, making inferences and filtering or using long-term memory. This is the case when reporting diagnosis, or reasons of specific past actions. This kind of verbalisation reduces the speed of the main task, and they are especially difficult when related to automatic actions with little consciousness, which are common for expert users.

The implications of verbalisation with voice recognition facilities will likely vary according to the level of consciousness of each reported fact. As people will naturally need to check if they are understood, an appropriate feedback is needed to limit the distraction.

Implications on upcoming activities

If voice facilities are deployed successfully, time should be saved for more careful monitoring, and the better quality of the EAR should support more effective diagnosis and actions.

Long term effects (of correct use)

During transition phases such as when a new actor is joining the medical team, there is the risk that a detailed EAR will lead to less communication, as the needed information will be wrongly taken for granted.

Long term potential drifts in the usage of the tool

There is a risk that new secondary tasks, not directly related to anaesthesia, will be assigned to the EAR, like recording more about the surgery act.

DEVELOPING THE VOICE INTERFACE

In this section, we propose a methodology to build the first prototypes needed to answer the questions described above.

Based on action research, the development will be an iteration of prototypes and experimentation. The first step is to establish task requirements and user needs. A set of spoken commands has to be defined to control the system, like to navigate between the different parts of the patient record. More generally, the phraseology – the way to speak to the system – has to be established before trying to implement it into a voice engine.

From natural speech

Part1

The first experiments are aimed to gather how anaesthesiologists would spontaneously express themselves to orally fill in an anaesthesia record. Experiments are conducted with minimum guidance, so they have a lot of freedom. Scenarios from anaesthesia simulation training can be used. A nurse or an anaesthesia secretary simply writes down what is being said by the anaesthesiologist for the anaesthesia record. After having done that with at least two different anaesthesiologists and the main types of anaesthesia, a nurse who has not participated in this scenario can try to fill out the anaesthesia record according to what has been written down. This will hopefully give a list of the main problems, such as ambiguities and contradictions.

Part2

Based on results from the first part, another set of simulations can be done. This time, anaesthesiologists receive a set of instructions and some guidance, to say their indications with less ambiguity, and to try not to forget important fields. In particular, anaesthesiologists start using keywords to make a difference between normal conversation and sentences targeted to the AR.

As a fallback alternative, it is possible to use a push-button to enable the voice recognition.

Part3

At this point, one can start establishing a phraseology, *i.e.* a set of rules about how to formulate the needed sentences, and how to process what has been said. Some discussions with various nurses, doctors, etc. are needed, as well as expertise from senior doctors.

Using list of existing fixed comments

There are lists of fixed comments that are currently used in EAR, and selected from a drop-down list on the touch-screen. They can be used as a starting point.

Wizard of Oz experiments

The next steps can be done by a succession of "Wizard of Oz" experiments: the voice recognition and the text entry are done by humans, perhaps a secretary. Such a testing is common with speech recognition applications in the early stages of design. This involves a human to play the part of the speech recognition computer, as a way of testing design prototypes before any actual programming is done. Most of the theoretical issues can be studied at this step. Then, the different tasks are progressively implemented in the computer.

Towards a full phraseology

New simulations will be conducted, keeping in mind that the computer cannot achieve the level of intelligence and expertise of a human, so most of the things have to be explicitly described, with phonetically distinct expressions. This time, the anaesthesiologist will try to conform to the phraseology when entering orally something in the anaesthesia record. Experiments and modifications of the phraseology will be made in loop, until finding a set of rules convenient for the anaesthesiologist and understandable by a machine.

Prototyping

The phraseology is then tested in a normal room, against an early prototype of voice recognition system, to be disambiguated, simplified and modified to improve the accuracy of recognition. Tests in anaesthesia simulators can then start. Volunteers try to address a fictive system during a normal simulation. Feedback tests should be made, in order to try various acknowledgment solutions for the recognitions, and interfaces as alternatives and complements to voice input. With the same kind of Wizard of Oz technique as before, a technician can remotely modify the screen to simulate an output from the computer.

CONCLUSION

This paper has presented a discussion and extracted a set of notions about introducing and testing voice-based electronic anaesthesia record. This can be used during the development and to evaluate integration tests of the new product, but also in a longer term. It illustrates the fruitfulness of collaborative efforts of engineers, sociologists and ergonomists early in the development process.

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