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Patient safety and the practice of anaesthesia: how hybrid networks of cooperation live and breathe

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Abstract:

This article is concerned with the analysis of cooperation in operating theatres. Based on participant observation, video recordings, and interviews, it delivers an ethnographic account of activities in surgical operating theatres. The study focuses on anaesthesia, exploring the importance of practices and routines in terms of patient safety, and offers a three-step model for analysing and categorising safety-relevant cooperation. Elements constituting local patterns of cooperation are elaborated, and finally some prospective areas for further research are outlined.

> "We organize ourselves in time, guessing, modelling, depending on the timings of other people and things. Sometimes things unfurl as planned; more often, there are twists and tangles along the way. How we manage these twists is in some sense what makes us quintessentially human, what ties us to the world."
>
> S.L. Star

1. Introduction

The sociological study of sociotechnical systems is most often linked to risks, failures, accidents or catastrophes, be it in concrete systems failure such as in nuclear power plants, air & sea traffic (Perrow, 1987), space flight (Pinch, 1991) or in the more abstract relations of society and technology (Beck, 1986, Luhmann, 1991). Sociological analysis usually starts when something has gone wrong or danger seems imminent. In this paper I would like to address the issue from a different angle. It is not a question of analysing which factors have contributed to an accident or of finding somebody to blame, but rather of studying the activities which were undertaken to avoid danger and compensate failure*.

Hutchins has done this in the case of navigation systems failure on board of a US Navy ship (Hutchins, 1996). He argues that in case of failure, the tasks and relations of components in a sociotechnical system are re-configured to compensate for the failed sub-system. In the following sections, I will analyse yet another sociotechnical system, namely the surgical operating theatre (OT). The study is based on ethnographic observations and video recordings and interviews in large and small hospitals in Germany and Australia. It is partly

* This perspective was developed in the RISK project (Routines and Risks of Distributed Action) which is part of the larger interdisciplinary project KOSIS (Cooperation and Safety in Socio-Technical Systems) at the University of Technology in Berlin.

based on an interdisciplinary discussion between psychologists of work & organisation and computer scientists with the aim of analysing and modeling safety-relevant cooperation in complex sociotechnical systems.

2. Safety and cooperation in the operating theatre

Drawing on research conducted in so-called *workplace studies* (see Knoblauch and Heath, 1999), I will focus mainly on describing and analysing the practices and activities displayed in the local situation of the OT, especially in the field of anaesthesia. *Patient safety* is regarded as a product of medical teamwork. It is a result of complex interrelations between humans and machines and is deeply rooted in the local practices of doctors and nurses, so this analysis relies to a large extent on *in situ* observation.

Classical safety engineering proposes to gain safety through *standardisation*: a preformed solution for already known or anticipated problems. This approach is dominant in industrial production, but is also prominent in medicine, where guidelines, protocols and good medical practice serve to maintain a high standard of health care. On the other hand, the work of doctors and nurses is inevitably subject to variability and change when they have to adapt actions, e.g. a treatment, to an individual patient. The interplay of *stability* and *flexibility* is therefore a key characteristic of *cooperation* in medical settings.

Many medical sociologists have commented on the incomparability of workflows in industrial plants and hospitals (Rohde, 1974, Siegrist, 1978) with reference to the low potential for standardisation of individual work and for cooperation in hospitals. The term cooperation has mainly been used in the sociology of work, dating back to Marx (Marx, 1968). Marx used the term to describe the way how (industrial) work of many is conduced according to a systematic (production) plan. Later, cooperation was also undersood to be determined by machines and technology in many ways (cf. Popitz, 1957).

Cooperation is conceptualised as a pre-arranged order of mutually dependent sub-tasks; its function is to integrate the diverse elements of industrial work created by the division of labour. As with standardisation and safety, this is only partly true for medical practice. Work in hospitals is only partly determined by external rationales; this observation led Strauss to coin the term *negotiated order* (Strauss, Bucher, Ehrlich, Sabshin and Schatzmann, 1963) in order to stress the importance of specific, local interactions in structuring work.

The approaches of Marx and Strauss pretty much represent two counterpart positions when it comes to studying the role of technology in work settings. *Technological determinism* highlights the power technology has over people and *social essentialism* elaborates the formative force of social affairs (for a discussion on medical technology see Timmermans and Berg, 2003). The following sections will neither stress the first, nor the second approach, but aim to combine empirical data and analytic concepts for a better understanding of work in high-tech settings. Cooperation in operating theatres inevitably depends on the use of machines and instruments. That is why I shall examine interrelations of humans and machines more closely in my analysis. The main question to be answered is: how is the workflow in a cooperation organised?

3. The different modes cooperation

In this section, safety issues, such as order, structure, flexibility and adaptation, are central. Safety-relevant activities in the OT are most often a collective effort of small teams: in anaesthesia, the team usually consists of an anaesthetist, an assisting nurse and some technical appliances.

This analysis is concerned with the question how system disturbances are dealt with before they develop into irreversible accidents, how problems are dealt with, and how order is restored. Fortunately, serious accidents are very rare in the observed hospitals. However, the daily work of OT personnel seems to be riddled with small *hiccups* in the workflow. These minor disturbances are so frequent that they are considered to be part of the routine by most team members. Nonetheless, the analysis of everyday work can reveal many interesting aspects about the structure of teamwork and the interactivities with machines[1]. That is why I shall concentrate my observations on the planned, scheduled and common operations.

I propose to distinguish three modes of cooperation under the spect of safety: *routine*, *compensation* and *improvisation*. These modes are categories of observable activities. They also serve as analytic terms to typify different states in the management of disturbances in the workflow. They are based on a pragmatic view of human action (cf. Dewey, 1922), and are developed to describe inter-individual events rather than intra-personal processes. Therefore the emphasis is on *observable mechanisms of cooperation*.

3.1 Routine

Most problems of everyday work are dealt with by applying routines (cf. Berg, 1992: 169 / Strauss, 1993: pp.191). In the OT, routines also take up the lion's share of activities. The routine activities that will be discussed now are those used to coordinate standard steps of work.

Routine work consists of standardised patterns of activities employed on a regular daily basis. Cooperative tasks like intubations, handling patients or interacting with anaesthetic machines are usually deeply embedded in everyday work routines. This is how the team sustains and fulfils consistent mutual expectations of how work should be done with very little coordinative effort. These standardised patterns of activity are the result of the legal frame and medical guidelines on the one hand, and are produced by local interactions and interactivities over time on the other hand.

Research in other areas, such as control rooms, (Heath and Luff, 1992) shows that the situational routines and problem-solving practices of personnel are likely to predominate over the official standards that are written down in manuals. The routines are not only confined to the relations between humans, but they are also emerging out of the interactivity with machines. Experienced anaesthetists often have their *own way* of using certain machines, turning off pesky alarms or bypassing annoying safety features. This does not mean that patient safety is diminished or neglected. The anaesthetists are reducing the amount of information and possible sources of distraction in order to be able to concentrate on what is relevant to them. Alarms are usually visible as well as audible, so turning off the sound will not turn off the alarm entirely.

1 In order to describe the complex interrelations between man and machine I will use a classification proposed by Rammert (1998), reserving the term *interaction* for the relationship between humans and the term *interactivity* in respect to the relation of humans and machines.

This also means that the team and the technology are *mutually tuned* to one another. It is a process of reciprocal alignment[2]. Once they work as a *good team* and their pattern of activities is aligned, cooperation is swift and effective. Furthermore these *socio-technical routines* prove to be quite durable and resistant to change. The trade-off between flexibility and structure plays a significant role in patient safety: the advantages and disadvantages of both need to be balanced in order to guarantee safe procedures.

In the social sciences, the observation of routine activities under the aspect of safety is underdeveloped in comparison to the study of breakdowns and accidents. Patterns of routine coordination can be briefly described in the following way: there is very little or nearly no verbal exchange about the task between the members of the team. The interactivies with machines are well trained and happen silently and quickly[3].

People usually use gestures to indicate their expectations to one another. A quick glance or a short movement of the hand is sufficient to organise the cooperation. An impressive example of non-verbal coordination is the interaction between two surgeons when stitching. One surgeon usually assists the other, and if they both have enough experience, the assisting surgeon will coordinate his actions merely by looking at his colleague's hands. The same goes for experienced nurses, who are able to judge doctors by their actions and engage in cooperation with them by themselves. In such cases, the organistion of cooperation relies on a high degree of *overlapping knowledge* (cf. Hutchins, 1996: pp 265), i.e. anaesthetists, surgeons and nurses share in a certain amount of knowledge concerning the others' tasks. Their actions are thus mutually accountable, and the coordination is swift.

To sum up, routines as problem solving patterns form a major part of every day work. They represent successful and well established solutions of frequent problems, and serve to sustain consistent expectations within the team. They grow out of interactions and situations and once in practice they are likely to remain a resource for further actions. When observing routine cooperation, the communicative aspects of coordination are mainly contained in gestures and facial expressions. There is little task-related verbal exchange, and actions intertwine at a relatively high speed.

3.1 Compensation

But what happens when routines fail to deliver the desired result? In most cases there are *backup strategies*. I call this kind of coordination compensation. Backup strategies are, like routines, patterns of action pre-formed to fit a specific situation.

Compensation strategies can be acquired by training or experience. In many cases, the personnel is trained to respond to a specific problem in an appropriate manner. Take emergency plans for instance: anaesthetists train to cope with uncommon but possible situations like ventricular fibrillation. These emergency plans are constructed like *algorithms*. These precise and sequential instructions serve to guarantee quick and correct reactions in time-critical situations. Compensation can then be described as using a set of alternative routines. They differ from the daily patterns of action in the aspect that they are not internalised by practice, but by additional exercise.

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2 Mead has stressed the importance of interaction in *games* to develop a functional self for the individual (Mead, 1975: pp.107). In teams there are similar processes of socialisation that bind the members and help to establish the alter egos as meaningful partners of interaction. In analogy, interactivities with physical objects, like devices and media, establish a socio-technical order where persons learn to take the perspective of machines like perfusors in oder to establish a hybrid network of cooperation (Rammert, 1998).

3 I have discussed the methodological implications of this elsewhere (Schubert, 2002).

In addition to the trained algorithms, there are local forms of compensation that stem from experience. The practice of *re-booting* is, for example, one strategy that has been proven successful in daily work in oder to deal with malfunctions of microelectronic devices. Also, malfunctioning perfusors are switched off and on again in the hope that the problem will disappear. This practice does not come from manuals or guidelines, but is the product of ongoing interaction with computers. Solving technical systems breakdown is mainly a process of countervailing machine processes that failed with compensatory human action. The first step is to substitute the dysfunctional component, then the component's original functionality needs to be restored. This can be done in two ways: either by trying to repair the component, or by exchanging it for another one. In the OT, both strategies are used according to the failed component's size: small components are exchanged, larger components are repaired.

Coordinating compensatory action is thus a matter of signalling a change of strategy to team members. The routine problem-solving pattern is replaced by a different pattern. Compensation can be regarded as a failsafe or backup mechanism, designed to counteract expected problems.

In the phase of compensation, the team displays a particular behaviour. If technological failure is involved, activities are usually repeated: unsuccessful routines are reiterated several times, until a change of strategy is considered. This *repetition* is a sign for commencing problems and if noticed, will serve as a signal for other team members to adapt their patterns of action. *Hesitation* is another signal, displaying uncertainty about how to continue. Both activities, repetition and hesitation, do not draw the attention of others directly towards the problem. They are subtle markers of a disturbance in the workflow and are only picked up, if person A pays attention to what person B is doing. In the OT, nurses who notice such a small disturbance are likely to interrupt their own work and get ready to assist the doctor. They wait and see how the situation develops and whether their help is needed.

Thinking aloud is a little less subtle behaviour, but it serves well to direct the attention of others towards a problem without having to ask explicitly for help. Anaesthetists who think aloud make their actions or problems noticeable to the nurse or uninvolved bystanders.

The above examples highlight the fine nuances of coordination during the phase of compensation. The distinction between routine and compensation is an analytical one. In real life situations, routine and compensation merge freely into one another. It is almost impossible to determine the exact empirical boundaries between them. Compensation is considered to be part of the daily grind by most staff members and not a deviance from usual business. Compensation is a source of local variations in working practices, because many strategies and patterns of actions have evolved out of situational contexts and are specific to local culture.

3.3 Improvisation

As I have mentioned earlier, routine and compensation are pre-formed solutions to certain problems. In addition to expected problems, unanticipated disturbances might occur. In such a case the team must develop a new solution *on the spot*. In contrast to standard problem-solving strategies this is called *improvisation*. This term stresses the importance of the situational resources and real time changes during the cooperation.

Since unexpected problems are encountered on the basis of available means, improvisation is tied to specific situational constraints, e.g. machines, tools, media, personnel. Improvisation re-configures the relations of components according to the disturbance. The re-configuration is a re-organisation of cooperation and requires particular forms of coordination. Since there are no commonly shared pre-formed strategies, the explicit exchange of verbal communication is central to this mode of cooperation. Improvisation relies on direct verbal orders to adapt patterns of action to suit the situation. Order is restored step by step in a *negotiated* process through the interactions of components as a potential solution *unfolds* out of the situation (cf. Hutchins, 1996: pp.317). In the case of technical systems failure, it is necessary to establish a quick substitute for a defect component, especially if the patient's life depends on it, e.g. in case of artificial ventilation. OT technology is usually designed to be redundant and many machine functions can be replaced by human action, in the cases when the components are *loosely coupled* (cf. Perrow, 1987).

When observing improvisation, one can see that actions are discontinued and problems are being verbalised. Also there are questions and queries concerning the breakdown. It is in this stage of uncertainty that re-configuration occurs. The contingencies of the situation need to be reduced until work can be resumed.

Routine, compensation and improvisation are essential modes of cooperation in operating theatres. Situations can be typified using the three modes of cooperation, making it possible to compare and contrast different situations. Coding situations according to their cooperative modes can be quite a difficult task, since they hardly ever are distinct and the transition between them is fluid. A fair amount of interpretation is needed, and verification by experts is essential. In the following table I have summed up the findings concerning the modes of cooperation, their mechanisms and observable activities:

	Routine	Compensation	Improvisation
Mechanism of coordination	- standardised patterns of action - established solutions - consistent mutual expectations	- alternative patterns of action - trained solutions - indication of change in pattern of action	- re-configuration of patterns of action - explicit verbal communication - direct orders
Observable activities	- coordination by facial expressions and gestures - little task related talk - swift interlocking of activities	- repetition of actions - hesitation - thinking aloud - wait and see	- problem related talk - discontinuing of activities - questions and queries

Table 1

In the context of structure and flexibility, the situational re-configuration of patterns of action is central to understanding work practices in complex settings. The *maintenance of a stable phase* turns out to be a key feature of everyday work since it is also quite significant for patient safety. The maintenance of a stable phase can be considered as a form of *repair work*, i.e. work that is performed in addition to anaesthesia and surgery, in order to maintain a safe course of action[4].

Strauss added *sentimental work* as an aspect of patient care (Strauss, Fagerhaugh, Suczek and Wiener, 1982) and *error work* in respect of counteracting the development or the consequences of mistakes (Strauss, Fagerhaugh, Suczek and Wiener, 1985: 242). In the light of the present study, *repair work* should be considered a related aspect of work, espe-

4 The term *repair work* has previously been used by Jörg Potthast to describe the work of maintenance personnell in an international airport and their collective identity in respect to technology (Potthast, 2001).

cially if medical technology is involved, especially since the process of coordination and re-configuration involves machines as well as humans, their activities closely interrelated and interwoven. In the next section I will look a these relations in more detail.

4. Sociotechnical Ensembles

As argued above, the classical concepts of cooperation, work and division of labour have their shortcomings once the presumption of technological determinism is dropped. The order of cooperation changes according to the situation and is dependent on local activities. To be able to make abstractions from this observation, some analytical aspects have to be taken into account. In this respect, the elements of the ensemble on which the re-configuration is based deserve closer attention.

Following the approaches of *technology in action* (cf. Rammert and Schulz-Schaeffer, 2002, Rammert, 2003) and likewise *technology in practice* (Timmermans and Berg, 2003), the operating theatre is conceptualised as a *sociotechnical ensemble*. I use 'ensemble' here instead of 'system' to avoid confusion with large scale concepts dealing with nuclear power or air traffic as such. Sociotechnical ensembles are hybrid networks in the sense that they enclose human as well as technological components and that relations between the components are significant to its specific function. The OT can thus be conceptualised as one hybrid network among many within the organisation of a hospital.

Narrowing the argument further, sociotechnical ensembles refer to a situation located distinctly in time and space. The ensemble's components are concrete individuals and objects. Their specific characteristics, particularities, skills, knowledge and functions are the elements constituting the ensemble.

Going into more detail concerning re-configuration and the operating mode of the ensemble, I will now emphasise the interweaving of activities during cooperation. Some research has been conducted on the *tacit order of teamwork* (Hindmarsh and Pilnick, 2002), analysing how anaesthetists organise their actions in the presence of a conscious patient. The following observations indicate that this kind of order is kept up even after the patient is under anaesthesia. The role of technological objects in interaction and interactivity will be examined in our project in addition to the tacit order.

My main concern will be to examine how ensembles establish reliable procedures in spite of the high variability of their actions. and how knowledge is distributed within the ensemble.

A rather unexpected observation made in the OT was the high level of aberrance from the classic division of labour of doctors and nurses. Using subtle ways and techniques, nurses have a larger part in the organisation of teamwork than is officially granted to them. For instance, a young nurse might ask a chief doctor to lift a patient's legs so she can prepare the operating table. Masking an order as a question does not destroy official hierarchy and the doctor can help without *losing face* (cf. Goffman, 1999). A surgeon might ask a nurse which instruments he should use or an anaesthetist might ask a nurse for her opinion on how to administer narcosis. Nurses tend to be in the OT most of the time and acquire substantial amounts of knowledge concerning surgery, anaesthesia and the general organisation of work, so it is sometimes nurses who re-arrange patients' schedules according to organisational requirements, anticipating surgeons' needs and considering past, present and future events. As a collective, nurses acquire, store and relay relevant information on patients, operations, machines, etc.

In particular situations, experienced nurses might know more than novice doctors. Looking at cooperation in such situations, it is interesting to see whether and how nurses can pass on such knowledge without corrupting the traditional doctor-nurse relationship.

In many interviews, anaesthetists have had a story to tell about an old nurse they met when they were beginners. This nurse was either an indispensable source of helpful information or, in unfortunate cases, a dark force better not to be messed with. Either way, nurses play an important role in anaesthetists' early careers. In analysing the work of nurses and doctors it is important to look at their relations and how they work together, because this significantly influences outcomes, i.e. patient safety.

When working with experienced anaesthetists, nurses are likely to pay them due respect. They do this by waiting for the anaesthetist to give them an order (also often masked as a question) before they act. When working with novice anaesthetists though, nurses often take a more active part in cooperation.

A video recording of an intubation performed by a novice anaesthetist and an experienced nurse revealed the subtle re-configurations of the ensemble. After watching it several times in slow motion I was able to re-construct the order of cooperation. The nurse is in charge of the intubation in an informal way, leading the young doctor through the process, preparing instruments and anticipating and avoiding possible difficulties. She seems to be one step ahead of the doctor and by supplying him with the right instruments at the right time, indirectly structures the cooperative workflow.

In one incident, the nurse holds onto the tube, even after handing it over to the doctor. The doctor is puzzled at first, but the nurse nods at him reassuringly. As the doctor pulls, the tube is consequently bent and when it has the right shape, the nurse lets go. The doctor is thus 'taught' without being 'told'.

Bending the tube is an interactive task involving the doctor, the nurse and the tube. In this particular incident, the re-configuration of the ensemble is necessary, because there is an asymmetry in knowledge between the doctor and the nurse. The nurse knows which shape the tube has to have to be inserted correctly, because she is experienced and well-trained. For his part, the doctor has to accept the nurse's help and play along. The tube turns out to be more than just a medical instrument: it is a medium through which knowledge is transferred.

Similar processes can be observed in microsurgery. Surgeons often do not tell novices how to hold the camera, instead they grab their hands, manipulate them, and tell the assistants they want to have it "like this". Certain forms of practical knowledge are difficult to be put into words, so teachers do without them. Knowledge is directly passed on in a configuration of bodies and tools.

The above examples show that cooperation in sociotechnical ensembles is influenced by three factors: a) the actual activities of personnel, b) their inter-individual experience and c) personal know-how.

Cooperation can be understood as a process in which data, information and knowledge are produced, shared, transformed, stored and passed on. Thus the relation of knowledge to cooperation has a considerable effect on the re-configuration of sociotechnical ensembles.

a) The maintenance of a stable phase is only possible through the active adaptation of activity patterns. As I have observed, nurses possess substantial knowledge about working in the OT and adaptation to disturbances is faster and more reliable the more knowledge is mutually shared. The classic concept of the division of labour does not account for these variations in competence and the subtle ways of bypassing hierarchies are only observable in the real situation. We can see how legal constraints and organisational needs function as the background for actual cooperation. They are invoked in critical situations, when command chains are useful for synchronising actions or in stressful circumstances, but only have a limited effect on everyday work.

Just as human action differs from the formal norms, the use of technology also varies from the engineers' intentions. Technology is used in local contexts and on the basis of common beliefs and practices. Stories are told about unreliable machines and young doctors are confronted with episodes where technological failure has led to tragic events.

In one hospital, for instance, staff in the waking room like to work without extensive technology. They rely on their medical skills and use only pulse oximetry and blood pressure cuffs to gather machine-mediated data on the patient's vital functions. In an interview, the acting chief of staff told me that they had made a collective decision to reduce medical technology in favour of their clinical skills. I was also told that in comparison to waking rooms with more technology, they performed just as well in terms of patient mortality.

The maintenance of a stable phase is no doubt partly dependent on the OT's social order, but as we see, it also relies on the way in which machines are tied into the network of human action. Stability comes from technical or social routines, in most cases from both. Since the balance between the two has no optimal state, there is no *one best way* of achieving and sustaining patient safety. Technology can be replaced by humans and vice versa. Culture and individual beliefs are key factors in organising cooperation and determining the shape and function of hybrid networks. Today, technological dominance is apparent in most large western hospitals and the study of evolving hybrid networks will gain in importance as this trend increases: balancing the advantages and weaknesses of these networks is of great importance to patient safety.

Distributed knowledge as a constitutive element of these ensembles is not only contained in rules, guidelines and records, but also in the stories, anecdotes and episodes passed on from one doctor or nurse to the next. The narrative structure of medical knowledge has been analysed only by few researchers (cf. Atkinson, 1995, Hunter, 1991) and certainly deserves closer attention.

b) Cooperation is also based on inter-individual experience. Staff members interact on the basis of a common *history* and use their knowledge about the skills and abilities of other team members to organise cooperation. Their history contains past interactions and the results of these interactions evolving over time. History helps to establish *trust*, or sometimes *distrust* between team members. It generally makes their actions mutually accountable and leads to safe and effective cooperation, and thus to the formation of routines.

Inter-individual experience also enables the emergence of overlapping knowledge. The process of overlapping often occurs in reversed order of hierarchies, i.e. people with less status acquire knowledge usually associated with higher status. Such a learning process is fundamentally situated in local culture. Only if doctors share their knowledge and extend the rights and duties of nurses can this distribution of knowledge take place. Knowledge then becomes attached to experience rather than status, and the more experienced the team members are, the safer the work becomes.

History and overlapping knowledge also shape teams' social structures. They establish practices and provide collective routines for tackling everyday problems and prove to be highly resistant to change. Once relations within the team are made durable by inter-individual experience and members know what to expect from each other, their relations are unlikely to change, but are reinforced during following interactions.

Sociotechnical ensembles display a tendency to standardise interactions and actions. Previous successful actions serve as blueprints for future actions. Undoubtedly these elements constitute what can be called good team cooperation, but on the other hand they can lead to undesirable consequences, e.g. what social psychologists have called *group think* and *risky shift* – the tendency to adopt a simplistic, cohesive view of a situation or to make more dangerous decisions. Again, a balance is needed between a well-tuned team and the ability to make changes if necessary.

c) Personal know-how is the other important aspect of cooperation comprising one individual's experience. Experts define situations differently in comparison to novices. An anaesthetist summed up the relationship between knowledge, experience and action in an interview: "You have to know a lot to do nothing". This seems to be a paradox, but describes the conjunction between knowledge and action very well. Experience changes the experts' perspective on events. The boundary between what is acceptable and what is not becomes less solid and more dependent on other observations, i.e. data are triangulated and interpreted before action is taken. Personal know-how establishes idiosyncratic frames of relevance that macerate formal regulations. In a situation where a patient might seem critical to a novice, an experienced anaesthetist can still be in control, e.g. when sudden changes in treatment might actually harm the patient or symptoms are due to the side effects of medication and will be of short duration.

Expert knowledge is largely implicit (Polanyi, 1983) and more like a sure instinct or rules of thumb. That makes it different from the explicit knowledge that novices acquire during formal education and training. Research on expert systems has shown that it is not easy to transform implicit expert knowledge into explicit guidelines and rules (Rammert, Schlese, Wagner, Wehner and Weingarten, 1998). Experience, however makes experts *resistant* to novel definitions of situations (Wagner, 1995). They tend to *stay in their tracks* instead of trying to integrate new or inconsistent information.

Once expert knowledge is transformed into guidelines or microelectronic devices, it is easily accessible by novices, giving them an advantage by bypassing years of learning. A novice sufficiently equipped with technology can deliver the same level of quality care as an expert who might not need nor want all these gadgets and devices.

As I have stated above, experts use technology based on their experience. Anaesthetists might turn off alarms that they consider irritating or useless, considering the patient as the primary source of information and technology only to be a subsidiary one. As long as the patient has red lips (enough oxygen), small pupils (enough narcotic medication), and a dry, warm forehead (no stress), he or she is well.

Machines transform vague impressions and inferences about a patients' state into discrete numbers and graphs. Anaesthetic monitoring provides accuracy at the price of introducing a possible source of error, e.g. a sensor falling off, a tube becoming blocked or a program error occurring. Experienced anaesthetists do not therefore take monitoring at *face value*, but judge it on the *perceived credibility* of the source (cf. Cicourel, 1990). They try to integrate data into a larger framework based on other observations, experience and personal know-how.

The maintenance of a stable phase, inter-individual experience and personal know-how reveal the subtle, local and individual elements and constraints of interaction and interactivity in sociotechnical ensembles. Interaction is based on the perceived credibility and ability of the other. Cooperation changes as the ensemble's components change. The components, humans as well as machines, are embedded in the context of local culture. Their actions and activities are tightly interwoven with another. They form a hybrid network, whose ties are set up and configured *in action* by staff and machines. Knowledge is distributed across the team and various media and machines as a key element of cooperation. Experts' implicit knowledge is often passed on in stories and anecdotes or in nonverbal fashion. Knowledge can be embodied in technology, gestures, looks or bodily configurations; it is knowledge *in action*, constantly being produced, transferred, stored, retrieved and changed within the ensemble.

5. Conclusion

The above observations and arguments above are not yet final and conclusive findings. They are an initial approach to an abstract concept of activities in high tech work situations concerning safety and cooperation issues. The perspectives of *cooperation in action* and the *balancing of stability and flexibility* provide an analytical and thematic framework for understanding interaction and interactivity in sociotechnical ensembles. The balance between stability and flexibility is one of the foremost safety issues concerning cooperation in the OT; the team's performance in situ as observational category and analytical perspective emphasises the flexible character of every day work.

The term *repair work* should be considered as a wildcard or variable, needing further study and definition. The main point of this is that the focus of work is shifting within socio technical systems of medicine away from the well documented doctor-patient relationship towards the *hybrid networks* and *sociotechnical ensembles* of doctors, nurses, patients and technologies. In analysing specific sociotechnical ensembles, repair work and the *maintenance of a stable phase* turn out to be a significant element in cooperation and a factor relevant to patient safety.

Further research is indicated in the areas of safety practices, distributed knowledge and the embedding of technological objects in social contexts. The latter has been described in workplace studies to some extent, though the analytical and theoretical implications have been less explored.

One interesting topic could be the transformation of the profession of anaesthesia through medical technology. This has been done for other fields of medicine looking at different technologies, e.g. ultrasound (Yoxen, 1989), the stethoscope (Lachmund, 1992) or MRI (Burri, 2001). Following the concept of the *clinical gaze* (Foucault, 1996), anaesthetic monitoring technology enables the doctors to see, where they used to be blind. Where the darkness could only be poked at by interpretation and inference, it is now pierced by the precise and objective numbers and graphs of ECG, EEG, and CO_2 monitoring and the like. The use of these technologies in operating theatres and intensive care units and their impact on anaesthetic work remains relatively unexplored.

Another set of practices that should be studied more carefully are teams' safety practices. How do members organise safe procedures and what are their perspectives on safety? Heath has pointed out how awareness is configured in centres of coordination (Heath, Sanchez Svensson, Hindmarsh, Luff and vom Lehn, 2002). In the OT *awareness* is also a key element of patient safety. Changes in the patient's state need to be noticed and, if necessary, relayed to the relevant person. Surgeons, anaesthetists and nurses comment on the patient's state, make hints, or verbalise their observations in order to make somebody else aware. These practices are dependent on the workplace situation, and safety practices in the OT might differ significantly from those in intensive care units (ICU) or other wards. Preliminary observations indicate the existence of different *safety regimes*, i.e. the organisation of safety practices in local contexts. An anaesthetist described the differences between patient care in the OT and the ICU as being comparable to the difference between driving a sports car and navigating a cargo ship. In the first case, reactions are quick and direct, whereas in the latter one effects of actions are delayed in time and have multiple contributory factors.

The distribution of knowledge could also be a subject for further research, especially in the training of novices in teaching hospitals. There seems to be a gap between the clear, explicit knowledge taught in universities and the somewhat messy and ambiguous practice of medicine, a phenomenon that can be observed in many if not all fields of applied science (cf. Delamont and Atkinson, 2001). How novices are socialised into their future fields of activity and how they go from being from novices to become experts are topics worthy of examination. In this context, the relevance of stories, anecdotes and episodes should be considered in more detail.

The importance of local practices for patient safety has become obvious. In the context of our project, the findings can be used to propose a novel way for formally describing cooperation in high-tech work settings. A way, in which the emphasis for organising cooperation lies on situational adaptation rather than prearranged structures and processes. Considering safety as a product of sociotechnical ensembles helps to build a dynamic understanding of situations, and an analysis of how hybrid networks of cooperation function is indispensable in understanding how they might fail. A detailed analysis can inform future safety engineering in designing safer and more robust and error tolerant systems. Local practices and deviations from the norm should not be seen as a threat to, but as a resource for, safety.

This is where the challenge lies in modelling such systems. An abstract description of coordination and cooperation needs to include all the variations in the workflow and all the contingencies and uncertainties of the local situation to be able to deliver an accurate account of the sociotechnical ensemble. The work we have started is a first step and will continue, because it is becoming more and more important with the increasing participation of machines in patient diagnosis and treatment.

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References

Atkinson, Paul (1995): Medical Talk and Medical Work. The Liturgy of the Clinic. London: SAGE.

Beck, Ulrich (1986): Risikogesellschaft. Frankfurt/M.: Suhrkamp.

Berg, Marc (1992): The construction of medical disposals. Medical sociology and medical problem solving in clinical practice. In: Sociology of Health and Illness, 14, 2, 151-180.

Burri, Regula (2001): Doing Images. Zur soziotechnischen Fabrikation visueller Erkenntnis in der Medizin. In: Heintz, B. and Huber, J. (Hrsg.): Mit dem Auge denken. Strategien der Sichtbarmachung in wissenschaftlichen und virtuellen Welten. Berlin: Springer. 277-303

Cicourel, Aaron V. (1990): The Integration of Distributed Knowledge in Collaborative Medical Diagnosis. In: Galegher, J., et al. (Hrsg.): Intellectual Teamwork. Social and Technological Foundations of Cooperative Work. Hillsdale, NJ: Lawrende Erbaum Associates. 221-242

Delamont, Sara and Atkinson, Paul (2001): Doctoring Uncertainty: Mastering Craft Knowledge. In: Social Studies of Science, 31, 1, 87-107.
Dewey, John (1922): Human Nature and Conduct.
Foucault, Michel (1996): Die Geburt der Klinik. Eine Archäologie des ärztlichen Blicks. Frankfurt/M: Fischer.
Goffman, Erving (1999): Interaktionsrituale. Frankfurt/M.: Suhrkamp.
Heath, Christian and Luff, Paul (1992): COLLABORATION AND CONTROL: Crisis Management and Multimedia Technology in London Underground Line Control Rooms. In: Journal of Computer Supported Cooperative Work, 1, 1, 24-48.
Heath, Christian, et al. (2002): Configuring Awareness. In: Computer Supported Cooperative Work, 11, 317-347.
Hindmarsh, Jon and Pilnick, Alison (2002): The Tacit Order of Teamwork. Collaboration and Embodied Conduct in Anesthesia. In: The Sociological Quarterly, 43, 2, 139-164.
Hunter, Kathryn Montgomery (1991): Doctors' Stories: The Narrative Structure of Medical Knowledge. Princeton: Princeton University Press.
Hutchins, Edwin (1996): Cognition in the Wild. Cambridge, MA: MIT.
Knoblauch, Hubert and Heath, Christian (1999): Technologie, Interaktion und Organisation: Die Workplace Studies. In: Schweizerische Zeitung für Soziologie, 25, 2, 163-181.
Lachmund, Jens (1992): Die Erfindung des ärztlichen Gehörs. Zur historischen Soziologie der stethoskopischen Untersuchung. In: Zeitschrift für Soziologie, 21, 4, 235-251.
Luhmann, Niklas (1991): Soziologie des Risikos. Berlin: de Gruyter.
Marx, Karl (1968): Kooperation. In: (Hrsg.): MEW Band 23: Das Kapital. Band I. Berlin / DDR: Dietz Verlag. 341-355
Mead, George Herbert (1975): Sinn / Spiel, Wettkampf und der (das) verallgemeinerte Andere. In: (Hrsg.): Geist, Identität und Gesellschaft. Frankfurt: Suhrkamp. 107- 122, 187- 206
Perrow, Charles (1987): Normale Katastrophen. Die unvermeidbaren Risiken der Großtechnik. Frankfurt: Campus.
Pinch, Trevor J. (1991): How do we treat techical uncertainly in systems failure? The case of the space shuttle Challenger. In: La Porte, T.R. (Hrsg.): Social Responses to Large Technical Systems. 143- 158
Polanyi, Michael (1983): The Tacit Dimension. Gloucester: Smith.
Popitz, Heinrich, et al. (1957): Technik und Industriearbeit. Soziologische Untersuchungen in der Hüttenindustrie. Tübingen: J.C.B.Mohr (Paul Siebeck).
Potthast, Jörg (2001): Kollektive Identität und Technik. Die Wartungstechniker von Roissy". In: Rammert, W. (Hrsg.): Kollektive Identitäten und kulturelle Innovationen. Leipzig: Universitätsverlag. 197-217
Rammert, Werner (1998): Giddens und die Gesellschaft der Heinzelmännchen. Zur Soziologie technischer Agenten und Systeme Verteilter Künstlicher Intelligenz. In: Malsch, T. (Hrsg.): Sozionik. Soziologische Ansichten über künstliche Sozialität. Berlin: Sigma. 91-128
Rammert, Werner, et al. (Hrsg.) (1998): Wissensmaschinen. Soziale Konstruktion eines technischen Mediums. Das Beispiel Expertensysteme. Frankfurt/M: Campus.
Rammert, Werner and Schulz-Schaeffer, Ingo (2002): Technik und Handeln. Wenn soziales Handeln sich auf menschliches Verhalten und technische Abläufe verteilt. In: Rammert, W. and Schulz-Schaeffer, I. (Hrsg.): Können Maschinen handeln? Frankfurt: Campus. 11-64
Rammert, Werner (2003): Technik in Aktion: Verteiltes Handeln in soziotechnischen Konstellationen. TU Berlin, Institut für Soziologie, Techniksoziologie, 2-2003
Rohde, Johann Jürgen (1974): Soziologie des Krankenhauses. Zur Einführung in die Soziologie der Medizin. Stuttgart: Ferdinant Enke Verlag.
Schubert, Cornelius (2002): Making interaction and interactivity visible. On the practical and analytical uses of audiovisual recordings in high-tech and high-risk work situations. TU Berlin, Institut für Soziologie / Techniksoziologie (TUTS), TUTS WP-5-2002
Siegrist, Johannes (1978): Arbeit und Interaktion im Krankenhaus. Vergleichende medizinsoziologische Untersuchungen in Akutkrankenhäusern. Stuttgart: Ferdinand Enke Verlag.
Star, Susan Leigh (1997): Anselm Strauss: An Appreciation. In: Sociological Research Online, 2, 1, Section 6.2 <http://www.socresonline.org.uk/socresonline/2/1/1.html>.
Strauss, Anselm, et al. (1982): Sentimental work in the technologized hospital. In: Sociology of Health and Illness, 4, 3, 254-278.
Strauss, Anselm (1993): Continual Permutations of Action. New York: de Gruyter.
Strauss, Anselm L., et al. (1963): The Hospital and Its Negotiated Order. In: Freidson, E. (Hrsg.): The Hospital in Modern Society. New York: Free Press.

Strauss, Anselm L., et al. (1985): Social Organization of Medical Work. Chicago: The University of Chicago Press.
Timmermans, Stefan and Berg, Marc (2003): The practice of medical technology. In: Sociology of Health and Illness, 25, 3, 97-114.
Wagner, Gerald (1995): Die Modernisierung der modernen Medizin. Die "epistemiologische Krise" der Intensivmedizin als ein Beispiel reflexiver Verwissenschaftlichung. In: Soziale Welt, 46, 3, 266-281.
Yoxen, Edward (1989): Seeing with Sound: A Study of the Development of Medical Images. In: Bijker, W.E. (Hrsg.): The Social Construction of Technological Systems. Cambridge: MIT Press. 281-303

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