Verbal Communication as a sign of adaptation in socio-technical systems: 
The case of robotic surgery

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ABSTRACT
Motivation – The aim of this paper is to study how a complex system such as surgery adapts itself to external changes such as robotic system using verbal communication as a manifestation of the surgeon’s adaptation work progress. Research approach – First, we compared verbal communication between surgeons in two conditions (laparoscopy and robotic surgery). Secondly we compared three teams with different levels of expertise with the robot on a repeated surgery act in order to distinguish between the momentary and the permanent changes. Findings/Design – We showed more acts of communication with the robotic system. The content analyses of the communication revealed a profound change of the structure of the task that requires new explicit collaborative modes. Research limitations/Implications – Although our sample is small, our communication grid can be used in other domains concerned with telework. Originality/Value – Verbal communication is used to study adaptation mechanisms.

Keywords
Robotic surgery, verbal communication analysis, adaptation

INTRODUCTION
As investigations of medical accidents have revealed, communication is one of the factors that is most frequently associated with accidents. For instance, in anesthesia 25% of deaths are due to inadequate communication, which represents 39 % of reported medical errors (Arbous, Grobbée, van Kleef, de Lange, Spoormans, Touw, Werner & Meursing, 2001). But, surprisingly, communication has not received much attention from researchers even though health care practitioners designate ”improving communication” as an important corrective strategy (Kluger, Tham, Coleman, Runciman & Bullock, 2000).

During the past decade, there have been two important developments in medical care relevant to the study of communication: 1) the increased specialization of medical sciences, which has increased the division and distribution of tasks among experts from different disciplines and, thus, the need for coordination and communication between healthcare providers, 2) the development and introduction of new computer-based technology in hospitals, that requires practitioners to communicate with computers, introduces new forms of media and more distance between the operators and their tasks.

The aviation industry has attempted to reduce the problems of cooperation between humans and automation by organizing both human-machine and human-human communication, using a straightforward and predefined division and distribution of tasks, a codification and standardization of the communication language, a principle of systematic verbalization and, cross-checking, and mandatory training of so-called “non technical skills” (Crew Resource Management). But some problems of communication obviously remain, as we can see with the case of the Sharm-el-Seikh accident (Egypt, January 4th, 2004), in which the crew failed to share a proper understanding of the autopilot status.

These difficulties faced in addressing cooperation demands might be grounded in the dominant tendency to use an analytical approach to solve a complex, non linear problem through division and simplification. The science of complex systems, however, addresses problems differently. What characterizes a system as complex is not the number of its component parts but the heterogeneity of the component parts and their relations among them, leading to a potentially unanticipated and autonomous outcome, namely an emergence. Particularly, the ability of a complex system to adapt itself to some extend against internal changes (e.g. new equipment, new people) as well as external changes (environmental), can be seen as an emergent property. This perspective is in accordance with new approaches to the safety of social-complex systems that have recently been explored under the name of resilience (Hollnagel & Woods, 2006; Nyssen, 2007). In most circumstances, the act of communication represents our best attempt to adapt to a specific
situation and can be seen as a manifestation of the adaptation work (Piaget, 1967; Le Moigne, 1999; Maturana & Varela, 1987, constructivism).

**Robotic / Laparoscopy Surgery and Communication environment**

Robotic surgery and laparoscopic procedures provide a good system to support a study on communication, adaptation, and new technology (see Figure 1). There have been a number of technological advances in surgery, and laparoscopy is certainly one of them. There is little doubt that laparoscopy represents a definite progress in patient’s treatment. However, there are a number of important drawbacks. For instance, the fact that long instruments are used through an opening (trocar) in the abdominal wall limits the surgeon’s degrees of freedom to 4: in and out, rotation around the axis, up and down and from medial to lateral. Robotic surgery has been designed to improve the process of Laparoscopy or Minimal Invasive Surgery (MIS). The system allows for: 1) the restoration of the degrees of freedom that were lost, thanks to an intra-abdominal articulation of the surgical tools, 2) three-dimensional visualization of the operative field in the same direction as the working direction, 3) modulation of motion amplitude by stabilizing or by downscaling and 4) remote control surgery. Because of these improvements, surgical tasks can be performed with greater accuracy (Hubens, Coveliers, Balliu, Ruppert & Vaneerdeweg, 2003; Marescaux, Leroy, Rubino, Smith, Vix, Simone & Mutter, 2002; Cadière, Himpens, Germay, Lupinc, Degueldre, Vandromme, Iizaw & Bruyns, 2000; Pasticier, Rietbergen, Guillonneau, Fromont, Menon & Vallancien, 2001; Carpentier, Loumet, Aupecle, Berrebi & Relland, 1999).

Laparoscopy procedures typically involve the simultaneous use of three or more instruments (e.g. laparoscope, probe or gripper and shears or other cutting tools). Because of this, at least one tool must be operated by an assistant. The assistant’s task is often limited to static functions of holding the instrument and managing the camera.

In classical laparoscopy, the assistant and the surgeon are face to face, and they use the same 2D representation of the surgical field to tailor the task.

In robotic surgery, the surgeon is seated in front of the console at a distant point, looking at an enlarged three-dimensional binocular display on the surgical field while manipulating handles that transmit the electronic signals to the computer that transfer the exact same motions to the robotic arms. Robotic surgery can be performed at distant locations. However, within the actual technological system, the surgeon is still in the same operating room as the patient. The computer-generated electrical impulses are transmitted by a 10-meter long cable that controls the three articulated “robot” arms. Disposable laparoscopic articulated instruments are attached to the distal part of two of these arms. The third arm carries an endoscope with dual optical channels, one for each of the surgeon’s eyes, which allows a true binocular depth perception (stereoscopy). The assistant is next to the patient, holding one or two instruments and looking at a 2-D display of the surgical field.

![Figure 1. Configuration of the operating theater in classical laparoscopy (left) and with the robotic system (right)](image)

**METHODS**

We carried out three studies to examine our hypotheses:

1) First, we compared surgical operations that were performed with a robotic system compared with classical laparoscopy. In the two conditions (robotic and classical laparoscopy), the surgical procedures and the team members were identical. They were experts in the use of classical laparoscopy (>100 interventions) and were familiar with the use of a robotic system (> 2 interventions). We chose two types of surgical procedures (digestive and urology surgery) because it is possible to perform them with either classical laparoscopy or with a robotic system. We observed 5
cholecystectomy (digestive) with the robotic system and 4 with classical laparoscopy, and 7 prostatectomy (urology) with the robotic system and 4 with classical laparoscopy.

2) Secondly, we compared routine and non routine operations: conversion from robotic surgery to classical surgery.

3) Thirdly, we compared teams with different levels of expertise during gynecology surgery with a robotic system. We compared three teams with different levels of expertise who successively performed two tubular reanastomosis of 36 Fallopian tubes: 1) both the surgeon and the assistant were experts with a robotic system (>50 operations with a robotic system), 2), the surgeon was an expert while the assistant was a novice with a robotic system (<10 operations with a robotic system); 3) the surgeon and the assistant were novices with a robotic system (<10 operations with a robotic system).

In the three studies, we recorded all the verbal communication between the surgeon and the assistant. We analyzed their content and identified six categories. We also measured the duration of the intervention, as this is an important performance criterion for surgeons.

The six types of communication were:

- Verbal demands concerning the orientation and localization of organs.
- Verbal demands concerning the manipulation of instruments and/or organs.
- Explicit clarification concerning strategies, plans and procedures.
- Orders referring to tasks such as cutting, changing instruments, and cleaning the camera.
- Explicit confirmation of detection or action.
- Other communications referring to state of stress or relaxation.

For each category, we measured the number of acts of communication, while taking into account the duration of the surgery (ratio = number of acts of communication / time (in seconds) X 100). The Mann-Whitney U test was used to compare the two techniques: classical laparoscopy and robotic surgery and the Kruskal-Wallis test was used across the board.

**RESULTS**

**Communication as a feedback adaptive process**

The average duration of the intervention was significantly longer (p<0.05) with the robotic system (cholecystectomy: 82.59±27.37; prostatectomy: 221.39±58.79) than with classical laparoscopic (cholecystectomy: 31.85±9.64; prostatectomy: 95.74±11.53).

Figure 2 shows that the introduction of the robotic system created a new pattern of communication. Our results show that not only was there more acts of communication with the robotic system, but also that different types of communication between the surgeon and the assistant were used. This pattern of results was similar for the two types of surgery.

Following our hypothesis, the increase of communication acts observed in the robotic system suggests that a portion of useful feedback is not provided by the robotic system anymore, and that the surgeon attempts to compensate this weakness of the system via verbal communication acts.

The significant increase in the number of communication acts (p<0.05) referring to orientation, manipulation, order and confirmation within the robot system suggests that a breakdown occurs in the collaboration between the surgeon and the assistant. The surgeon works alone and continually needs to ask the assistant about the orientation and the placement of the instrument (which is manipulated by the assistant) in order to facilitate the identification of the organs. Explicit demands, order, and confirmation are needed because the system configuration impedes face to face communication and prevents the assistant from anticipating the expected course of the surgeon’s actions. Additionally, by introducing a distance between the surgeon and the patient, the robot configuration creates a new requirement for collaboration when s/he needs proprioceptive feedback, as illustrated in the following example of communication.

Example of interaction: **Surgeon at the console:** “could you tell me if you are touching something here, because I see a particularity ”, **Assistant surgeon near the patient:** “yes, I am touching something hard - it is a bone”.

269
Communication and adaptation processes with new surgical technology

Communication as a sign of trouble
We observed two conversions: one in urology from a robotic surgery to open surgery and one in digestive surgery from robotic surgery to classical laparoscopy surgery.
As uncertainty increases during the case due to progression from expected to unexpected variability, initial procedures that are operationalized through preparatory configuration become irrelevant. In this case, conversion becomes imperative and may require the use of procedures that are not practiced by the surgeon anymore as it was the case for prostatectomy in open surgery.
Each of these conversions is associated with an increased number of verbal communications (see figure 3). These communications concerned explicit clarification of strategies (replanning) and expectations concerning orientation and manipulations. We also observed less communication that referred to confirmation. During a crisis, the surgeon acts and does not take the time to verify the receipt of his action or request.

Communication as a dynamic process
Our results show that the number of acts of communication is reduced with repeated experience: from the first operation to the second operation of Fallopian tube anastomosis, but also with the degree of expertise of the team with the robotic system (see figure 4).
The duration of the intervention was significantly different (p<0.05) according to the surgeon’s expertise level: interventions are longer with novice surgeons (58.37±5.66) than with an expert at the console (32.67±10.46) and with two experts (25.85±8.66).
Detailed analysis of communication showed that the number of communication acts referring to orientation, manipulation and strategies was significantly reduced (p<0.05) when both surgeons were experts. Not surprisingly, the number of acts of communication referring to order and confirmation was significantly greater when an expert was present. In the contrary, the reduced number of acts of communication referring to orders and confirmation when both surgeons were novices attests to the absence of organization and structure that the surgeons have to compensate through more communication on ongoing action control (manipulation and strategies).

**CONCLUSION**

Based on our results, it is clear that a robotic environment changes the feedback loop and that verbal communication used by surgeons is a feedback-adaptive process to compensate the feedback information absent in the robotic environment. Verbal demands concerning manipulation, orientation, confirmation, and orders attest to the fact that the surgeons need information in order to carry out their task, identify the organs, and control their action. Indeed, the patterns of communication reveal the needs for feedback and, thus, the defeating aspects of feedback from the robotic system.

Our results also show that both the number of communication acts and the type of communication evolve with the agent–robot environment interactions. The fact that there are regular interactions between the surgeon and the assistant creates implicit communication and reduces the need for explicit communication and furthermore suggests successful adaptation to the environment. However, our results also indicate that the surgeon’s emergent adaptive learning response is achieved more readily through interacting with the classical laparoscopy system than with the robotic system. By introducing a distance between the surgeon and the assistant, the robotic system prevents face to face communication, which normally serves as a critical feedback for this adaptive process. Instead, the robotic system requires greater attention and continual efforts to communicate during even routine surgical procedures. However, as mentioned earlier, when complications occur, increased verbal communication is required to clarify plans and expectations in order to enable coordinated actions between the surgeon and the assistant.

These results reveal the value of verbal communication as a sign of adaptation or difficulty with adaptation of socio-technical systems. Indeed, our studies suggest that verbal communication can be seen as an adaptive feedback process that allows the agents to maintain an adequate performance level, minimizing the defeating feedback from the technical system. This adaptive response of the system is triggered by the environmental change (the change of the technical system) but emerges and evolves through agent-environment interactions. Thus, it is compatible with Piaget’s constructivist view of adaptation: driven by the need to fit environmental constraints and emerging through interaction with the environment.

The concept of adaptation is also central to newer research on resilience engineering that views safety of complex systems as a system property that emerges from agent-environment interactions. In psychology, the term “resilience” is used to designate the human ability to survive after a significant trauma that has destroyed his/her equilibrium (Bowby 1973, Cyrulnik 2003). We will therefore utilize the term resilience to designate the system’s ability to recover from a change that destroys the system’s structure.

We have discussed that the conversion cases represent a fundamental breakdown for the system, yet we have also seen how the surgeons, and not the robot, have mechanisms for recovering from the situation before it affects the patient by replanning the cases into classical surgery. This means that the system’s capacity for resilience resides in the human part rather than in the technical part of the system. Indeed, adaptation emerges through the history of different agent-environment coupling over time (open surgery, classical laparoscopic surgery, robotic surgery) that enhances the...
agent’s autonomy towards the variability from the environment. This is similar to Maturana and Varela’s work on the biology of cognition and autopoiesis (Maturana & Varela, 1980, 1987). According to Maturana and Varela (1980), living systems are not at all the same as machines made by humans. Machines, including robots, are allopoietic. The organization of an allopoietic machine is given in terms of a concatenation of processes independent of the organization of the machine. Thus, the changes that an allopoietic machine goes through are necessarily subordinated to something different from itself. In contrast, a living system is truly autonomous in the sense that it is an autopoietic machine whose continual interactions between components and environment, their transformations and destruction regenerate and maintains the system to be viable, in an emergent fashion, driven by the need to fit with environmental variability constraints. The result will be what Varela has called “a history of mutual congruent structural changes”.

Although recent work from Joint Cognitive systems engineering discusses issues like autonomy, resilience, variability and adaptation (Woods a Hollnagel, 2006), much prevention effort is still spent on control mechanisms and how to anticipate breakdown. However, from our point of view, attempting to predict and control the breakdown sterilizes the new approach developed above. The results captured in this chapter support the idea that studying both the behavior of the system and the communication process provides markers of the system’s adaptation and inadequate adaptation and, in turn, will help to develop adaptive technology that enhances coupling between agents and their environment.

REFERENCES


