Virtual Reality in Surgery: Between Satisfaction and Stress

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Abstract

The present study is focused on usability issues related to laparoscopy, emphasizing the surgeon's overall satisfaction with the mediated perception of reality. We were particularly interested in assessing the differences between this mini-invasive surgical technique and classical surgery, trying to underline both its advantages and limits. We also tried to evaluate the level of stress induced by this method, among the surgeons who use it on a regular basis, together with the adopted coping strategies. Laparoscopy, even though grounded in classical surgery, has its own distinctive features, which require flexibility in order to facilitate the transfer of skills. Despite its limited range of applicability, used discriminatively and carefully, together with well-organized training sessions, this technique can bring satisfaction to both surgeon and patient.

Introduction

Computer technology has become a significant feature in all dimensions of our lives, and Medicine is not an exception. As Satava and Simon (1994) anticipated, the delivery of health care can be highly improved by an *electronic interface*, which "will make possible the future of endoscopy and endoscopic surgery by taking advantage of the emerging technologies in robotics, micro-robotics, telepresence, and virtual reality".

Virtual reality (VR) is a generic term, encompassing the idea of computer-generated simulation of world, in which the user can become immersed. It represents the state of the art in multimedia systems, but with an emphasis on vision (Sas & Moisil 1999). Medical applications of VR technologies are spectacular and fruitful and have recently started to emerge (Satava 1994). According to Satava and Jones (1996), there are two major trends in applying VR in medicine: as an interface or as an environment. The interface allows a more intuitive and natural way of collecting and processing information, while the environment enhances "the feeling of presence during the interaction". Some of the most significant applications consist of surgical simulation, which allows surgical residents to train themselves; telepresence surgery, which enables surgeons to be present at a remote operation room; robotic cameras and laparoscopes, which enable the physician to be present in the patient's body; visualisation of complex medical databases (Satava 1995).

Concept of Telepresence

Telepresence surgery is a new technology that enables surgeons to perform operations on patients at physically remote locations. According to Bowersox *et al.* (1996) "this new method provides the sensory illusion that the surgeon's hands are in direct contact with the patient". Ravani (1991) defined telepresence as a technology that links together the human operator through his manipulative actions and perceptual functions with a remote site. According to him, "effective telepresence must give the human operator the feeling of being *present* at the remote site by allowing him to see and feel the objects being manipulated and also provides him with enough manipulation functions to closely match his full dexterity in performing a task". Besides solving the distance problem, telepresence offers other benefits, such as minimizing the exposure of surgeons to diseases and reducing potential costs as a result of reduced trauma (Satava 1994).

Laparoscopy

Laparoscopy, applied for the first time by Semm (1987), does not exclude, but completes the classical surgical intervention. The development of miniature cameras made this technique possible. The mini-invasive surgery, called surgery with minimal access, led to fundamental changes of the surgery concept. The basic idea is one of limiting trauma to tissue not functionally or anatomically linked with the target organ.

As Coleman, Nduka and Darzi (1994) argued, the nature of laparoscopic surgery enables it to take advantage of advanced technologies such as virtual reality and telepresence. As they mentioned, "high-definition screens, three dimensional sensory feedback and remote dexterous manipulation will be the next major developments in laparoscopic surgery".

In the case of laparoscopy, the augmented reality is used for merging computer images with real time images of patient's body (Moline 1997). This became possible through video technology or robots directed by surgeons, physically present in the operating room.

Classical surgery or so-called "open surgery" is carried out by making incisions, often not small, while the surgeon directly interacts with the patient's body. From a different perspective, the mini-invasive surgery is performed by small incisions whereby a miniature camera is introduced, facilitating the visualisation of internal organs. In addition, even the manipulation of the specific surgical tools can be carried out in a mediated manner, through the virtual environment, where "robots reproduce the movements of humans using virtual instruments" (Moline 1997), with significantly increased precision. In both cases, telepresence and laparoscopy, the surgeon operates not directly on a real body but through an image of it.

Despite the widely accepted importance of this advanced medical technique, there is a lack of research focused on the psychological evaluation of its impact on the surgeons' perception of reality and performances achievable through it.

Study Methodology

The present study tries to identify the impact of laparoscopic technique on surgeons' behaviour, namely their perception of reality, the associated level of stress, the performance achievable and the induced degree of satisfaction. In other words, the attention is focused on the usability of the laparoscopic technique in comparison with that of classical surgery.

Initially, we will proceed with a brief definition of the term *usability*, according to International Standards Related to Usability (ISO 1997), which delineate three conceptual dimensions:

- *Effectiveness* as "the accuracy and completeness with which specified users can achieve specified goals in particular environments."
- *Efficiency* as "the resources expended in relation to the accuracy and completeness with which the users achieve goals."

- *Satisfaction* as “the comfort and acceptability of the work system to its users and other people affected by its use.”

In order to assess the usability of this surgical technique, we considered attitude measurement, as the most suitable, which consists of collecting physicians’ opinions regarding it. This paper presents a case study, following the line of exploratory studies. These are primarily oriented to problem formulation and hypothesis development, as an important initial step in any research process.

Study Hypothesis

The question is whether working directly on an image of the patient’s body induces an alteration in the way in which reality is perceived by surgeons. The gap between the image and the real body, between the feedback provided through the screen and the reality, might trigger a disparity between what the surgeon sees and consequently does and what he feels like he does.

Emphasizing the same issue, Heim (1993) points out that “surgeons complain of losing hands-on contact as the patient evaporates into a phantom of bits and bytes”, because of the “psychotechnological gap [which] opens up between doctor and patient”.

A possible answer for bridging this gap could be sense of presence. Biocca, Kim & Levy (1995) argue that “presence is part of an ancient desire to use media for transportation and experience “physical transcendence” over the space we live in”. In an overused and widely accepted assertion, Sheridan (1992) describes telepresence as a “sense of being physically present with virtual objects at the remote teleoperator site”, while Witmer and Singer (1994) define presence “as the subjective experience of being in one place when one is physically in another”.

The first goal of this paper is to identify and analyse factor clusters, namely those, which influence the physician’s performance, while he is acting not directly in a real space, but in a technologically mediated one. In virtual worlds generated by computer, a good perception of space and volume is a priority, especially in cases where because of the nature of actions occurring in virtual environment e.g. surgical interventions, handling of objects requests precision and attention. The more the physician is *present* there, inside the displayed patient’s body image, the better the perception of medical image is.

Study Objectives

The objectives of the present study are summarized bellow:

- To identify the differences in perceiving mediated reality triggered by laparoscopic technique.
- To identify factors influencing surgeon’s perception of reality.
- To identify the level of perceived stress and coping strategies for surgeons practicing laparoscopic surgery.

Sample

The *sample* consists of twenty physicians who practice both classical surgery and laparoscopic surgery, all males, within the age range 35–65. The characteristics of the surgeons’ sample are summarized below. All the subjects are specialized in surgery and urology, more than 50% being within the age range 35–40. More than half of surgeons have a length in medical practice within the range 10–20 years, and an experience in practicing laparoscopic surgery of less than 2 years.

Methods

The methods used were psychological tests for identifying the level of *perceived stress* (Levenstein *et al.* 1993) induced by laparoscopic technique, and the *adopted coping strategies* (Carver, Scheier & Weintraub 1989). For analysing factors that influence the surgeons' perception of mediated reality and their performances, we also interviewed each subject of our sample. The interviews were focused containing semi structured questions, whose succession was flexible, stressing a theme and hypothesis previously established. The background idea was the adjusting to the interviewed subjects' personalities and their ideation stream. Table 1 provides a brief summary of the various dimensions and variables, which encode the concept of mediated perception of reality. Grounded on this operationalisation, we built an interview guide.

Dimensions	Variables
Laparoscopic technique characteristics	Specificity
	Advantages
	Disadvantages
	Limits
	Special requests
Attitude regarding this technique	Surgeon's satisfaction
	Patient's attitude
Perception of reality	Perception of space
	Perception of shape
	Perception of size
	Perception of third dimension
	Perception of position
	Perception colour
	Perception of movement
	Perception of time passing
Haptic sense	Involvement of haptic sense
Presence	Sense of presence
Performance	Performance assessment
Stress	Perceived stress

Table 1: Concept Operationalisation

Results and Discussion

We present the results obtained through the qualitative content analysis of interviews. For a better understanding, they will be structured according with the interview guide themes, and underlined by quoting the most relevant ideas expressed by surgeons.

The specificity of laparoscopic technique, also called velvet surgery or keyhole surgery, as it was depicted by the subjects' answers, primarily consists in the mediated contact between the surgeon and the target organ. It requests training, experience, imagination and a set of particular manual skills. The most important advantages and disadvantages, as the surgeons perceived them are summarized in Tables 2 and 3 respectively. Generally, the *reality comprehension*, mediated by laparoscopic devices is limited and distorted, due to the fact that it allows perception just from a single angle: "one can not see the forest because of the trees," and also to the difficulty of handling devices. Neutral opinions did not stress any difference in how the reality is perceived, claiming that: “it is normal and nothing is unusual”. On this continuum one end emphasizes the strengths and the other end the limits, pro opinions claim that the reality is better perceived through this mediation, due to the increase of subtle details, difficult to perceive otherwise.

Advantages	Freq.
Less post-surgery complications	33 %
Reducing hospitalising time	29%
Quicker recovery	14 %
Reducing surgery time	9%
Decreasing risks	5%
More precision	5%
Improved comfort for surgery team	5%

Table 2: Advantages

Disadvantages	Freq.
Contraindications	34 %
Surgeon’s training	17 %
Expensive devices	17 %
Longer surgery time	11 %
Limited observing capacity	11 %
Limited haptic interaction	5 %
Limited handling possibilities	5 %

Table 3: Disadvantages

The perceived mediated *shape* is very good, with a quality comparable with the real one, due to magnifying lenses, which enrich the visible details. *Size* perception is difficult, but possible using the already known anatomic landmarks. Other opinions noticed that size could be even better perceived because of the greater visibility of all the details. There is also flexibility in size perception provided by the zoom option of miniature camera, thus “the whole organ can be seen and / or (just) certain parts of it”. Unfortunately, the zooming facility involves a drawback consisting of the induced relativity of anatomical landmarks, a fact that can be overcome only by years of experience. Gaining the ability to integrate *three-dimensionality* (depth) is a cumbersome and time-consuming process, given that the screen image is a two dimensional one. Despite this, the surgeon should act in three dimensions and should to be able to anticipate and “feel it somewhere forward of his fingertips”.

Training and experience are the key factors involved here, together with some level of intuition. After the experience is already acquired, there are no problems in perceiving the depth, due to anatomical landmarks easily recognized, which lead the spatial orientation inside patient’s body.

More problems arise from the perception of *position*. At the very beginning it is confusing: “you don’t know where you are”, because of the overturned plans. This spatial asynchrony makes things to be perceived diagonally, thus “the image on the screen is not a perfect reflection of reality”. Everything is “seen inversely”, like in a mirror, due to the changing of the light source place. The expected performance might reflect the involvement of “cognitive processes with no clear-cut behavioural correlate such as mental rotation or the processing of a modulated visual input” (Balslev *et al.* 2000). Of course, after the experience is acquired, the perception of position is carried out in a very simple and easy way: “I know how they are and where they are (the organs), so I’m orienting myself. If I didn’t know and someone else would just tell me, I don’t think I could manage it”.

While *time passing* is better perceived in classical surgery, in laparoscopic surgery there is a compression of it. Due to a higher level of concentration and overloading, it seems like “time is flying”. This fact is normal for every learning curve, where each operation requires attention and significant effort. In order to improve the initial learning curve, a surgical simulator can be an appropriate solution. For instance, Chaudhry *et al.* (1999) developed a laparoscopic simulator, which can also provide an objective assessment of psychomotor skills. This high quality surgeon-computer interface allows a quick familiarization curve to the half of sessions on the simulator, with an important decrease in both time taken and total errors made. Grounded on this idea, now it is easily understood why “at the beginning the time is flying, then it passes normally”.

The difficulties arising from the perception of size are related to perception of *movement*, due to the same diagonal asynchrony between the screen image and the real one, “it is difficult to reverse the movement, because of the opposite diagonal (the image and the gesture)”. This mismatch between the direction of movement image on the display and the direction of the real movement impedes the performance since “the movements seam to run idly”. This drawback of the laparoscopic technique increases the general overload, brought by working with every new technology, stressing the initial discomfort, “it seems that you are stumbled”. After the experience is acquired, this issue is relatively easily overcome, so the surgeon asserts, “there are no differences in perception of movements”.

The perception of *colour* does not suffer any impairment quite contrarily the displayed colours are real, vivid and thus even “more beautiful” than the real ones. Of course this fact can be double-edged, since it could lead to an increased feeling of unreality.

The *feeling of unreality* is primarily induced by sensorial deprivation, due to the fact that olfactive sense and most important, tactile sense are less involved. Compared with classical open surgery, the surgeon is extremely limited by laparoscopic technique because “there is no touching sense involved and the surgeon can not feel anything”. Moreover, working with special surgical tools, as “prolongations of one’s hands” induces a “break between the reality and the gestures”. Because of the device mediation, and indirect contact with patient’s body, the perceived movement on the display seems to be less articulated, without being grounded on concreteness, thus increasing the “psychotechnological gap” (Heim 1993). Sometimes the surgeon can be surprised by poetical images, which appear on the screen, as “caves with stalactites”, while other times he really feels himself as being “completely inside the patient’s body and operating there”.

The *stress* induced by laparoscopic technique is greater comparatively with classical surgery, because for any new technology the learning curve demands some time and a lot of energy in order to acquire the necessary skills. Moreover, in using this technique, the complications that can appear at any moment, are more difficult to control and could request immediate conversion to an open surgery. The training and experience acquired induce calm and safeness.

Patient’s attitude regarding laparoscopic technique is positive. Once the patient finds out its advantages, he/she is delighted, preferring it to the classical one. The *performances* are perceived as being very good and sometimes even superior in laparoscopic surgery, mainly because of the reduced risk of post surgical complications. Despite of its attractiveness, the method still has just a limited range of applicability, compounded by a set of restrictions, so it should be used discriminatively and carefully. Still the advocates of classical surgery see the laparoscopy just as a method, indeed en vogue, “but which is not the true Surgery”. The *stress* scores, obtained through perceived stress questionnaire (Levenstein *et al.* 1993) are av. = 65.88, st. dev = 4.75 (Table 4). The stress induced by using laparoscopic technology is perceived as being moderate, an issue which assures the most propitious level of activation, stimulation and adaptability to the activity being carried out. This is interesting knowing that the physicians’ work environment and especially that of surgeons’ suppose a high level of stress. The explanation could be in the efficiency of adopted *coping strategies* (Carver, Scheier & Weintraub 1989), or in work satisfaction.

The most frequently used coping strategies are focused on: conscious focus of effort in order to adapt to stress factors; organizing stages and ways of actions; suppressing impulsive and premature tendencies to act, if the situation does not allow it; accepting the threatening action or the fact that "there is nothing to be done". The less frequently used coping strategies are asking for advice, information, and support, expressing negative emotions or even searching for divine help.

Average value	Stress scores	Stress levels
65.88	30-60	reduced
	60-90	average
	90-120	high

Table 4: The stress score

Generally, the main coping strategy used by surgeons is an active one, focused on problem, which supposes direct actions, planning, waiting for the opportune moment and the acceptance of defeats (that can get thus new significance). A less used strategy is one oriented towards social support consisting primarily in requesting advice and material or moral help. These are grounded on understanding, sympathy and possibility of emotional discharge.

Very likely, self-confidence proved its efficiency. Another explanation for the low score of social support strategies can be found in the image that the physician should offer to the patient: safeness, calm and confidence, where the hesitations, doubts or emotional explosions have no place.

Conclusions

This study allows us to identify two sets of factors determining surgeon's performance in using the laparoscopic technique. Part of these are grounded on the technical aspects regarding the device characteristics such as the clarity of image, the synchrony of movements and their images on the display, the realism conveyed, the ease of working with it, in other word its usability. The other set of factors concern human factors, such as handling, flexibility, learning capacity, patience, spatial ability, intuition, good perception of mediated reality, focused attention, stress level and coping strategies.

The bridge between these two sets of factors is achieved by training and acquired experience, together with satisfaction regarding the device and method as a whole.

Laparoscopy as a desktop VR system permits a very interesting but also paradoxical changing of plans. It allows the surgeon to be there, in the patient's body, due to sense of presence. It triggers advantages like greater visibility for details or better control. There is also a price to be paid for it, namely less physical contact with the patient's body, when it is well known that surgery is mostly a visual and a manual craft. On the other hand, this can be seen as an advantage since the distance between surgeon and patient could allow a more objective and less emotional approach to the surgical act.

The subjects' answers covered a broad range, but they can be organized on a continuum of pros and cons. On one end the reality is perceived as significantly better through laparoscopic technique, while on the other end, the subjects complained of its limits and restrictions. Neutral opinions did not stress any differences regarding the perceived reality through laparoscopy in comparison with classical surgery. We found an overlap between this continuum and the experience in using this technique. The greater the accumulated experience, the greater the comfort in using this technique, and thus the alterations grounded in mediated reality perception have less negative impact. Undoubtedly, surgeons' attitudes towards laparoscopy can also be correlated with their cognitive style e.g. critical thinking, synthetic thinking, level of imagination etc. (Sas & O'Hare 2001).

There is an interesting exception: one of the surgeons, whose length of experience in using laparoscopy is greater then average, but with the highest length in classical surgery practice, still experiences difficulties due to limits of this technique, which "is not the real Surgery". His outstanding and internationally recognized value together with long years of experience of traditional surgery biased him. Definitely, the laparoscopic method, even grounded on classical surgery, has its own, distinctive features, which require flexibility for the necessary transfer of skills and their fitness in the new frame. Too many years of previous experience in traditional surgical method could bias negatively, so the switch to the new methodology is no longer easily achievable.

Even if the overall picture is restrictively perceived due to the difficulty of handling instruments with a limited freedom of movement and because of the viewpoint restraint, the laparoscopic method brings the advantage of increasing the subtle details of perceived shapes, enabling surgeons to see them clearer and easier. The drawbacks triggered are overcome by training and acquired experience. The perception of colour does not suffer any impairment, while the size perception can be corrected mainly by previously known anatomical landmarks. The problems regarding disorientation are due to overturned plans and spatial asynchrony between movements and images. The ability of integrating the three-dimensionality is hard to achieve and the experience and training carried out are the keys for this problem. Some correlation with surgeon's spatial abilities can also be discovered (Balslev *et al.* 2000). One of the common solutions to overcome these limits is the 3D-image representation of patient's internal cavity on a computer screen. Thus, two important advantages can be highlighted: stereoscopic view and synchrony between gestures and their image on the display. In a comparative study carried out by Van Bergen *et al.* (1998) the authors measured the subjective surgeons' satisfaction of 2D and 3D vision systems. The conclusions proved that the latter one brings an obvious benefit for complicated surgical manoeuvres, since the rapidity and safeness had increased. The single limitation of a 3D vision system is the requirement of medium spatial perception capabilities.

The alterations in perception of time passing cover again a broad range. The fact that tactile (and hearing) senses involved in time perception are less involved when one uses laparoscopic technique, can offer the explanation. The overload can also distort the time perception, so it passes "very slowly, [the surgery] is like an embroidery, which takes excessive patience". The sensory deprivation induces a feeling of unreality. Because of device mediation, and indirect contact with the patient's body, the perceived movement on the display seems to be less articulated, without being grounded on concreteness, thus increasing the "psychotechnological gap" (Heim 1993). The jump from the feeling of mediated reality to immersion could be a function of surgeon's cognitive style, realism of conveyed image, training or experience acquired.

The stress induced by usage of laparoscopic technology is perceived as being moderate, an issue which assures an optimal level of activation, stimulation and adaptability to the activity. This is possible due to the efficiency of adopted coping strategy: an active one, focused on the problem, which involves direct actions, planning, waiting for the opportunity and acceptance of defeats.

Despite its limited range of applicability, surgeon's satisfaction regarding this technique is high due to a very good performance level achievable through it. Used discriminatively and carefully, together with very well organized training sessions, it can bring satisfaction to both surgeon and patient, being beneficial for the medical care.

Future Work

The question we tried to answer was if the simulation induced by the VR spoils the dimension of verity or realism for the perceived reality, and if it does, to what extent, and which is the acceptable threshold within which the surgeons can still feel they are operating there, in a real body. How does this technique alter indirectly surgeons' performance, in terms of reality perception, sense of presence, stress and overload? The present study answered these questions only partly, while the others remain open to be investigated, in order to harness this advanced video technology.

On the basis of these results we will go on with the study by modelling a cognitive model of interaction between the surgeon and the computer-generated image, whose final aim is development of ergonomic interfaces, able to adjust efficiently to user's personality.

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