Measuring Workload and Performance of Surgeons Using Body Sensors of Smartwatches

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Abstract We present the first steps toward building an intelligent system to measure the workload and surgical performance of minimally invasive surgeons. This pilot study was conducted during two training courses in minimally invasive suturing, one in microsurgery and one in laparoscopic surgery. During each training activity, surgeons wore a smartwatch with the happimeter application running on it. This system recorded a set of physiological and motion parameters during the surgical execution. We found that monitoring the surgeon's maneuvers and physiological parameters during surgical activity has the potential to play an important role in predicting the workload and surgical performance, especially regarding physical and mental demand and the level of distraction during surgery.

Introduction

The introduction of laparoscopic surgery has made it possible to reduce the number of incisions required during the surgical procedure, minimizing the trauma and therefore reducing the associated pain, the risk of infection and the length of hospital stay. In laparoscopy, surgeons operate through surgical ports on the patient's abdominal wall and using long instrument and endoscopic camera. In the case of microsurgery, surgeries are performed by means of visual magnification and microsurgical instruments to carry out interventions on the vascular and nervous systems, among others. Apart from the numerous benefits for the patient, these surgical techniques present several limitations for the surgeon. Some of these challenges are loss of depth perception (two-dimensional vision), forced postures during surgery due to the restricted movements, diminished tactile feedback, and inverted instrument movements due to the surgical ports. All of this leads to an increase in the surgeon's

mental and physical workload during surgery, as well as a potential onset of musculoskeletal disorders.

Several wearable devices have been recently developed for surgical applications, most of them focused on interaction with patient's preoperative information and telementoring purposes [1, 2]. However, there is a lack of this technology that allows us to monitor and analyze the wellbeing of the surgeon while operating, as well as the development of the minimally invasive surgical procedures. To the best of our knowledge, this is the first project focused on the use of wearable technology and artificial intelligence to look for solutions in the prevention of emerging health problems of surgeons, as well as in the prediction of the quality of his/her surgical performance during the surgical practice. In this work, we present the first steps towards building an intelligent system for measuring the workload and surgical performance of minimally invasive surgeons.

Materials and methods

This pilot study was conducted during two training courses in minimally invasive suturing. One course was focused on microsurgical techniques and the other on laparoscopic surgery. During each training activity, surgeons wore a smartwatch with the happimeter app running on it. This system [3] recorded a set of user motion and physiological parameters during the surgical performance. The smartwatch collects body movements through the accelerometer sensor of the smartwatch, heartrate through the heartrate sensor, speech parameters (no content) through the microphone, close interaction through the bluetooth sensor, and location changes through the GPS. The data is transmitted from the watch (currently we are using the Android Wear Ticwatch) to a server in the cloud, where a machine learning system collects the data, trains the models and predicts pleasance, activation, and stress levels. With regard to the motion parameters, the values (direction) of the X, Y and Z components of the acceleration in the movements of the surgeon's hand (AccelerometerX, AccelerometerY and AccelerometerZ) and their magnitude (i.e. change in velocity; AccelerometerMagX, AccelerometerMagY and AccelerometerMagZ) were used.

At the end of each trial, participants were asked to complete the The Surgery Task Load Index (SURG-TLX) [4] questionnaire, which is a subjective questionnaire to evaluate the workload during a surgical activity. This multidimensional assessment method is based on six dimensions defined as mental demands, physical demands, temporal demands, task complexity, situational stress, and distractions.

Microsurgical training

The first training activity in this study was a course in nerve and vascular microsurgery. Resident surgeons, with different experience levels, performed a vascular anastomosis using a physical simulator (Fig. 1a).

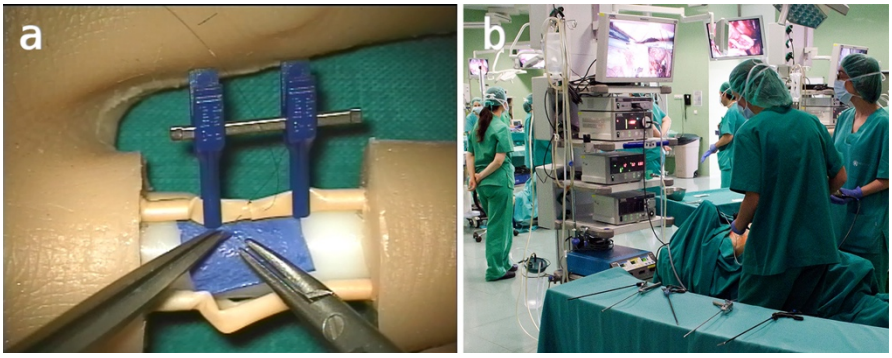

Fig. 1. Microsurgical anastomosis on a simulator (a). Training course on laparoscopic surgery (b).

During this activity, the surgeons' technical skills were assessed using the Stanford Microsurgery and Resident Training (SMaRT) Scale [5]. The SMaRT scale consists of 9 categories graded on a 5-point Likert scale, including Instrument Handling, Respect for Tissue, Efficiency, Suture Handling, Suturing Technique, Quality of Knot, Final Product, Operation Flow, and Overall Performance.

Laparoscopic training

The second activity was a course on laparoscopic suture, in which surgeons, with different levels of experience, were evaluated during the performance of a laparoscopic gastrotomy in an ex vivo porcine model (Fig. 1b). During the course of the training activity, participants exchanged the roles of principal surgeon and camera assistant. Therefore, in this case, the quality of surgical performance was not individually assessed.

Results

Microsurgical training

Eight resident surgeons, between first and fifth year of residency and an average experience of less than 10 microsurgical procedures performed, participated in this study. With regard to the SMaRT assessment, the surgical skills of the residents during the performance of the microsurgical tasks were generally scored as moderate, specifically concerning the respect of tissue, the quality of the final product, and the overall performance (Fig. 2). All participants completed the surgical workload questionnaire. In general, they scored the training task as physically demanding and complex.

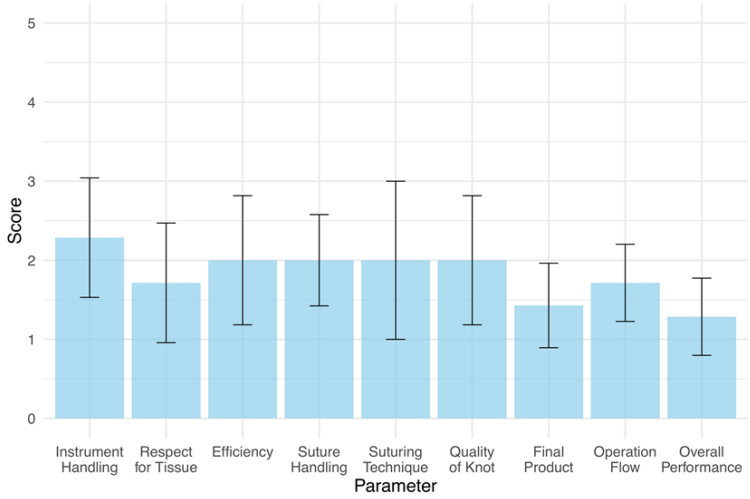

Fig. 2. Average values of the SMaRT parameters for the microsurgical task.

Regarding the correlation between the motion and physiological parameters and the surgical skills during the microsurgical activity, there was a positive correlation between the magnitude of the Y component of the hand acceleration and the quality of the suturing technique and knot tying (Fig. 3). Concerning the surgical workload, there were correlations between the acceleration of hand movements in the X axis and the mental demand, complexity of the task and level of distraction during the task performance (Fig. 4). Additionally, there were also strong correlations between the acceleration of the hand motion in the Z axis and the temporal demand of the task and between the pitch/tone of the voice and both the distractions during the task and the surgeon's heart rate.

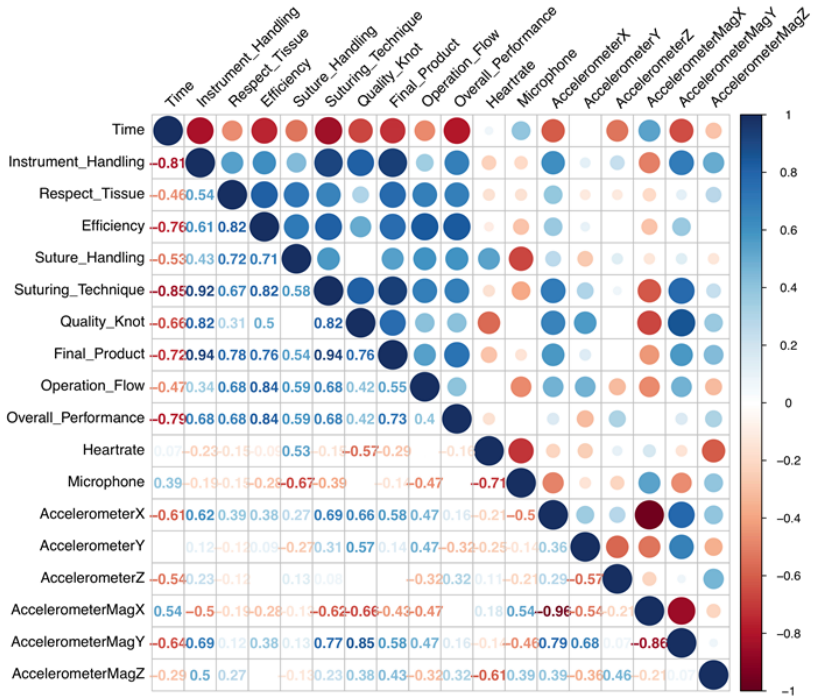

Fig. 3. Correlation matrix between the happimeter parameters and the SMaRT categories for the microsurgical task. The correlation coefficients are showed at the lower part of the graph. Color intensity and the size of the circle are proportional to the correlation coefficients.

Laparoscopic procedure

During the laparoscopic course, seven surgeons participated in this study. They were one third-year, one fourth-year and two fifth-year resident surgeons and three consultant surgeons, with an average experience of between 10 and 50 laparoscopic procedures performed. All participants completed the surgical workload questionnaire. They reported high values of mental, physical and temporal demands and stress during the execution of the laparoscopic procedure. They also reported that the level of complexity of the task was high. Results showed strong correlations between the acceleration of the hand movements, mainly for the X and Y components, and the level of the physical demand during the laparoscopic procedure (Fig. 5).

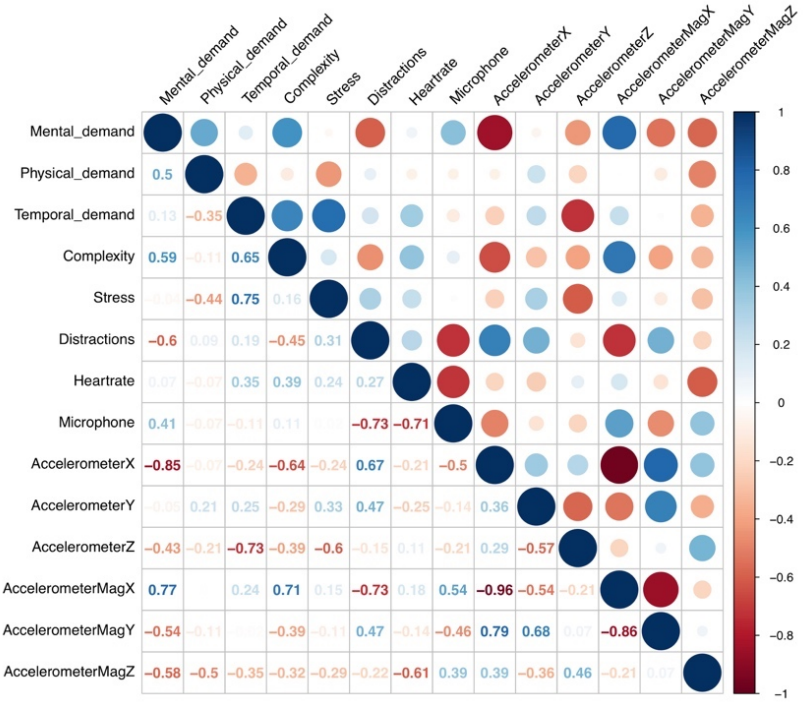

Fig. 4. Correlation matrix between the happimeter parameters and the SURG-TLX factors for the microsurgical task.

Discussion

Participants in this study considered the system an attractive solution to assist the surgical practice, seeking to improve the surgeon's physiological conditions and surgical performance during surgical practice. They stated that the device did not bother them during the course of the training activity or in the performance of the surgical tasks and procedures. In addition, the system does not require personal data of the subject other than information related to hand movements, heart rate and tone of voice. Participants were well-disposed to provide feedback and complete the questionnaire regarding their workload levels during the course of the study. Providing information of the surgeon's mental and physical workload, distraction and stress levels, and quality of the surgical technical performance, can have a significant impact on his or her surgical outcomes.

In general, surgeons considered both microsurgical tasks and laparoscopic procedures to be physically demanding. In both disciplines of minimally invasive

surgery, the surgeon's hand movements seem to be quite related to the physical and mental demand of the surgical task or procedure being performed.

During the microsurgical course, the surgeons' surgical performance was generally scored as moderate. This could be due to their relatively low experience in microsurgery and to the fact that the task evaluated was one of the first in the entire microsurgical training course.

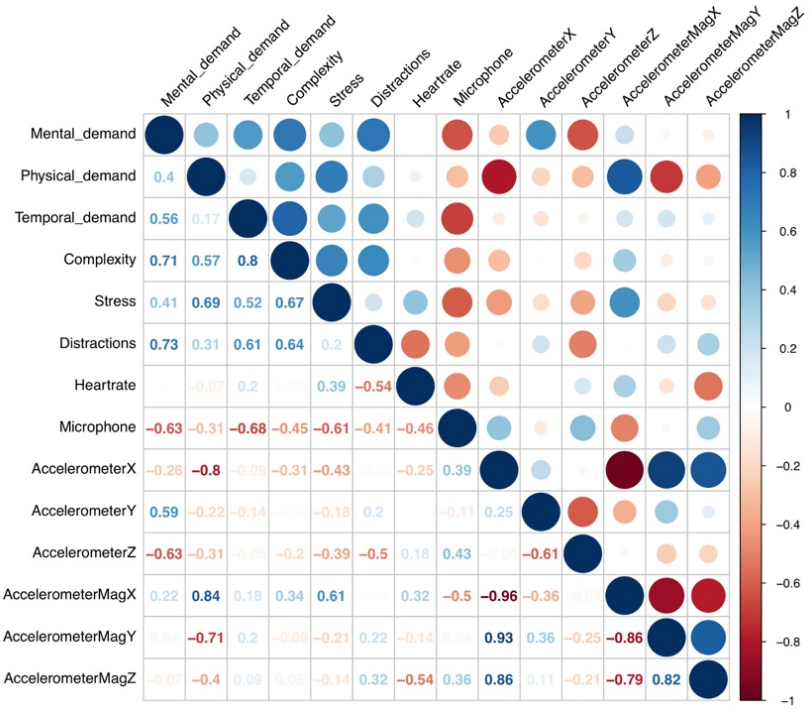

Fig. 5. Correlation matrix between the happimeter parameters and the SURG-TLX factors for the laparoscopic procedure.

Analyzing the relationships between the motion and physiological parameters recorded by the happimeter system and the microsurgical performance, it seems that the magnitude of the X and Y components of the hand acceleration during the microsurgical performance could be used as a part of a further model for predicting the quality of microsurgical suture.

Additionally, the acceleration of the X component may have a strong relationship with how mentally demanding and complex a microsurgical task is considered by a novice surgeon. Therefore, these factors could be used as indicators of surgical competence and how confident or stressed a novice surgeon feels during the performance of a task. A strong correlation was also found between the tone of voice/noise during the execution of the surgical activity and the distraction levels and the heart

rate of the surgeon. This environmental parameter may be considered a potential factor influencing the concentration and stress levels of the surgeon.

In the case of the laparoscopic procedure, there were a strong correlation of the hand motion and the increase of the physical demand during the surgery. As we might expect, an increase in hand movements using the laparoscopic instruments generally leads to an increase in physical demand during a surgical procedure.

This preliminary study presents a series of limitations which will be considered in future studies. The surgeons who participated in the laparoscopy course alternated in their roles as surgeon and camera assistant on several occasions during the course of the activity. Subsequent studies will analyze tasks or surgical procedures in which the surgeon and the assistant perform the same function throughout the procedure and thus will be able to fully evaluate their individual surgical performance. The number of participants and surgical tasks were limited. Further studies with a larger sample should therefore be carried out.

We have found that tracking surgeon's motion and physiological parameters during the surgical practice might play an important role in predicting their workload and surgical performance. Taking into account the results of both studies, the acceleration of the hand motion, mainly for the X component, may be related to the physical and mental demand and complexity of a surgical task (surgeon's workload), and the tone of voice/noise to the level of distraction during surgery.

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