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

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 motion and physiological parameters during the surgical performance. The smartwatch collects body movements through the accelerometer of the smartwatch, heartrate through the heartrate sensor, speech parameters (no content) through the microphone, close interaction through the bluetooth sensors, 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 predicts pleasance, activation, and stress levels. For the motion parameters, the values of the components X, Y and Z (i.e. direction; AccelerometerX, AccelerometerY and AccelerometerZ) of the acceleration of hand movements 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], which is a subjective questionnaire to evaluate the workload during a surgical activity. This multidimensional questionnaire 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 was a course in nerve and vascular microsurgery. Resident surgeons, with different experience levels, performed a vascular anastomosis in a physical simulator (Fig. 1a).

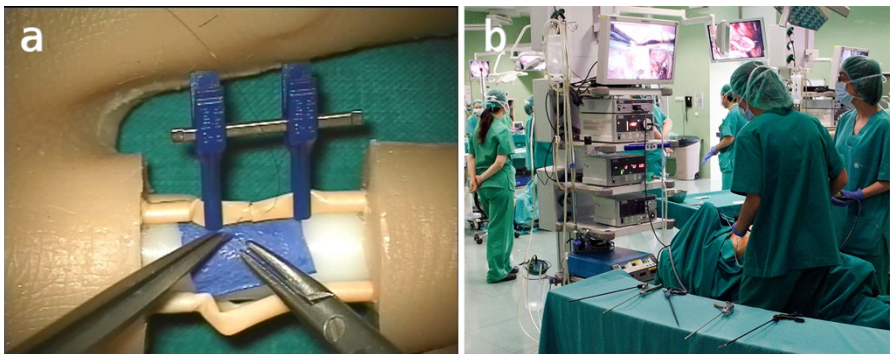

Fig. 1. Microsurgical anastomosis on a simulator (a). Training course on laparoscopic surgery (b).

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 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. The surgical skills of the residents during the performance of the microsurgical tasks were generally scored as moderate, specifically regarding the respect of tissue, the quality of the final product, and the overall performance. All participants responded the surgical workload questionnaire. They scored the task as physically demanding and complex.

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 X component of the hand acceleration and the quality of the suturing technique and knot tying. Concerning the surgical workload, there were correlations between the acceleration of hand movements in the X axis and the mental demand (Fig. 2). Additionally, there were also a negative correlation between the acceleration of the hand motion in the Z axis and the temporal demand of the task, a positive correlation between the magnitude of the X component and both the complexity of the task and the pitch/tone of the voice, and a negative correlation between the magnitude of the acceleration in the X axis and the increase of distractions during the task performance.

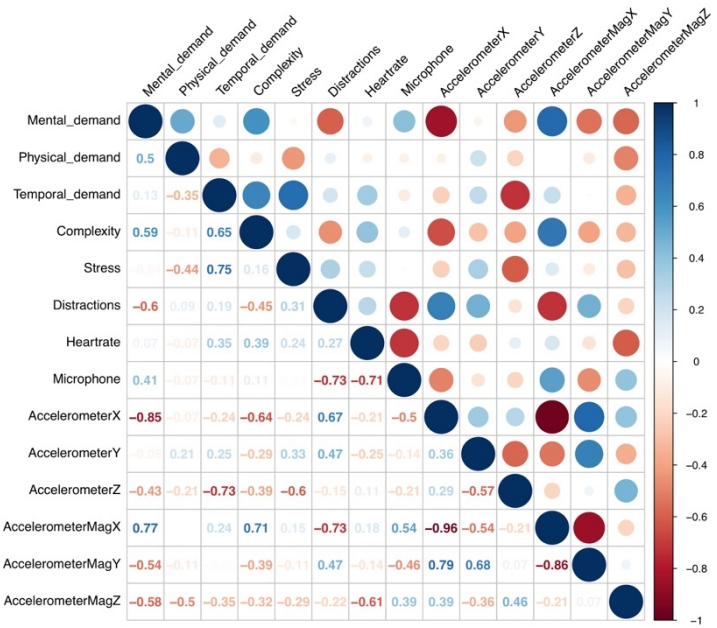

Fig. 2. Correlation matrix between the happimeter parameters and the SURG-TLX factors for the microsurgical task.

Laparoscopic procedure

During the laparoscopic course, seven surgeons participated in this study. They were one third-year, one fourth-year and two fifth-year residents surgeons and three consultant surgeons, with an average experience of between 10 and 50 laparoscopic procedures performed. All participants responded the surgical workload questionnaire. They reported high values of mental, physical and temporal demands and stress during the performance of the laparoscopic procedure. They also considered high the level of complexity of the task. Results showed strong correlations between the acceleration of the hand movements, mainly for the X component, and the increase of the physical demand during the surgical procedure (Fig. 3).

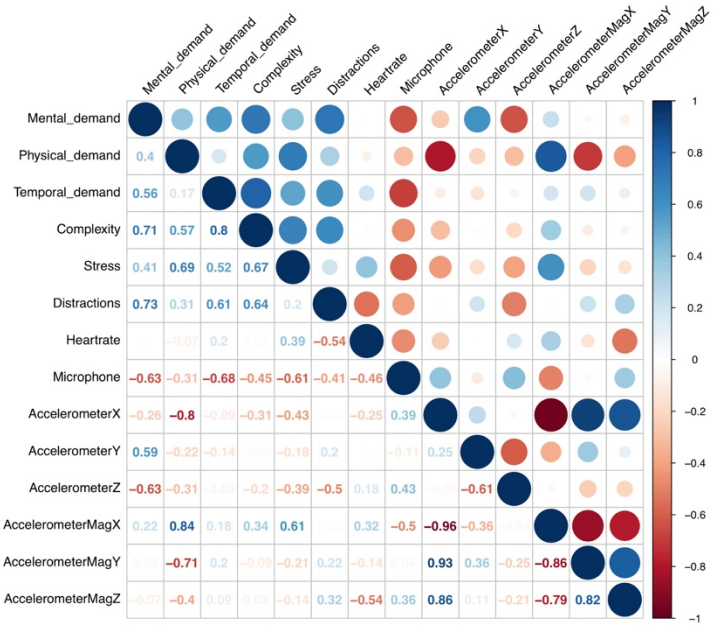

Fig. 3. Correlation matrix between the happimeter parameters and the SURG-TLX factors for the laparoscopic procedure.

Discussion

The participants considered the system as an attractive solution to assist the surgical practice, seeking to improve the surgeons' physiological condition and the quality of the surgical performance. The use of this system does not require the use of users' personal data and allows them the regular use of the surgical equipment during the intervention. Participants showed a high willingness to provide feedback and complete the survey. Raising the surgeon's awareness of the mental and physical workload, as well as the level of distraction, during a surgical procedure may have a potential impact in terms of surgical outcomes.

During the microsurgical course, surgeons were evaluated as moderate with regard to their surgical skills, which could be due to their relatively low experience and to the fact that it was one of the first tasks of the entire microsurgical training course.

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. Besides, the acceleration of the X component may have a strong relationship with how mentally-demanding and complex a microsurgical task can be 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.

In the case of the laparoscopic procedure, there were a strong correlation of the hand motion and the increase of the physical demand of the surgery. As we can expect, an increase in movements using the surgical instruments 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 participating in the laparoscopy course exchanged their roles of surgeon and camera assistant during the course of the activity. Subsequent studies will analyze surgical tasks or procedures in which the surgeon and assistant remain in their roles throughout the procedure and thus we will be able to evaluate comprehensively their individual surgical performance. The number of participants and surgical tasks were limited. Therefore, further studies should be done with a wider sample.

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, and the pitch or tone of the speech to the level of distraction during surgery.

Acknowledgments This work has been partially funded by the MISTI Global Seed Funds, Junta de Extremadura (Spain), and FEDER funds (GR18199).

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