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Acting in a Robotic Environment Requires New Skills for Physicians

Abstract: In context of the Corona pandemic, telemedicine acquired a new significance. Whereas previously the aim was to override given barriers, now, in the case of a pandemic, the main idea is to create an intentional distance between patients and healthcare professionals in order to avoid cross-infection. To meet the needs of a fully diagnostic examination, a robotic based system was designed. However, collaborative robotic systems bear new risks, that have to be dealt with. To prepare future physicians for telediagnostics, we developed a training curriculum for the telemedical examinations. It is based upon multiple stages including a skill trainer, healthy volunteers, supervised examinations of real patients and an exam. In a first proof of concept, we demonstrated the existence of a learning curve and significant better performance after the passed curriculum compared to an untrained collective.

Keywords: telemedicine, examination, robotics, training, telediagnostics

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1 Introduction

Telemedicine has a wide range of applications. For example, it can improve access to healthcare services in rural areas, organ transplants, or even healthcare on the battlefield. [1,2,3] Thereby, the distance between the examining physician and the patient can be imposed or can be intentional. The Corona pandemic has dictated the need to create an artificial barrier between potentially infected individuals. Classic protective measures often still carry the risk of infection and also interfere with workflow. Thus, patients and physicians should also avoid direct contact whenever possible. As part of the BMBF-funded *ProteCT* project, in collaboration with the Franka-Emika GmbH and the Munich School of Robotics and Machine Intelligence, we have constructed a cabin that allows patients to be examined at any distance using robotic arms (*Panda*, Franka-Emika GmbH, Germany) and telediagnostic equipment. A robotic based system is required to perform diagnostic tasks related to the patient's individual anatomy. The central component of the cabin is a robotic arm for auscultation, percussion, and palpation, controlled by a *Leader arm* operated by the remote physician. All movements of the *Leader* are mirrored by the *Follower* and *force feedback* enables a sensitive and safe examination. [4] In a preliminary study with 10 untrained physicians, we found that a safe and accurate control of the robotic arm requires prior instruction and training. In addition, we found that the supervising study physician, who was particularly involved in developing the concepts and device configuration, developed skills in controlling the robotic arms that were significantly better than those of all individuals who used the robotic examination arm for the first time. Thus, we derived a blueprint for a possible skill training from the experience with the untrained physicians and the successive improvement of the study physician's robotic skills. In this paper, we propose a training

Table 1: Problems with the new experience of a telemedical examination

Problem	Solution
Altered feeling of space and movement	Training with simulation of different situations
Altered perception of sound e.g., in auscultation and percussion	Mediation of the new sound experience by means of audio records (even pathological examples)
Feeling for forces, potential injuries, and the psychological aspect	'Change of perspective'
Medical and technical emergencies	Simulation of dangerous situation

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and education program to assure the safety and controllability of future telemedical systems.

2 Material and Methods

The examination in our cabin includes e.g., the measurement of blood pressure, temperature, oxygenation, an otoscopy, and inspection of the oral cavity. All of which are safe and reliable without any special prior training. However, in the above-mentioned preliminary experiment with 10 untrained physicians and 10 healthy volunteers, we identified the remote control of the robotic arm for the examination as a critical point concerning the whole process.

Therefore, we constructed an Arduino Uno *(Arduino S.r.l.)* based skill trainer with specific tasks for the clinical examination (Figure 1). It resembles movements when heading to characteristic landmarks, e.g., during the auscultation and provides exercises for applying adequate pressure during the palpation. Also, general precision skills are trained by hot-wire like tasks. The course is executed using the original revolver like robotic end-effector. This further raises difficulty, as the end-effectors which are not in use, should not come in contact with the obstacle course, respectively the patient. Moreover, we created a baseline collective of untrained individuals which can serve as a reference for progress during the training process.

The following two stages of the practical part include further training first on healthy volunteers and later real patients under the guidance of an experienced telemedical physician. The whole proposed curriculum is presented in the results section. The statistical software R version 3.6.3 was used for the analysis and the plots. [5]

3 Results

The preliminary study with 10 untrained physicians and 10 healthy volunteers revealed that there are many concerns about the safety and efficiency of the telediagnostic cabin. In addition to the desire for technical improvement, it was unanimously noted by the participating physicians that prior training and more detailed instruction were mandatory prerequisites for future use of the system. Before the study, the physicians had a short training of only 15 minutes. The subsequent interviews revealed that this was not satisfactory. The main problems with the new skills needed for telemedical examination and conversation are shown in Table 1, along with our approaches to manage them. According to the evaluation process during the project *ProteCT*, our design of a training curriculum includes 5 stages (**T**, **P1**, **P2**, **P3**, **E**). **T** stands for the theoretical part, which should provide a minimum knowledge about robotics, forces, structure of the cabin, and the robotic arms used. Stages **P1**-**P3** then include practical lessons that presume ascending levels of skills. **E** represents the exam that allows the telemedicine practitioner to examine real patients without supervision. (Figure 3)

3.1 Theoretical background (T)

Since few physicians have ever had contact with telemedicine or even robotics, we propose to introduce participants to basic concepts. Specific features of the respective system should be covered as well.

3.2 Practical training (P1-P3)

The practical training begins with basic movement training to get a feel for range of motion and forces and ends with the ability to examine real patients. Therefore, we designed our training as follows: **P1** training on a skill trainer, **P2** examination of healthy volunteers, **P3** examination of real patients with an experienced telemedical physician as supervisor. At least in **P2**, a 'change of perspective' should take place in the sense that the trainee assumes the role of the patient and undergoes a complete examination by an advanced telemedical physician in the specific setting. This allows the trainee to get an idea of the fears and the atmosphere during the examination from patient's view, as well as to improve the sense of forces.

Since training without human patients should be the first step in **P1**, we designed an already mentioned training parcours with very specific tasks (Figure 1). A phantom enhances the skills needed for auscultation, palpation, and percussion with a remotely controlled robotic arm. The training is performed once in horizontal and in vertical orientation to simulate both a lying and a standing patient. In detail, the model consists of 4 different sections: First, the trainee must place the tip of the robotic arm on an artificial chest with marked targets to evaluate and optimize accuracy during auscultation of the heart. The auscultation positions of the aortic, pulmonary, mitral, and tricuspid valves are marked with silicone targets. (Figure 1 **A**) Then a path flanked by wires must be passed to exercise optical and manual coordination during the movement. When the robotic end-effector comes in contact with the wire, the electric circuit is closed, and an error is noted. (Figure 1 **B**) In the next step, the artificial abdomen of the model has to be palpated. Materials of varying consistency simulating the abdominal wall are placed in tubes of a certain length. The tubes are oriented in different directions so that the trainee is forced to apply the system without damage. (Figure 1 **C**)

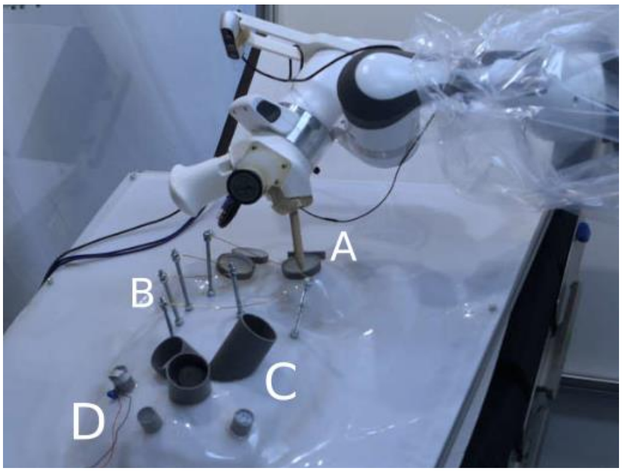

Figure 1: Parcours for training before examination of patients - **A)** Auscultation, **B)** Coordination of movement, **C)** Palpation from different directions, **D)** Applying pressure to the lower part of the abdomen

The final step is to apply pressure to force gauges installed on the lower part of the artificial abdomen on very small silicone targets. (Figure 1 **D**) The time required for the entire process is measured to evaluate and further optimize the efficiency of the examination.

To assess individual ability levels and progress, we used an evaluation tool consisting of the *time index* and the *error index*, which is calculated by the deviation from the mean values of both parameters in an untrained collective. The skill level of a trainee can then be calculated by dividing the number of errors *(ErrorsTrainee)* and the time required for one attempt *(TimeTrainee)* by the mean of all attempts of untrained individuals *(ErrorsUntrained, TimeUntrained)*.

$$ErrorIndex = \frac{ErrorsTrainee}{\frac{1}{n}\sum_{i=1}^{n} ErrorsUntrained_i} \quad (1)$$

$$TimeIndex = \frac{TimeTrainee}{\frac{1}{n}\sum_{i=1}^{n} TimeUntrained_i} \quad (2)$$

Results of each attempt are shown in a scatter plot with the *time index* on the x axis and the *error index* on the y axis (Figure 2). Achieving values in the lower left part of the graph indicates that the trainee is getting better than the untrained collective. As a proof-of-concept Figure 2 provides results of 6 untrained individuals (coloured) and a trained physician (black). Each individual had 3 tries to account for immediate learning effects. We further used the Student's T-test with a significance level of 0.05. The mean time taken by the untrained collective to complete the course in horizontal

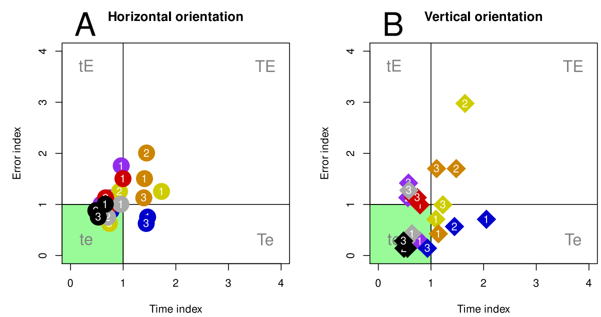

Figure 2: te) short time and few errors, **TE)** long time and many errors, **Te)** long time and few errors, **tE)** short time and many errors / each color stands for an individual / the white number within a symbol designates the number of the trial / the skill level is suggested to be higher the closer the combination of time and error index is situated to the left lower (**te**) corner. The black symbols mark the values of the trained physician.

orientation was 157.5 ± 59.1 s, and the mean number of errors was 8.3 ± 4. The trained clinician had a mean of 7 ± 1 errors after 3 trials (p=0.067) and took a mean time of 84.3 ± 4 s (p=0.0004). (Figure 2 **A**) In the vertical orientation, the mean time of the untrained collective was 154.8 ± 61.1 s, and the mean number of errors was 7.8 ± 4.1. The trained physician averaged 76 ± 6.1 s (p=0.0002) and 1.3 ± 0.6 errors (p=0.0001). (Figure 2 **B**) Thus, the trained physician performed significantly better than the untrained collective.

As next step, in section **P2**, healthy volunteers are examined. Errors to a certain extent are possible and forgivable. Since a sense of forces and space is already present at this stage, injuries are rather unlikely. Interviews and debriefings can improve and optimize the examination process. The last step **P3** should be the examination of real patients with an experienced and trained tele-physician as supervisor. Our experience from the final clinical trial to evaluate the functionality of our tele-robotic cabin was positive in terms of performance and safety. Regarding the proof-of-concept, the supervising physician examined 20 patients from our local emergency department, after passing the training process mentioned above. The examination was precise and safe. No critical incident or injury was encountered.

3.3 Exam (E)

The competence assessment at the end of the learning process should include a theoretical and a practical part. As a key component, an evaluated complete examination must be performed on a voluntary, healthy individual. After that, the physician is able to independently perform examinations with the telemedical system on real patients.

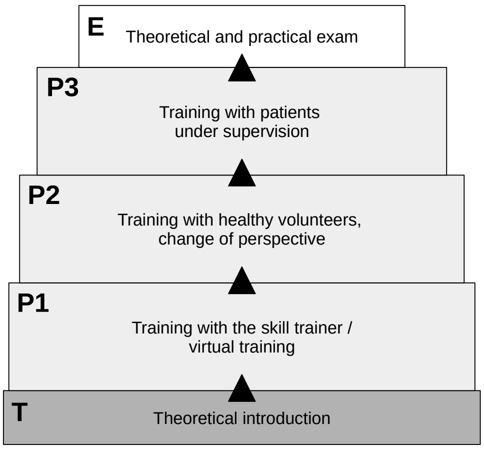

Figure 3: T: Theoretical part **P1**: first stage of the practical training by means of the skills trainer **P2**: second stage with healthy volunteers and change of perspective **P3**: Examination of real patients under supervision of an experienced telemedical physician **E**: Theoretical and practical exam

4 Discussion

We present a first concept of a possible future training program for physicians performing clinical examinations with a robotic arm in a dedicated examination cabin. A certain awareness is required to avoid injury and anxiety on the patient's side. While the proposed concept still needs to be validated and improved, it could be the basis for a future curriculum. As new technology always comes along with new risks, efficient training programs also have to be elaborated. Several aspects of a training curriculum could be derived from other related areas like robotic surgery for example. Similar skill level assessments regarding time needed to complete a task and the error rate are already in use for example in training curricula for the da Vinci system [6] or for laparoscopy [7]. Therefore, our examination trainer shares several aspects with classical laparoscopic box trainers with the striking difference of an extracorporeal and thus much more extensive space for movement and higher forces with distinct requirements for safety aspects. Since the cabin and the remote cockpit occupy a certain amount of space, simulations in the sense of virtual training are possible new developments. Another important aspect is the training and education of medical assistant personnel that must manage possible emergencies by the patient's side in absence of the examining physician. Thus, the telemedical examination opens the door to new chances but even to new challenges that have to be faced. As this paper does only describe a draft of a possible training program, time periods and the most effective number of iterations have to be figured out as next steps. Furthermore, as the telemedical cabin is designed based on modular principles, an extension to more sophisticated examination techniques is likely. Different medical disciplines may require different techniques as neurologists may prefer a comprehensive assessment of cranial nerves [8], internal specialists may insist on the possibility of an ultrasound device as robotic end-effector. [9] Each of these examination techniques requires specific training. The future aim should be, to offer a telemedical representation for each possible classical examination technique coming along with the appropriate training curriculum.

5 Conclusion

The potential applications of telemedicine are manifold. Further development will be accompanied by new functionalities and new risk profiles. It is imperative to evaluate and regulate this issue at an early stage in the context of patient safety. The concept of a telerobotic training curriculum is one possible approach.

Author Statement
Conflict of interest: Authors state no conflict of interest.

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