A Built-In Guidance System to Monitor Vital Signs in Space and on Earth

Roger Huerta†; Sylwia Izabela Kaduk†; Lukas Fatai; Hakon Rusch; Tobias Weber; Stefan Sammito

INTRODUCTION: Different types of remote expeditions often require an expedition crew to conduct medical emergency assessments without prior medical training. Modern technology offers new devices that support diagnosis with a simple guided user instructions interface. It is not yet clear how quickly medically untrained individuals can acquire the required skills with such a device. This study investigated the time and quality of obtained outcomes, as well as the mental workload when using a vital signs monitor and its guided procedure interface during a simulation of a medical emergency event.

METHODS: There were 50 individuals (25 medically inexperienced, 25 medically trained) who participated in this study. In a randomized order subjects measured electrocardiography, noninvasive blood pressure, pulse oximetry, and body temperature. The procedure was repeated after a 20-min break. Completion time, data validity, and mental workload were analyzed.

RESULTS: Average times to obtain stable and reliable signals of all recorded vital signs were significantly shorter for both groups during the second attempt and for medically experienced individuals in comparison to medically inexperienced individuals. The number of errors did not change between attempts for both groups. The mental workload was higher during the first attempt in both groups for most vital sign acquisitions.

DISCUSSION: Automated devices could be easily and quickly used by members of a given expedition, even if the crew lacks advanced medical training. With relatively little training provided by a built-in guidance system, medically untrained individuals can achieve a basic level of proficiency in reliably obtaining valid vital signs.

KEYWORDS: emergency medicine, automated diagnostics, military medicine, telemedicine, guided medical procedures, human space exploration, space medicine.

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A major challenge for human remote operations and exploration missions is the exploration crew does not have immediate access to medical treatment and/or essential medical equipment. These would be a critical resource for many different emergency scenarios which can occur during remote operations and exploration missions on Earth and also in space.[1]

In the field of medical space operations, the development of new technologies, particularly recent advances in telemedicine, has led to significant improvements in the way medical support is provided from the ground. More importantly, these technological advances have increased the medical autonomy of the crew, a feature that will be extremely important in future deep-space exploration missions beyond low Earth orbit.[2,3] For deep-space exploration missions, evacuation times to return the crew to Earth will be significantly longer than currently on the International Space Station (ISS), where the crew can be evacuated within 24 h in case of an emergency to receive full medical care on Earth. Additionally, the greater distances to Earth associated with the exploration of space lead to limitations in radio options and the established telemedical

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connection. Radio delays ranging from seconds to several minutes significantly limit telemedicine support from the ground. Such a situation makes in-built guidance a practical tool that could support astronauts even if ground-support advice is not immediately available. Longer evacuation times mean that the crew must be ideally equipped to recognize and treat medical emergencies anywhere and anytime, with little or no support from the ground. It is also crucial for the crew to safely and validly assess health status, e.g., for regular checks or before performing an extra vehicular activity, without receiving major instructions from the ground station. Basic medical diagnostic and treatment tools are, therefore, essential elements for any future medical system for deep-space exploration. At a minimum, this medical system should be able to obtain reliable and stable vital signs in real time and provide basic treatment capabilities such as an automated external defibrillator (AED). Equipped with artificial intelligence, such a system can also help the crew make decisions independently of the ground station. Moreover, the system should be able to transmit medical data streams to the ground, where the data can then be analyzed and interpreted by trained flight surgeons to provide remote (emergency) care instructions to the crew. Such a system can also be of great value in the sense of terrestrial spin-off beyond the pure space application for usage in reconnaissance expeditions in remote regions of the Earth, as well as in natural disasters or in military scenarios. In addition, such a system can also provide a decision-making aid in the field of home care for possible further inpatient therapy needs.

The NASA Artemis program will consist of several phases, including crewed missions orbiting the Moon as well as crewed missions with lunar surface activities. The orbit of the so-called Lunar Gateway is very elliptical and one orbit around the Moon takes about 10 d. This implies that evacuation times will significantly exceed current ISS evacuation times and the crew must be prepared to perform certain medical (emergency) scenarios autonomously, without ground support. In addition, the Artemis program and the Lunar Gateway missions are also intended to serve as stepping stones to future missions to Mars, to gain more experience in long-term deep-space missions, to test and evaluate new technologies beyond low Earth orbit, and to learn more about human psychophysiology in very extreme, remote environments.[2]

Considering the above, the European Space Agency (ESA) Space Medicine Team is currently investigating whether the compact advanced health monitor "Tempus Pro" from Philips[4] could be a candidate device for future Lunar Gateway operations to enhance crew autonomy and improve astronaut medical care. The Space Medicine Team therefore initiated a series of ground-based and ISS technology demonstrations and studies to simulate specific emergency scenarios to test the functionality, usability, and operability of the "Tempus Pro" in relevant environments (the Tempus Pro project). One of the studies of the Tempus Pro project was carried out in collaboration between the German Air Force Centre of Aerospace Medicine and ESA's Space Medicine Team to test the built-in guided user training capability with medically inexperienced and medically trained professionals. Using the integrated guidance system, the present study aimed to investigate whether soldiers of the German Armed Forces (Bundeswehr) with only first aid course training could obtain and record stable vital signs from a real person within a time that did not exceed critical emergency medical thresholds. The second group of medically trained Bundeswehr professionals (e.g., paramedics, nurses, physicians) was included in the experiment to provide a valid reference for medical skills and skill retention times.

It was hypothesized that 1) individuals whose medical training was restricted to a first aid course and who did not have experience in medical work would be able to obtain stable and valid vital signs using the built-in guidance system within a time that is critical for (emergency) medical applications; 2) medically trained professionals would obtain stable and valid vital signs significantly faster than the first group; 3) both groups would improve times during a second measurement; 4) medically trained professionals would experience less mental workload than individuals with only first aid course training; and 5) both groups would experience less mental workload during a second measurement.

METHODS

Subjects

Recruited for the study, which was ethically approved by the North Rhine Medical Association (Duesseldorf, Germany) on 10 May 2021 and registered under number 2,021,053, were 50 subjects. The subjects were volunteer soldiers from the German Armed Forces. Subjects were divided into two experimental groups according to their level of medical expertise. Group E consisted of medically experienced soldiers (N = 25, women = 9) who had completed at least paramedic training and worked in the emergency department of the German Armed Forces Military Central Hospital in Koblenz. This group included paramedics, nurses, and physicians. The median age of this group was 31.0 yr (min: 23.3 yr, max: 52.4 yr). Group U (individuals with no professional medical training; N = 25, women = 4) consisted of soldiers who had received only a first aid course and/or the military equivalent of this, and who reported they had no personal experience with the Tempus Pro device and that they had never performed an electrocardiography (ECG) examination, a pulse oximeter measurement, or a blood pressure measurement. They were recruited from the German Air Force Support Unit in Cologne, Germany. The median age of this group was 30.4 yr (min: 18.5 yr, max: 55.1 yr).

This study used nonrandomized group allocation and an environment simulating a medical emergency during a remote mission or expedition. A visualization of the study protocol and the sequence of events is shown in **Fig. 1**. In each case, the test patient was a Caucasian man.

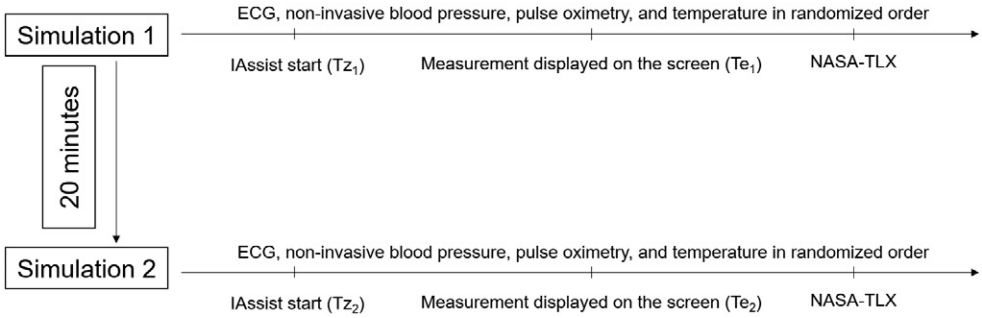

Fig. 1. Experimental procedure of the study. The order of all physiological measurements was randomized for every subject.

Materials

The telemedicine device used in this study was the Tempus Pro, from Phillips RDT (Farnborough, UK), which is a commercially available vital signs monitor with telemedicine capabilities and a built-in step-by-step instruction system called iAssist.

The Tempus Pro was developed with the support of ESA's Space Solutions Program and is used by emergency medical services and the military around the world,[4] as well as at remote locations like Antarctica base.[5] It is a monitoring tool used by ESA's flight surgeons for all launches and landings involving ESA crew and is currently being considered for use on future deep-space exploration missions, as it potentially meets several medical needs and requirements for missions beyond low Earth orbit.

Depending on the specific needs and requirements, Tempus Pro can be connected to various "peripherals" (other medical devices that can communicate with the main Tempus Pro unit as a central hub). Compatible peripherals, which can all be connected at the same time, include a 3- or 12-lead ECG, a pulse oximeter, a capnometer, a noninvasive blood pressure cuff, and two electrical thermometers. It also includes a built-in video camera and the ability to connect to a flexible exploration camera (which can be used as a laryngoscope or as an otoscope). It can also be connected to an ultrasound device. Moreover, it has telemedicine capabilities, allowing real-time data transfer from any remote location on Earth to any other designated location on the planet (e.g., a control center with a physician). Finally, the Tempus Pro has a built-in step-by-step guidance mode called "iAssist." Guided step-by-step instructions appear as images with underlined text, allowing the user to navigate through medical diagnostic procedures in the order of the displayed steps.[2]

Procedure

Before the study began, all subjects received a subject information sheet and signed an informed consent form. All subjects were asked to complete a questionnaire to assess their level of medical training and their experience in measuring ECG, blood pressure, and oxygen saturation. This was done as an additional check to ensure that the inclusion criteria were appropriate for both groups from the different departments and that none of the subjects in the U Group had previously performed such a measurement. After completing the paperwork, the subjects were directed to the simulation room where they again received a short briefing on the overall procedure. It was explained that the duration of each task would be measured from start to finish and that their main aim was to obtain and record stable and valid signals of all outcomes in the shortest possible time. During this briefing, it was also emphasized that both the duration and validity of the measurements would be analyzed as the main outcomes of the experiment. Finally, it was explained that the Tempus Pro monitoring device would be available and switched on at the start of the experiment, with a pre-established telemedicine connection to the study operator's computer.

During the experiment, subjects were asked to take vital signs from a Caucasian male test patient who was simulating a medical emergency while lying on an insulated mat on the floor. The Tempus Pro was placed next to the "patient" with two vital signs sensors already connected to the device: the noninvasive blood pressure cuff and the pulse oximeter. The standard device setup is shown in **Fig. 2**. All ECG leads and the temperature cable had to be plugged in by the subjects and were placed

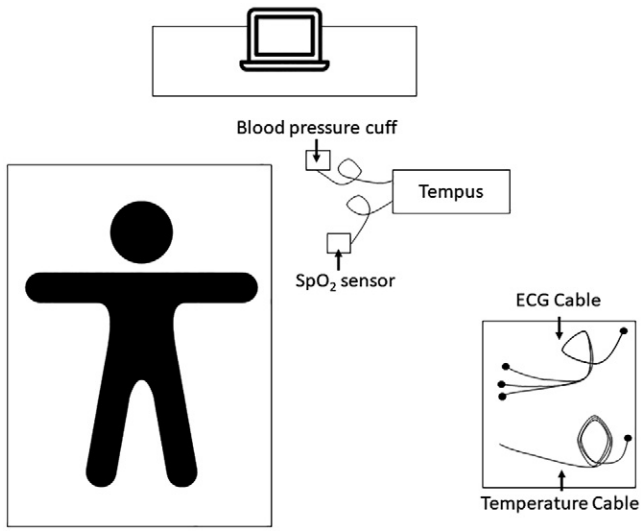

Fig. 2. Experimental set-up. The "patient" lies on an insulated mat next to the Tempus Pro device with two sensors already plugged-in and two requiring a connection. The laptop with a remote connection established with the Tempus Pro device was placed on a table where the two operators sat. The laptop screen of the operator table was out of view of the subjects.

next to the device. Subjects were then instructed, in a randomized order, to obtain and record the vital signs of interest as quickly as possible. At the start of each session for each vital sign, subjects were asked to press the iAssist's button associated with the required vital sign, which initiated the time measurement (Tz1/2). The second time point Te1/2 was recorded when a stable and valid vital sign of the patient was correctly displayed on the Tempus Pro monitor, thus ending the session for each vital sign. This means, for example, that there should be a clear ECG trace or that the blood pressure displayed on the screen should be within the normal range for the patient being tested. The validity and stability of the vital signs were assessed by the two operators, who checked the signal quality on their external laptops. At the end of each vital sign data collection session, subjects were given the NASA task load index (NASA-TLX) sheet to assess their mental workload for each task.[6]

During the first simulation of the experiment, this process was repeated for each vital sign. Four different iAssist vital sign instructions were assessed in this study: the ECG, the pulse oximeter, the noninvasive blood pressure, and the temperature measurement. After a 20-min break, the procedure was repeated in the second simulation of the experiment. The order of the four vital signs was randomized between subjects but remained the same for each subject in simulation 1 and simulation 2 of the experiment.

The primary outcome of this experiment was the time in seconds to successful (stable and valid) establishment of each vital sign data stream (Te1/2). It was defined that if a subject did not achieve a successful measurement within 5 min, a cutoff would be applied to avoid unnecessary prolonged manipulation of the test patient. All procedures of all subjects were simultaneously recorded by the operators and on a laptop using the Tempus Pro remote video screen-sharing tool. Additionally, all errors made by the subjects that delayed the measurement result or resulted in invalid measurements were documented by the operators. The number of errors identified by the operators was documented and assigned to its corresponding group (U or E) and simulation number (first or second).

The secondary outcome of the experiment was the NASA-TLX score, which measures the mental workload associated with each measurement session. The NASA-TLX is a questionnaire which measures six components of mental workload and an overall mental workload score. The six subscales are mental demand, physical demand, temporal demand, effort, performance, and frustration. Subjects were asked to rate the level of various task-related demands on a visual analog scale.[5,6] In this study, the NASA-TLX score was calculated as the average of all the six subscales without weights.

All data were then pseudo-anonymized and all recorded data files and corresponding times to the end of each session were presented to the emergency medicine experts for their evaluation. To assess the test results by emergency medicine specialists, a total of nine physicians specialized in the field of emergency medicine (six from the military, three from ESA) were asked to classify which of the vital signs recordings were medically acceptable in terms of data validity and time to completion of each session (response options: "acceptable" vs. "unacceptable"). With this classification, it was then possible to decide which of the studied groups required too much time to obtain the vital parameter and would, therefore, be unacceptable in an emergency scenario. This method of analyzing the data recorded in this study was chosen because there is no standardized guideline to indicate the required duration of the measurements in a medical emergency (e.g., a blood pressure measurement). This approach was chosen to obtain a statement for medical emergency situations which, although rare, can often be life-threatening and time-critical. This assessment cannot be used for normal routine examinations or merely time-uncritical illnesses.

Statistical Analysis

Physiological signals were automatically preprocessed within the Tempus Pro device. Statistical analysis was performed using IBM SPSS 24.0 (IBM, Armonk, NY, USA). A nonparametric Wilcoxon test (due to the nonnormal distribution) or the Chi-squared test was used to test significance. Due to the small number of female subjects, no separate analysis was carried out for male and female subjects.

RESULTS

For both groups, the duration of simulation 1 was significantly longer than the duration of simulation 2 (all $P < 0.05$). All measurements were significantly longer for the inexperienced group (U) during both simulation 1 and simulation 2. Details are shown in **Table I**.

A comparison of the NASA-TLX tool for the inexperienced group (U) between simulation 1 and simulation 2 revealed a significantly lower mental workload during simulation 2 for all measurements (see **Table II**). The experienced group (E) reported a lower mental workload during simulation 2 for measurements of ECG ($z = -2.374$, $P = 0.018$), noninvasive blood pressure ($z = -2.376$, $P = 0.017$), and temperature ($z = -2.823$, $P = 0.005$), but not for pulse oximetry measurement ($z = -1.527$, $P = 0.127$), which had the same mean mental workload for simulation 1 and simulation 2 (Table II). During simulation 1 (Table II), the inexperienced group (U) reported a significantly higher mental workload for the measurement of ECG ($z = -2.301$, $P = 0.021$) and noninvasive blood pressure ($z = -4.470$, $P < 0.001$), but not for pulse oximetry ($z = -1.565$, $P = 0.118$) or temperature ($z = -1.448$, $P < 0.148$). There were no significant differences between the groups for simulation 2 (Table II).

There was no significant difference in the number of erroneous measurements between simulation 1 and simulation 2 for both the inexperienced (U) and the experienced groups (E) (see **Table III**). Only the comparison of the inexperienced group with the experienced group shows significantly fewer measurement errors in the experienced group for pulse oximeter and temperature measurements. The most common error was

Table I. Comparison of Durations Between Simulation 1 and Simulation 2 for the Inexperienced Group (U) and Experienced (E) Group.

PHYSIOLOGICAL MEASUREMENT	GROUP	MEASUREMENT DURATION SIMULATION 1 (s)	MEASUREMENT DURATION SIMULATION 2 (s)	z	*P*
Electrocardiogram	U	141 (46)	95 (43)	−4.732	<0.001
	E	79 (35)	69 (40)	−4.063	0.006
z		−5.066	−3.89		
p		<0.001	0.001		
Noninvasive blood pressure	U	153 (52)	93 (20)	−4.346	<0.001
	E	80 (20)	71 (13)	−4.265	<0.001
z		−5.696	−4.930		
p		<0.001	<0.001		
Pulse oximeter	U	45 (19)	25 (10)	−4.244	<0.001
	E	22 (6)	20 (5)	−4.321	0.026
z		−5.293	−3.804		
p		<0.001	<0.001		
Temperature	U	57 (33)	34 (16)	−4.373	<0.001
	E	39 (22)	23 (8)	−4.374	<0.001
z		−4.552	−4.137		
p		<0.001	<0.001		

Presented *P*- and z-values correspond to the Wilcoxon test. The durations are expressed as median values in seconds with the interquartile range in the brackets.

placing the oximeter sensor on the finger of the same hand as the noninvasive blood pressure sensor, which occurred in almost half of the measurements performed by the experienced group (E). The second most common error was placing the temperature sensor in the wrong place, followed by errors related to the ECG electrodes (wrong positions). The exact list of all errors with the error frequency of experienced and inexperienced users in simulation 1 and simulation 2 can be seen in **Table IV**.

The evaluation of the measurement durations, assessing whether the measurement times reached a critical level for a nonsimulated medical emergency, is shown in **Fig. 3**. For the inexperienced group (U), the majority of measurements were judged to be notably too long during simulation 1, but not during simulation 2. The exception was noninvasive blood pressure, which was judged to be too long in 89% of cases during simulation 1 and in 67% of cases during simulation 2 for group U. For the experienced group (E), the majority of measurements during simulation 1 and simulation 2 were deemed to be sufficiently fast for a nonsimulated medical emergency.

DISCUSSION

This study investigated the practicality and usefulness of the Tempus Pro vital signs monitor for recording key vital signs in a simulated medical emergency. Both medically experienced and inexperienced study subjects were able to obtain vital sign recordings within a clinically relevant time during the second emergency simulation. This finding partially confirms the main hypothesis of this experiment, that medically untrained individuals would be able to obtain stable and valid vital signs using the built-in guidance system within a critical time frame for (emergency) medical applications. The experiment also showed that medically experienced individuals were always

Table II. Comparison of the Mental Workload Between Experienced (E) and Inexperienced (U) Groups and Simulation 1 and Simulation 2.

PHYSIOLOGICAL MEASUREMENT	GROUP	NASA-TLX SIMULATION 1	NASA-TLX SIMULATION 2	z	*P*
Electrocardiogram	U	2.7 (2.5)	1.8 (1.3)	−3.771	<0.001
	E	1.8 (1.6)	1.3 (0.8)	−2.374	0.018
z		−2.301	−1.230		
p		0.021	0.219		
Noninvasive blood pressure	U	3.3 (3.0)	1.3 (1.6)	−4.107	<0.001
	E	1.2 (1.0)	1.0 (0.8)	−2.376	0.017
z		−4.470	−1.685		
p		<0.001	0.092		
Pulse oximeter	U	1.3 (1.0)	1.0 (0.7)	−2.362	0.018
	E	1.0 (0.8)	1.0 (0.2)	−1.527	0.127
z		−1.565	−0.968		
p		0.118	0.333		
Temperature	U	1.5 (2.2)	1.0 (1.0)	−3.683	<0.001
	E	1.3 (0.9)	1.0 (0.3)	−2.823	0.005
z		−1.448	−0.954		
p		0.148	0.340		

Presented *P*- and z-values correspond to the Wilcoxon test. The durations are expressed as median values in seconds with the interquartile range in the brackets.

Table III. Number of Erroneous Measurements with the Percentage in Parentheses for Experienced (E) and Inexperienced (U) Group, Simulation 1, and Simulation 2.

PHYSIOLOGICAL MEASUREMENT	GROUP	NUMBER OF ERRONEOUS MEASUREMENTS SIMULATION 1	NUMBER OF ERRONEOUS MEASUREMENTS SIMULATION 2	χ^2	*P*
Electrocardiogram	U	5 (20%)	3 (12%)	0.595	0.440
	E	2 (8%)	3 (12%)	0.222	0.637
χ^2		1.492			
P		0.221			
Noninvasive blood pressure	U	6 (24%)	6 (24%)	0.000	1.000
	E	3 (12%)	0 (0%)		0.074
χ^2		1.220	6.818		
P		0.269	0.009		
Pulse oximeter	U	11 (44%)	10 (40%)	0.082	0.774
	E	15 (60%)	14 (56%)	0.081	0.774
χ^2		1.282	1.282		
P		0.258	0.258		
Temperature	U	5 (20%)	6 (24%)	0.117	0.733
	E	4 (16%)	1 (4%)	0.747	0.388
χ^2		0.136	3.934		
P		0.713	0.047		

P-values and χ^2 values correspond to the Chi-squared test.

faster than medically inexperienced individuals. However, the inexperienced individuals supported by the Tempus Pro's built-in assistance system called iAssist were able to obtain stable and valid key vital signs within a critical emergency medical time frame after only one simulation. The mental workload of all subjects was significantly reduced during the second medical emergency simulation. This indicates that all subjects significantly improved their skills and knowledge after only one emergency medical simulation. However, the number of incorrect measurements did not change significantly between the two simulations. This suggests that more extensive feedback and/or more training sessions would be needed to reduce measurement errors. The most error-prone outcome was pulse oximetry, with over 40% of erroneous measurements in the inexperienced group and 60% of erroneous measurements in the experienced group. The most common error occurring in both groups was placing the pulse oximetry sensor on the wrong side (i.e., the same side as the blood pressure

Table IV. Detailed List of Errors in the Experienced Group, Inexperienced Group, Simulation 1, and Simulation 2.

PHYSIOLOGICAL MEASUREMENT & ERROR TYPE	GROUP	NUMBER OF ERRONEOUS MEASUREMENTS SIMULATION 1	NUMBER OF ERRONEOUS MEASUREMENTS SIMULATION 2
Electrocardiogram			
Wrong electrodes position)	U	4	2
	E	2	1
Wrong cable connection	U	1	1
	E	0	2
Other (plug found late)	U	1	0
	E	0	0
Noninvasive blood pressure			
Cuff upside down	U	1	2
	E	0	0
Cuff in the wrong place	U	4	2
	E	2	0
Other (cuff very loose, initially on the wrong arm, cable in the cuff)	U	3	5
	E	2	0
Pulse oximeter			
Finger clip error	U	1	2
	E	1	1
Finger clip on the wrong hand	U	11	10
	E	14	14
Other (initial wrong menu chosen)	U	1	0
	E	0	0
Temperature			
Sensor in the wrong place	U	5	6
	E	4	1
Other (arm not pressed, wrongly plugged cable)	U	2	1
	E	1	1

U: inexperienced group; E: experienced group

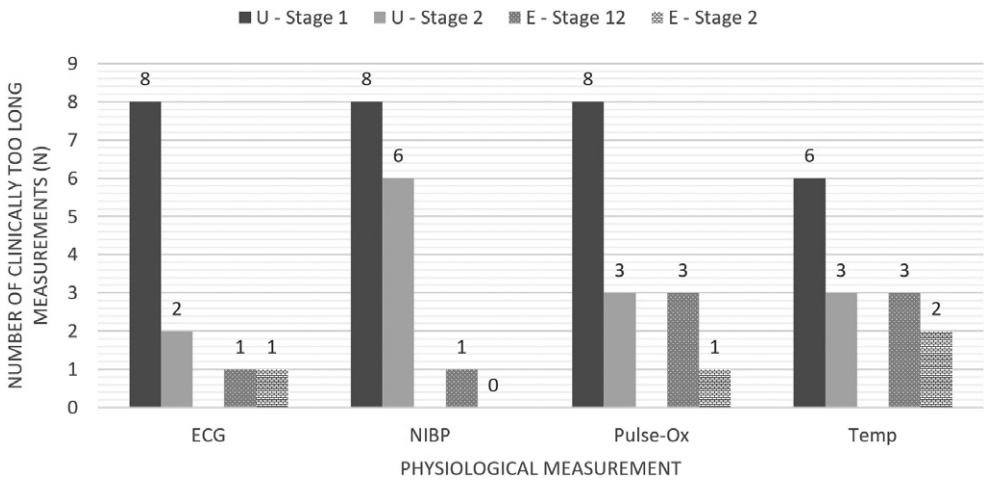

Fig. 3. Absolute number of measurements evaluated as too long for a true medical emergency for each outcome measured.

measurement). This type of error may be mainly related to subjects' lack of attention during the procedure or when reading the instructions, rather than a lack of skill or knowledge. It is possible that this error could be significantly reduced by providing additional highlighted information on the correct side of the measurement on the screen of the device. The finding that the medically experienced group had a higher number of this error, which affected more than half of the measurements, would support this hypothesis. However, the reason why this specific error was more evident in the experienced group would require further investigation, both to confirm the reasons and to propose valid countermeasures to prevent it in real emergency scenarios. In summary, the present results indicate that the speed of obtaining valid and stable vital signs improved in just one previous emergency simulation, but there was no measurable training effect on the number of errors associated with incorrect sensor placements.

The results of the present study showed that inexperienced individuals required more time to obtain stable and valid vital signs despite being guided by the built-in support system of the Tempus Pro device. However, the measurement times of both groups improved significantly after only one simulation, such that both medically experienced and medically inexperienced users of the Tempus Pro were able to obtain stable and valid vital signs within a time that was deemed clinically acceptable by emergency medicine experts after only one emergency medical simulation. These results are consistent with findings that inexperienced persons can safely master ultrasound,[7,8] tube-thorcostomy,[9] and hemostasis measures[10,11] with appropriate instructions via a telemedicine connection.

The results presented here are relevant for (emergency) medical applications during various remote missions and expeditions (in space and on Earth), but also for regular medical check-ups or for medical evaluation before starting extra vehicular activity. The present results showed that it is possible to train medically inexperienced individuals, with relatively little effort, to a level of proficiency that allows them to collect stable and valid vital signs using an automated telemedicine device, such as Tempus Pro, in a professionally acceptable and timely manner. It is not a surprising observation that the medically inexperienced group showed a longer measurement time and a higher mental workload during the medical emergency simulations compared to the medically experienced individuals. However, it is a remarkable observation that medically inexperienced individuals were able to achieve a clinically relevant measurement time after performing the task only once, and that their mental workload was also significantly reduced after one training session/medical emergency simulation.

The results of this study are somewhat consistent with similar studies involving people being tested to use an AED. These studies suggest that people's ability to perform cardiopulmonary resuscitation with an AED is significantly improved after 50 min of training.[12,13] Of course, there are many important differences between operating an AED and the Tempus Pro, including both their unique automatic assistance systems, but both devices are medical products that provide detailed instructions specifically tailored for medically inexperienced individuals.

These results suggest that an automated assistance system can make medical devices accessible to anyone with little training to meet basic medical needs in medical emergencies, which could be lifesaving. It should also be noted that the medically experienced group achieved a clinically relevant time of measurement on first use, suggesting that the device is intuitive and accessible to medically experienced individuals. Medically experienced people should hence be able to obtain valid and stable vital signs within a critical time frame for medical emergencies without receiving any prior training. Of course, it should be common sense that all Tempus Pro users, regardless of their level of medical experience, should receive user-level training before using the device in real emergency situations to ensure the best possible medical diagnosis and subsequent treatment.

One of the limitations of this study was the rather small sample size, which is due to the pilot nature of this study. Another important point to note is that the measurement

times were assessed by emergency medical experts, which may have introduced a degree of data attrition bias. However, this approach was necessary because there are simply no guidelines in emergency medicine regarding critical times to obtain key vital signs in a medical emergency. The authors of this study would therefore strongly recommend that the medical emergency medical community agrees on international standards which could then be used as a reference for training and (re)certification of medical personnel and expedition crews. An additional limitation, but also a strength of this study, was that the test patient was always the same man. On the one hand, this ensured that the test patient had no influence on the measurement results. On the other hand, it is known that ECGs often take longer to perform in female patients. As only 25 people in total could take part in this study for each group, we decided not to include a female patient in our study, as this would have meant that the number of subjects would have had to be significantly larger. To achieve the desired study objectives in the present study, it was deliberately ensured the test patient had as little influence as possible on the comparative measurement results.

An additional limitation is that we were not able to analyze the effect of the sex of the subject on the outcome of our study due to the small numbers of female subjects. This should be done in future studies.

In conclusion, this research has important implications for medical emergencies during (remote) expeditions and missions in space and on Earth. Automated devices with a support system for diagnostics and telemedicine, such as Tempus Pro, could be easily and quickly used by members of a given expedition, even if the crew lacks advanced medical training. The results of the present study suggest that relatively minimal training, provided by a built-in guidance system, is required to ensure that medically untrained individuals can achieve a basic level of proficiency in reliably obtaining valid vital signs, a medical skill that could be lifesaving in a genuine medical emergency.

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REFERENCES

1. Shaw MTM, Dallimore J. The medical preparation of expeditions: the role of the medical officer. Travel Med Infect Dis. 2005; 3(4):213–223.
2. Manzey D, Reichenbach J, Onnasch L. Human performance consequences of automated decision aids: the impact of degree of automation and system experience. J Cogn Eng Decis Mak. 2012; 6(1):57–87.
3. Davis EA, Mosesso VN Jr. Performance of police first responders in utilizing automated external defibrillation on victims of sudden cardiac arrest. Prehosp Emerg Care. 1998; 2(2):101–107.
4. Pritchard ND. Tempus Pro patient monitoring system. Wright-Patterson AFB (OH): U.S. Air Force School of Aerospace Medicine; 2015. Technical Report AFRL-SA-WP-TR-2015-0006.
5. Gil-López P, García-Córdoba J, Sánchez-Aristi L, Herrera-Iglesias T, García-Tejerina R, et al. Present and future of Spanish military telemedicine. 25 years of the military telemedicine unit at the Central Defense Hospital "Gómez Ulla.". Sanidad Militar. 2020; 76(3):197–204.
6. Hart SG, Staveland LE. Development of NASA-TLX (task load index): results of empirical and theoretical research. In: Hancock PA, Meshkati N, editors. Human mental workload. Amsterdam (Netherlands): Elsevier Science Publishers B.V. (North-Holland); 1988:139–183.
7. Sargsyan AE, Hamilton DR, Jones JA, Melton S, Whitson PA, et al. FAST at MACH 20: clinical ultrasound aboard the International Space Station. J Trauma. 2005; 58(1):35–39.
8. McBeth P, Crawford I, Tiruta C, Xiao Z, Zhu GQ, et al. Help is in your pocket: the potential accuracy of smartphone- and laptop-based remotely guided resuscitative telesonography. Telemed J E Health. 2013; 19(12): 924–930.
9. Kirkpatrick AW, Tomlinson C, Donley N, McKee JL, Ball CG, Wachs JP. To watch before or listen while doing? A randomized pilot of video-modelling versus telementored tube thoracostomy. Prehosp Disaster Med. 2022; 37(1):71–77.
10. Kirkpatrick AW, McKee JL, McBeth PB, Ball CG, LaPorta A, et al. The Damage Control Surgery in Austere Environments Research Group (DCSAERG): a dynamic program to facilitate real-time telementoring/telediagnosis to address exsanguination in extreme and austere environments. J Trauma Acute Care Surg. 2017; 83(1, Suppl. 1):S156–S163.
11. Kirkpatrick AW, McKee JL, Netzer I, McKee IA, McBeth P, et al. A randomized trial of mentored vs. nonmentored military medics compared in the application of a wound clamp without prior training: when to shut up and just watch! Mil Med. 2020; 185(Suppl. 1):67–72.
12. Tsai MF, Wang LH, Lin MS, Chen MY. What do adolescents learn from a 50 minute cardiopulmonary resuscitation/automated external defibrillator education in a rural area: a pre-post design. Int J Environ Res Public Health. 2019; 16(6):1053.
13. Kelley J, Richman PB, Ewy GA, Clark L, Bulloch B, Bobrow BJ. Eighth grade students become proficient at CPR and use of an AED following a condensed training programme. Resuscitation. 2006; 71(2):229–236.