PILOT SAFETY – SUPPORT BY BIOMEDICAL MONITORING IN PILOTS WITH HEALTH RISKS

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Abstract

In 1976, John K. Moody flew a motorized light sports aircraft (LL) for the first time at an Experimental Aircraft Convention (EAC). It was a motorized hang glider. [12,17] Ultralight aviation is the flying of lightweight, 1- or 2-seat fixed-wing aircraft. The use of single-seat micro-light aircraft, in German “leichte Luftsportgeraete (LL)”-class with an empty mass of up to 120kg "single-pilot cockpits" and up to 600kg “double seat cockpits” as defined in [1] and [2], is increasing in Europe since its introduction by various EU member states. Looking at the certification of LL pilots and pilots from private, passenger and cargo aviation, clear differences become apparent. Current European rules mandate age limits of 60 yrs. for commercial single-pilot operations and of 65 yrs. for multi-pilot operations. [2] When not flying for commercial purpose, pilots of micro-light aircraft are not obliged to undergo an annual or semiannual (over 60 yrs.) medical examination by an aeromedical examiner (Medical) in order to assess their fitness to perform all flying tasks and risk of in-flight incapacitation due to a medical event [1]. This means that private flying is permitted for pilots over 65 years of age, if the regular Medical is performed successfully, but micro-light pilots are allowed to fly their aircraft well into old age without it. To fly without regular Medicals increases the risk of flight incapacitation and fatal flight accidents for these pilots.

The topics of the MOREALIS research include the analysis and assessment of the pilot's medical condition and cognitive abilities, the integrity of the aircraft, as well as the decision-making based on this and - ultimately - the automatic emergency landing with an aircraft specifically designed to protect the pilot. All data is used as input into an aircraft intervention management System (AIMS). To detect pilot’s flight capacity, the MOREALIS partners DLR, Institute of Aerospace Medicine (DLR-ME), STAR Healthcare Management (SHC) and the Professorship for Aeronautical Engineering at the University of the Bundeswehr Munich (UBM-FMFF) collaborate. DLR-ME determines the relevant diagnoses to be monitored and identifies suitable medical sensors. SHC collates the sensor-data in real time in a medical condition app, that uses an adapted version of the National Early Warning Score (NEWS) to determine medical fitness in-flight. UBM-FMFF registers the pilot's cognitive abilities and determines his attention using innovative and proven methods. [10] The medical as well as the cognitive status are utilized in the aircraft intervention management System.

This document describes the development of a medical-biometric monitoring system for pilots of single-seat micro-light aircraft. The system shall be able to continuously monitor medical parameters relevant to flight ability. Based on algorithms, a real-time data analysis should categorize the pilot's condition into defined staggered limit values, which are presented to the pilot as well as forwarded to the aircraft intervention management system of the planned microlight aircraft. It should be possible to customize the system with regard to the individual limits of the medical parameters

Keywords: pilot, medical incapacitation, monitoring, NEWS

Materials and Methods

While there are many studies, some of them extensive, on the incapacity of pilots in commercial aviation, the information situation for LL is rather poor. As devices for recreational flying, the authorities focus less on these than on commercial aviation.

Research into the causes of serious accidents in aviation is often limited to accidents in commercial aviation, with fatal incidents involving passenger and cargo transport taking center stage. Accidents in private aviation are also considered by the authorities for the investigation of aviation accidents due to legal requirements. The situation is different for LL: Few comprehensive reports or statistics are available here.

In order to identify the requirements for a combined medical, physiological and cognitive pilot monitoring system, as planned in MOREALIS, only a literature search remains suitable.

This was performed on the internet, at Pubmed and Google Scholar.

The appropriate literature should provide references to LL flight accidents that were related to the condition of the pilot in flight, his previous illnesses and his age.

The literature review was supplemented by chapters from the book Ernsting's Aviation Medicine.

Medical (or in-flight) incapacitation means the complete loss of any ability to perform tasks in-flight. Impairment means that a crew member cannot perform all tasks due to reduced performance. The medical incapacitation of pilots in-flight is rare. It can have various causes. The more common causes include loss of consciousness, gastrointestinal complaints, neurological and cardiac events. [3,5,6,7]

In 2007, the Australian Transport Safety Bureau (ATSB) described, which medical conditions led to pilot incapacitation in its report: Pilot Incapacitation: Analysis of Medical Conditions Affecting Pilots Involved in Accidents and Incidents. The investigation period covered 01 January 1975 to 31 March 2006. The 98 incidents found were caused by medical or physiological reasons. 16 aircraft accidents and 82 incidents, one of which was serious, were identified. Pilot incapacitation accounted for 0.6 per cent of all incidents registered with the ATSB) during the reporting period. The 29.6 per cent of the 98 incidents occurred on scheduled flights and 22 per cent on private single cockpit flights. As other sources also consistently report, the group of gastrointestinal illnesses accounts for the largest proportion of flight incapacities at 21.43 per cent. Smoke and fume events ranked second at 12.24 per cent, followed by loss of consciousness at 9.18 per cent and heart attacks at 8.16 per cent [7].

In [6], male U.S. pilots on passenger flights on 47 passenger aircraft from 1993-1998 were studied. 39 incapacitations and 11 impairments were recorded. The rate of medical events was 0.058 per 100,000 flight hours. The probability that such an event led to an air accident was 0.04. Neurological and cardiac complaints are the more serious emergencies that lead to flight diversions, or require medical assistance from the ground. [5]

In [12] Pagan et al. analyzed the contextual accident information of 66 cases of ultralight accidents and separate active and latent failures, which were cause of the accident. Active failures are the immediate causes of accidents, such as engine failure or collision with another aircraft. Latent failures, on the other hand, are discrepancies which contribute to active failures, such as improper fuel/oil mixture or no radio on board. Every accident was analyzed. 33 or 50% of the accidents occurred during the cruising phase, 33% during take-off and landing. 26 or 39.4 % of the accidents involved losing control during flight, 17 or 25.8% were caused by in-flight engine failure and 7 or 10.6% resulted from the aircraft crashing into another aircraft. Many pilots lacked of experience or were unfamiliar with the proper maintenance or configuration of their aircraft. Unfortunately, the study does not give any information on whether pilot medical incapacitation made part of the causes of accidents during the individual flight phases.

The study of the German Federal Bureau of Aircraft Accident Investigation (BFU) on flight safety of microlight aircrafts, parachutes and hang gliders analyzed accidents and incidents in the years 2000 to 2019. The number of aviation accidents investigated was 148. Of the involved aircrafts 130 were microlight aircraft. There were 225 occupants on board the 148 LL. In 71 LL (48%) the pilot was the sole occupant, while in 77 (52%) there were 2 people on board. In the period in question the BFU investigated 72 accidents involving aerodynamically controlled microlights with 2 occupants on board. Of the 148 LLs analyzed, 101 LL (68.2 %) were involved in a fatal accident, 24 (16.2 %) in an accident with serious injuries, 5 (3.4 %) in incidents with minor injuries and 18 (12.2 %) with no injuries. In two of the 148 LL involved in a fatal accident (collision in flight), the pilots survived either seriously injured or uninjured, while the occupants of the other aircraft were killed. An average value of 1.4 fatal accidents per 100,000 take-offs was calculated for the observation period. For the 99 fatal accidents, the BFU had autopsy reports from 71 pilots and 35 other occupants. In 7 cases (9 %), the autopsy reports revealed medical or toxicological findings relevant to the causes of the accident or indications of pre-existing conditions of the pilots. In 2 cases in which the pilots survived, pre-existing conditions relevant to the accident were identified. 3 suicides were identified. Intoxication in 3 cases and illness in 4 cases were identified as preconditions for safety-critical actions as well as pilot incapacitation in 4 cases. The pilots responsible for the cases analyzed in the study were predominantly male. 33% of them were 50 to 60 years old and 30% older than 60 years. Unfortunately, the study does not provide results that are purely related to microlight aircraft. Only 130 of 148 accidents investigated involved this class of aircraft. [18]

Chronic illnesses and acute medical emergencies increase with age. Age is a risk factor for the occurrence of medical complications in-flight. The risk of flight incapacitation, which can cause serious aviation accidents based on cardiovascular diseases, rises with age.

In the UK in 2003 there were more old private pilots than old professional pilots. 1628 were licensed pilots over 70 years of age, of whom 178 were more than 80 years old. 3.5 per cent of fatal incidents may have been caused partly or fully by physical incapacity… due to cardiovascular causes in the older age group. A number of studies demonstrated the relationship between increasing age and an increasing risk of cardiovascular events in pilots. The results of a personal retrospective study of medical documents relating age to the diagnosis of coronary arterial disease (CAD) in 174 professional pilots in the UK showed that over 70 per cent of the total cases were aged over 50 Years and the incidence increased after that age. Atrial fibrillation is another age-related symptom that is related to age. There is a good evidence that the statistical chance of an incapacitating thromboembolism due to atrial fibrillation increases sharply after 60 years. [16]

In cardiology, atheroma is a deposit on the inner walls of arteries, especially the coronary arteries. They reduce the lumen area of the artery to the point of complete occlusion. The result is that no blood and therefore no oxygen can reach the areas of the heart muscle supplied by them, which causes a heart attack.

The more the lumen of the coronary artery is reduced the higher is the risk for a cardiac event. In order to determine the prevalence of atheroma, the coronary arteries from 1188 pilots (died in-flight or in fatal accidents) were evaluated to discover the extent of the coronary artery disease extent. Arteries with the lumen area reduced by less than 20 per cent were classified as having no coronary disease, 20-50 per cent as having a mild disease, 51-70 per cent moderate disease, while severe disease required a reduction greater than this. 37 per cent of the pilots 61+ and 20.8 per cent in the group 56-60 years showed signs of a severe coronary artery disease.

Coronary artery disease					
Age (years)	Total	None	Mild	Moderate	Severe
17-20	50	48	2	0	0
21-25	157	128	21	5	3
26-30	204	156	29	10	9
31-35	183	121	37	17	8
36-40	178	103	41	25	9
41-45	116	59	49	16	12
46-50	110	39	33	21	17
51-55	83	34	19	19	11
56-60	53	15	16	11	11
61+	54	20	9	5	20
Total	188	723	236	129	100

Table 01 - Occurrence of coronary artery disease in pilots [15]

In 2007, the Australian Transport Safety Bureau (ATSB) described which medical conditions led to pilot incapacitation in its report: Pilot Incapacitation: Analysis of Medical Conditions Affecting Pilots Involved in Accidents and Incidents. The investigation period covered 01 January 1975 to 31 March 2006. The 98 incidents found were caused by medical or physiological reasons. 16 aircraft accidents and 82 incidents, one of which was serious, were identified. Pilot incapacitation accounted for 0.6 per cent of all incidents registered during the reporting period. The 29.6 per cent of the 98 incidents occurred on scheduled flights and 22 per cent on private single cockpit flights. As other sources also consistently report, the group of gastrointestinal illnesses accounts for the largest proportion of flight incapacities at 21.43 per cent. smoke and fume events ranked second at 12.24 per cent, followed by loss of consciousness at 9.18 per cent and heart attacks at 8.16 per cent. [7]

The Federal Aviation Administration (FAA) Office of Aerospace Medicine describes the initial capabilities needed to support safe flight operations in the case of an incapacitated pilot. The aspects of a pilot’s physiological state which, in the absence of a second flight deck crewmember, would instead need to be monitored through sensing technologies. The report reviewed the maturity and validity of current (November 2022) technologies for detecting six incapacitation types: sudden cardiac death, epileptic seizure, stroke, sleep, hypoxia and acute pain syndrome. [8,13]

Results

In MOREALIS sudden cardiac death and hypoxia are covered by monitoring heart rate and blood oxygen saturation. Epileptic seizure, stroke, sleep, and acute pain syndrome could be identified by cognitive monitoring.

MOREALIS is a system that supports the pilot by monitoring and rating biometric and cognitive parameters. In fact, it is a combination of two different methods to assess the physiological status of the pilot, which complement each other.

For this reason, the focus is not on diagnoses, but on the pilot's symptoms and behavior, which help to identify conditions that deviate from the normal. We therefore decided to try to identify relevant parameters from different perspectives.

First of all, we asked experts at the Aeromedical Centre of the Institute of Aerospace Medicine what the possible emergencies in flight are from the perspective of the aviation physician and which sensors could be used to identify them. Our Aeromedical Centre is an aeromedical facility that offers and carries out medical fitness examinations for pilots and flying personnel in both commercial and private aviation, so called Medicals. [4] The DLR Aeromedical Centre is also regularly involved in the medical assessment for the selection of new astronauts on behalf of the European Space Agency and in medical assessment of astronaut’s medical state before and after space missions.

Sensor search

The literature described the most represented reasons for pilot incapacitation, as there are:

1. acute pain syndrome
2. epileptic seizure
3. gastrointestinal illnesses
4. heart attack and or coronary artery disease
5. hypoxia
6. loss of consciousness
7. smoke and fume events
8. stroke

We developed a table with medical symptoms and the related parameters to determine adequate sensor types.

MOREALIS Symptoms and Sensors		
symptom(s)	**parameter(s)**	**adequate sensors(s)**
cardiac arrhythmia	heart rhythm, heart rate	1 or 3-channel ECG, e.g. smart watch
ventricular tachycardia	heart rhythm	1 or 3-channel ECG
ventricular fibrillation	heart rhythm	1 or 3-channel ECG, spO2 measurement, RR-(blood pressure) measurement
hypotension	blood pressure	RR-measurement
hypo-/hperthermia	body temperature	body temperature monitor
pain (initial pain)		
hypertension > drop in blood pressure > hypotension	blood pressure	RR-measurement
sweat breakout	sweat, skin conductivity	sweat sensor, skin conductivity measurement
dilated pupils	pupil width	eye-tracking
facial distortion	facial muscle tone	observation
pain (somatic - deep pain)		
sweating	sweat, skin conductivity	sweat sensor, skin conductivity measurement
trembling	trembling	sensors within the hand control
nausea	subjective	interview
vomiting	optical registration	observation, interview
shortness of breath (dyspnoea)	oxygen partial pressure - spO2	pulse oximetry, respiratory rate measurement
paresis, paralysis	change in strength, in mobility	observation, interview
speech disorders, speach loss	speach	interview
symptoms of dizziness		
drownsiness	subjective	interview
nausea	subjective	interview
vomiting	optical registration	observation, interview
visual disturbances	subjective	interview, eye-tracking
sweat breakout	sweat, skin conductivity	sweat sensor, skin conductivity measurement
noise in the ears	subjective	interview
visual impairment, loss	field of vision, clear vision	interview
tiredness	blink rate, muscle tone, responsiveness, pupil stability, pupil width, saccades	observation, eye-tracking, dead man's switch
unconciousness, microsleep	responsiveness	observation, eye-tracking, dead man's switch
	muscle tone	sensors within the hand control
hyperventilation	respiration rate	respiratory rate measurement
seizure	muscle tone, consciousness, breathing (EEG)	observation, dead man's switch, pulse oximetry

Table 02 - Symptoms, parameters and sensors

The recognition of symptoms requires medical and cognitive sensors. On the medical sensors site we identified the following parameters to monitor:

1. heart rate
2. heart rhythm
3. blood pressure
4. blood oxygen saturation (spO2)
5. respiration rate
6. body temperature

In a next step we searched for suitable sensors. The requirements were:

1. no restrictions on the pilot when flying the ultralight aircraft
2. should not burden the pilot – good wearing comfort
3. easy to use
4. lightweight
5. small size
6. wireless communication to avoid disturbing cables in the cabin
7. continuous data streaming
8. no streaming to external servers
9. demonstrably accurate

As a result of our market search we identified COSINUSS 2, a sensor measuring heart rate, heart rhythm, respiration rate and body temperature.

Figure 01 - Sensor COSINUSS 2 ©COSINUSS

COSINUSS is an in-ear sensor which can be configurated for left or right ear use. It is lightweight, transfers data via Bluetooth™. Following the manufacturers information, the sensor can be perforated thus radio communication is possible without restrictions. COSINUSS 2 exists also in a medical product version for use e.g. in hospitals.

Fulfills all technical requirements.

Figure 02 - CAPICAL Sensors in the Pilot Seat ©SFL-GmbH

CAPICAL sensors are so called capacitive sensors. They don’t need contact to the skin of the pilot like adhesive electrodes. They are sensors for heart rate, one-channel ECG and Cardiac arrhythmia. To be able to measure, the vector of measurement of two electrodes must cross the heart like in medical ECG tests. Thus, the sensors have to be integrated in the pilot seat. Together with CAPICAL we still work on the interface adoption.

Fulfills all technical requirements.

Both the sensors match all our requirements except the detection of blood pressure. Conventional blood pressure monitors are working with the Riva-Rocci method. A pressure cuff is positioned around the upper arm, wrist or finger, is inflated using an air pump system and measures systolic and diastolic blood pressure when the air is released. These systems are not easy to use and burden the pilot with every measurement. We’re still looking for a suitable and precise device which meets our requirements.

At present we identified a device which measures blood pressure and pulse wave with a LED-based method located in a wrist band. In addition, heart rate and heart rhythm are measured.


Figure 03 - AKTIIA 24/7 Blood pressure monitor ©AKTIIA

1. no restrictions on the pilot when flying the ultralight aircraft (OK)
2. should not burden the pilot – good wearing comfort (OK)
3. easy to use (OK)
4. lightweight (OK)
5. small size (OK)
6. wireless communication to avoid disturbing cables in the cabin (OK)
7. continuous data streaming (?)
8. no streaming to external servers (?)
9. demonstrably accurate (OK)

At present we are getting into contact with the manufacturer.

<u>Pilot Data Monitoring</u>

DLR and Star Healthcare cooperate in "Work Package 2400 – Diagnose Systems (AP2400)" to develop a Pilot medical data monitoring system. The data will be used to determine the pilot medical state. In later step the DLR/SHC medical data management and interpretation will be integrated with the cognitive monitoring data of UBM-FMFF in a so-called panel software

Based on the results of the literature research, we decided to use medical state monitoring of the medical causes of pilot incapacitation that are responsible for serious incidents, including aircraft accidents. These are sudden cardiac death (SCD), cardiac arrhythmia (CA) and hypoxia.

In the project epileptic seizure, stroke and sleep as well as pilot's attention are to be detected by the cognitive pilot monitoring system of UBM-FMFF monitoring the pilot's attention.

The relevant medical parameters for continuous medical monitoring were identified and assigned for the medical causes mentioned.

Event	Parameter 1	Parameter 2	Parameter 3	Parameter 4
heart attac	oxygen Saturation	heartrate	heart rhythm	
sudden cardiac death	oxygen Saturation	heartrate	heart rhythm	breathing rate
cardiac arrythmia	oxygen Saturation	heartrate	heart rhythm	
hypoxia	oxygen Saturation	heartrate		breathing rate

Table 03 - Medical parameters to be monitored

Due to the ongoing search of a blood pressure monitor, up to now blood pressure monitoring has not entered the development process. It however can be integrated later. Body temperature is not included, because it doesn't enter into the pilot state scoring.

Pilot state scoring bases on the National Early Warning Score (NEWS). [9,10,11] The score defines staggered limit values. 7 parameters are needed to calculate the early warning score. But Parameter 3 "Any Supplemental Oxygen" is not suitable for our inflight Monitoring.

For this reason, MOREALIS at present supports only 5 of 7 parameters due to the lack of the blood pressure sensor.

Physiological Parameters	3	2	1	0	1	2	3
Respiration Rate	≤8		9-11	12-20		21-24	≥25
Oxygen Saturation	≤91	92-93	94-95	≥96			
Any Supplemental		Yes		No			
Temperature	≤35.0		35.1-36.0	36.1-38.0	38.1-39.0	≥39.1	
Systolic BP	≤90	91-100	101-110	111-219			≥220
Heart Rate	≤40		41-50	51-90	91-110	111-130	≥131
Level of Consciousness				A			V, P, or U

Table 04 - NEWS: 7 Parameters and 7 values, orange and red values are critical and serious

The values are added together to get the total NEW Score.

NEW score	Clinical risk	Response
Aggregate score 0–4	Low	Ward-based response
Red score Score of 3 in any individual parameter	Low–medium	Urgent ward-based response*
Aggregate score 5–6	Medium	Key threshold for urgent response*
Aggregate score 7 or more	High	Urgent or emergency response**

Table 05 - NEWS-thresholds and triggers

NEW score	Frequency of monitoring	Clinical response
0	Minimum 12 hourly	• Continue routine NEWS monitoring
Total 1–4	Minimum 4–6 hourly	• Inform registered nurse, who must assess the patient • Registered nurse decides whether increased frequency of monitoring and/or escalation of care is required
3 in single parameter	Minimum 1 hourly	• Registered nurse to inform medical team caring for the patient, who will review and decide whether escalation of care is necessary
Total 5 or more Urgent response threshold	Minimum 1 hourly	• Registered nurse to immediately inform the medical team caring for the patient • Registered nurse to request urgent assessment by a clinician or team with core competencies in the care of acutely ill patients • Provide clinical care in an environment with monitoring facilities
Total 7 or more Emergency response threshold	Continuous monitoring of vital signs	• Registered nurse to immediately inform the medical team caring for the patient – this should be at least at specialist registrar level • Emergency assessment by a team with critical care competencies, including practitioner(s) with advanced airway management skills • Consider transfer of care to a level 2 or 3 clinical care facility, ie higher-dependency unit or ICU • Clinical care in an environment with monitoring facilities

Table 06 – Clinical response to the NEWS trigger thresholds

For MOREALIS we developed risk steps and actions to be taken in-flight.

Table 07 - MOREALIS Risk steps and actions

SHC developed a first interpretation of the early warning score monitoring 7 parameters as well but “blood glucose”, “attention” and “atrial fibrillation” replace” “level of consciousness”, “supplemental oxygen” and “systolic blood pressure”.

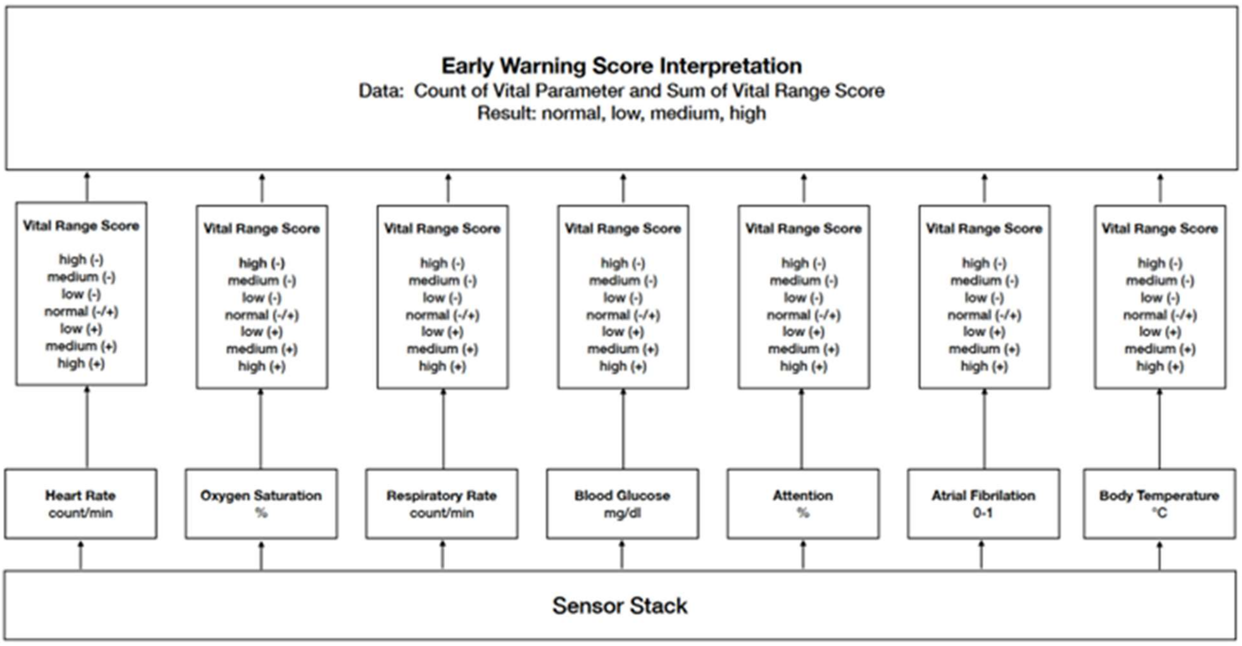

Figure 04 - Schematic representation of a modified NEWS interpretation

At present 6 parameters find entrance to the scoring mechanism, suitable to detect the pilot state and in the worst case a pilot incapacitation.

Working with these parameters, SHC started developing a panel to control software and hardware (sensors). The Current platform requirements are macOS 13+ and iOS 16+.
The following figures show the SHC Panel Software which integrates sensors, activation process and the representation of the sensor values in different colors depending on the specific early warning score. It indicates the critical values with a warning message.

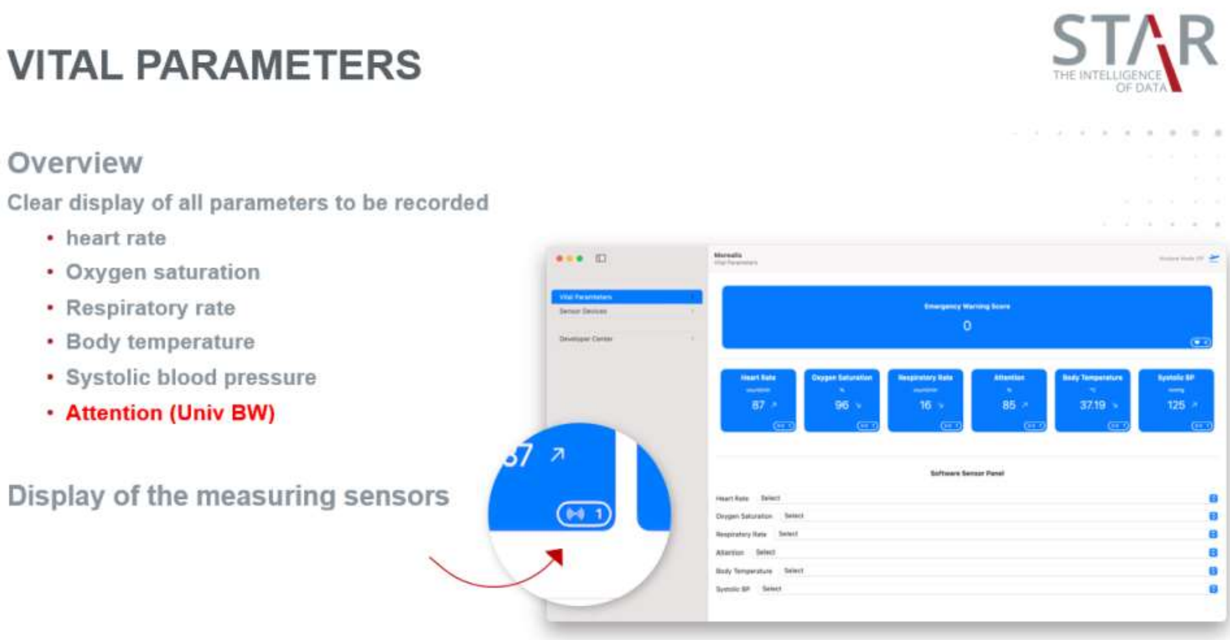

Figure 05 - Panel software: vital parameters; the cognition data "**Attention – UNIV-BW**" will be integrated into the panel software as well.

VITAL PARAMETERS

Airplane Mode

- Switched on by the pilot at the start of the flight and switched off again after landing
- In this mode, the measurements are taken and the pilot must interact with the system if the score drops
- Data is also exported to an optional web server via POST (the URL can be customized in the application)

Figure 06 - Panel software: Airplane Mode

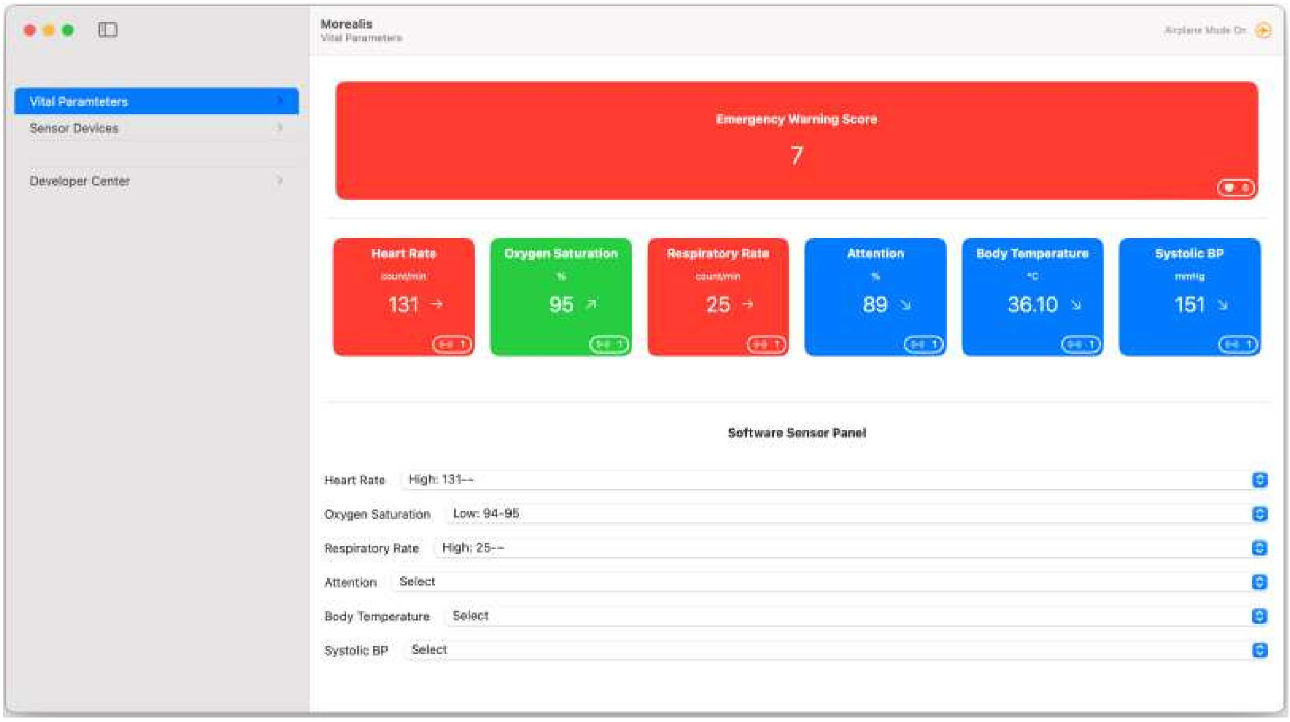

Figure 07: 2 vital signs left normal range

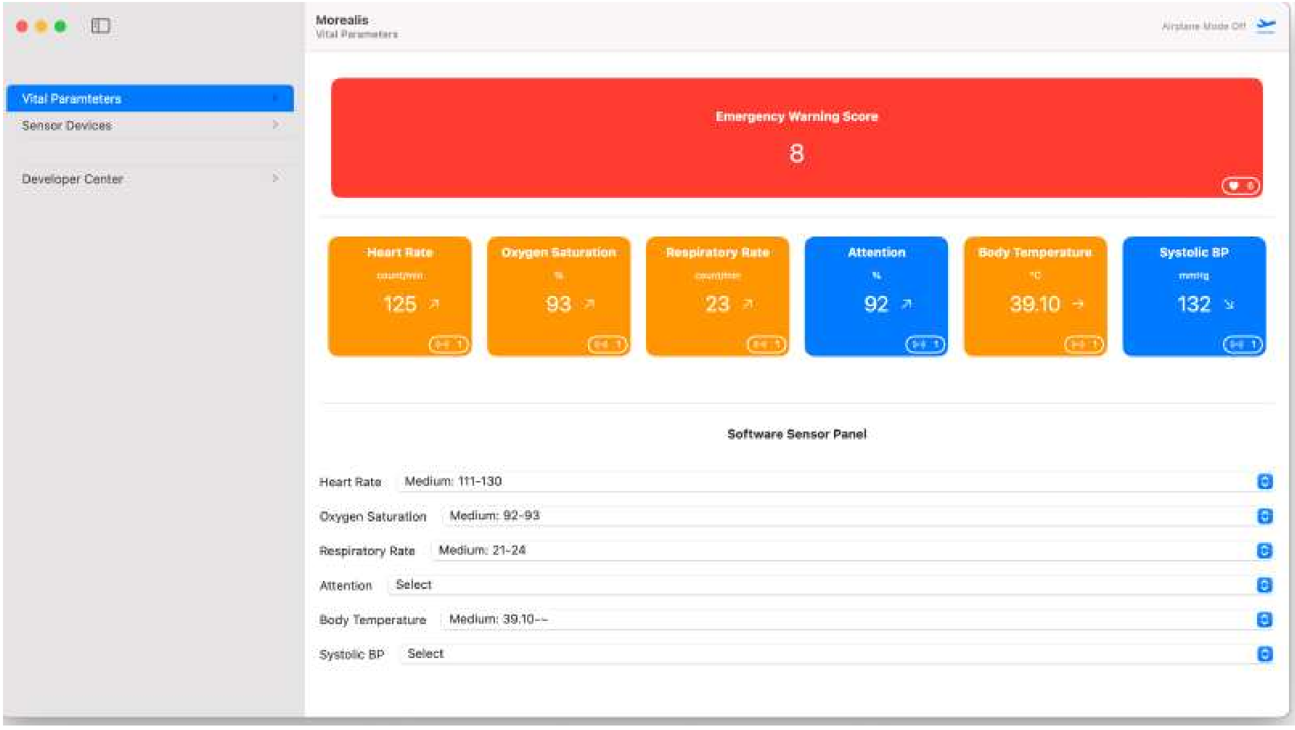

Figure 08: Change of vital parameter values and increasing NEW-score

Figure 09: “Warning”-level “One vital sign moved to the critical range. Confirm that you still feel fine and press the window”

Figure 10: “Attention”-level “Some of your vital signs have deteriorated. Confirm that you still feel fine and press the window. - You are required to land the aircraft and undergo a medical examination.”

Possible Cognitive Symptoms	**+' occurs more frequently, '-' tends not to occur**						
by estimated descending frequency	**nervous/ jittery control inputs**	**missing/ delayed reaction**	**tense muscles/ control elements**	**tunnel vision**	**nervous look**	**view deviation from POI**	**no reaction to auditory stimuli**
hypotonic dehydration	+	+	+		o	+	
tiredness	-	+	-	+		+	+
hypoglycaemia		o	-	o	o	o	
Sunstroke	+				+		
heat collapse	-	+	-				+
travel sickness (kinetosis)		+		o	o	o	
hypothermia							
grade 1 excitation	+				+		
grade 2 adynia - exhaustion stage			+	o			
grade 3 paralysis	-	+	-				+
withdrawal symptoms in smokers		o	+		o	+	
acute carbon monoxide poisoning	-	+	+	o	-		o
(incipient) heart attack	o	+	+	o	o	o	o

Table 7 – Diagnoses vs. cognitive detection

The cognitive monitoring allows to identify symptoms of medical diagnoses or physiological states. Often symptoms, which are not covered by medical monitoring, can be identified with cognitive methods and help to determine the pilot state. Medical symptoms can influence pilot's behavior as well. Both methods of pilot monitoring complement each other.

Discussion

Pilot in-flight incapacitations in single-seat-microlight aircraft in pilots are scarce, but will rise in number due to the growing number of older pilots flying without regular Medicals on one hand and due to rising number of LL in general. Age is a risk factor for pilots as shown e.g. in [15]. Not all emergencies in the single cockpit can be identified by the monitoring of medical parameters. And not every supervision of cognitive parameters can. But cognitive observations can explain deviations from medical parameters and vice versa. To feed the medical parameters and the cognitive observation in a scoring mechanism has the potential to identify the pilot state. This combination can help to better recognize pilot conditions that endanger people and aircraft. But MOREALIS goes beyond that. This is because the aircraft intervention management system monitors the aircraft itself and the flight parameters as well. In an emergency, it will automatically and autonomously carry out a controlled emergency landing in an open field, provided that a free landing site can be found using satellite recognition and navigation. An emergency signal is also sent. MOREALIS is intended to protect older pilots or pilots with little flying experience in LL. We are currently making good progress.

The next steps in the MOREALIS project:

1. integration of the blood pressure hardware AKTIAA or other into the panel system and early warning score
2. integration of the CAPICAL sensor into the seat cushion
3. integration of the COSINUSS sensor into the pilot's headphones
4. integration of the cognitive data from AEM UBM-FMFF and
5. connection of the panel software to the AIMS using ROS 2 interface description language

The project ends 12-2024.

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List of Abbreviations

UBM-FMFF	Professorship for Aeronautical Engineering at the University of the Bundeswehr Munich
AIMS	aircraft intervention management system
ATSB	Australian Transport Safety Bureau
BFU	German Federal Bureau of Aircraft Accident Investigation
CA	Cardiac Arrhythmia
CAD	Coronary Arterial Disease
DLR	German Aerospace Center
DLR-ME	DLR Institute for Aerospace Medicine
FAA	Federal Aviation Administration
NEWS	National Early Warning Score
SCD	Sudden Cardiac Death
SHC	STAR Healthcare Management
LL	Ultra-Leicht-Luftsportgeraete, Micro-light Aircraft Ultra-light Aircraft