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Flight Sensing Shirt - a smart shirt for physiological monitoring of fighter pilots

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Unexplained Physiological Events (UPEs) are a significant threat to military pilots. During UPEs pilots may experience reduced flight performance or impairment caused by hypoxia, nausea, disorientation, or gravity induced loss of consciousness. With aircraft technology advancements the cognitive burden on military pilots increases. There is a growing demand for systems with the capability to alert pilots to potential UPE episodes. We are currently developing and validating a smart shirt, with seamless integration of sensors and feedback systems, to support the pilots assessment on their physical status, which helps to increase flight safety and mission effectiveness

Smart shirt with seamlessly integrated bio-sensors

The shirt is designed for functionality, wearing comfort and safety. The sleeveless 'second skin' garment has a tight fit and is made with fireproof fabrics. Making use of a modular approach to laminate functional sensor foils onto fabric, we obtained a slim and comfortable garment with good skin contact. The shirt and the functional inlays are processed separately and have been joined together by thermal lamination. The inlay consists of ultra-thin medical grade skin contact sensors for ECG and bio impedance monitoring. The sensors and stretchable circuitry are printed on thermoplastic polyurethane foils. Two main integration approaches were investigated with constant, and replaceable integration in the shirt. The location of the sensors were tested thoroughly to ensure high signal quality with minimal disturbances with other equipment, such as the safety belt and G suit.

Human Centrifuge and DESDEMONA trials

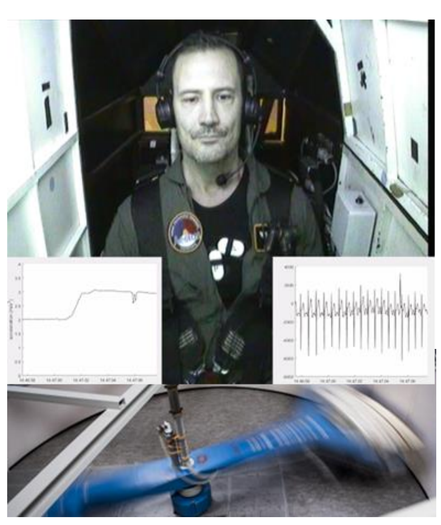
Validation of shirt prototypes in the human centrifuge and flight simulator DESDEMONA allowed us to introduce operational conditions and disturbances in a controlled manner. We collected bio signals for ECG and respiratory status at increasing G-force levels. Analyzing the data parallels between the quality of the measured bio signals and the measurement position, sensor materials, fabrics and design of shirts interactions be assessed. The learnings gathered from these tests highlight two main challenges: motion artifact of sensors (skin electrode contact and measurement robustness), and interconnection of stretchable circuitry to readout electronics.

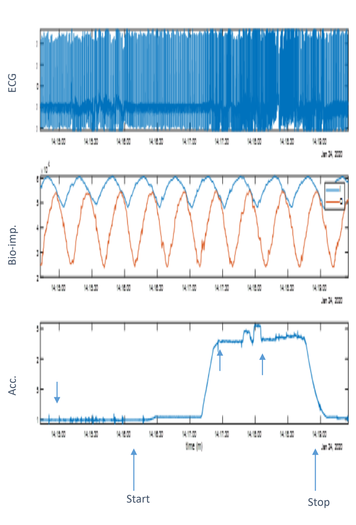
Smart alert system

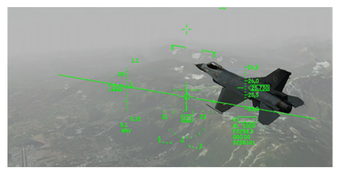
Converting physiological data into actionable information can increase flight safety. We investigated the complex interrelations in the bio measurements and developed graphical user interfaces with the aim of providing pilots with insights into their physiological response during flights. The pilot can be informed using warnings when physiological parameters are outside of normal. This has the potential to assist in decision making, mitigating or even preventing UPEs.

Reflections

Introducing robust physiological sensing solutions into the cockpit has the potential to prevent many UPEs from occurring. The Flight Sensing Shirt offers promising new technology to support operators and senior leadership. Preventing UPEs can save lives and increase mission effectiveness. It also can provide insight into physiological parameters during physiology training (e.g. centrifuge, hypobaric chamber). In the next phase, we are aiming to bring the Flight Sensing Shirt to technology readiness level 7 by refining the sensor design to increase robustness, develop scalable process designs and validate Flight Sensing Shirts jointly with a smart alert system.







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