Health Interventions at the Edge

Helen Austin[1], John Puddy[1], Andrew Richardson[2], Chris Gaffney[3], John Hardy[4], David Cheneler[2], Samuel Rust[2], Ali Al-Saadi[4]

[1]Ultra PCS, Arle Court, Hatherley Ln, Cheltenham GL51 6PN, [2]School of Engineering, Lancaster University, Lancaster, LA1 4YW, [3]Lancaster Medical School, Health Innovation One, Lancaster University, Lancaster, LA1 4AT, [4]Department of Chemistry, Lancaster University, Lancaster, LA1 4YB

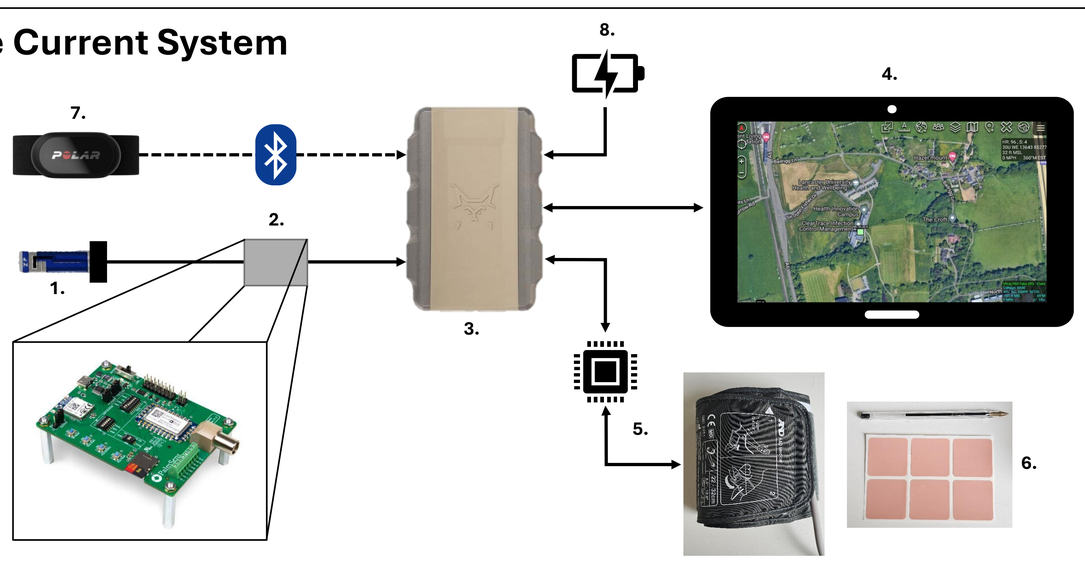
Introduction

Wearable devices offer instant access to vast amounts of health data, the challenge is knowing how to interpret the data into actionable decisions. This requires medical / sports science knowledge and the number of medical staff in the field capable of making these actionable decisions is limited.

Ultra PCS and Lancaster University have developed an end-to-end system designed to monitor welfare and remotely deliver an intervention from a command post by a trained professional. This aids in reducing the burden on field medical staff by prioritising efforts where most needed.

A prototype closed loop implementation system has been developed for proof-of-principle demonstration. The system utilises an UltraLYNX power and data hub to receive, combine and categorise data from wearable sensors at the edge. This system could communicate a priority red, amber, or green (RAG) indicator to the designated command post where a trained professional can view the sensor data and administer a pre-determined substance via an actuation cuff to the end user. Physiological monitoring is conducted using a commercial heart rate monitor and a novel potassium sensor created by Lancaster University.

The Current System

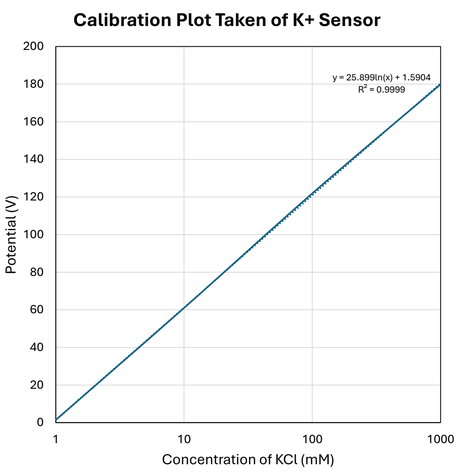


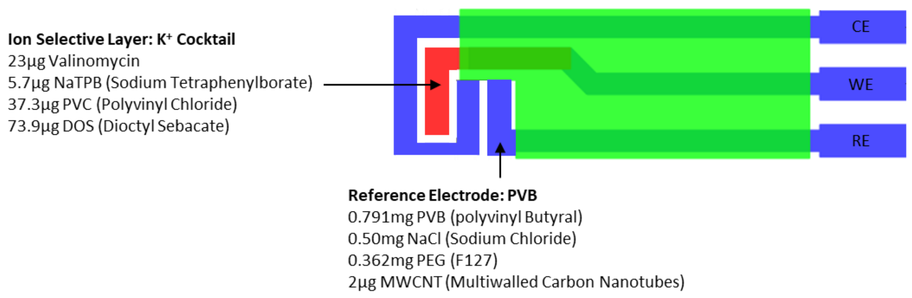
1. Potassium sensor – a small (26.3 x 7.2 x 0.3mm) plastic-based chip modified to respond to potassium in sweat. This is connected by a wire to a potentiostat.
2. Potentiostat – an electronic device which controls the sensor chip and stores measurements. These measurements are transmitted to an UltraLYNX™ hub.
3. UltraLYNX™ – a power and data communication hub capable of handling and processing signals from multiple sources. This is the centre of the entire system and can display information to the wearer and will control the intervention delivery device (arm cuff).
4. An android device hosting ATAK-CIV, an application used for communication. Heartrate and potassium data is displayed here and commands to control the arm cuff flow from ATAK-CIV to UltraLYNX™.
5. Microcontroller & Arm cuff – identical to a blood pressure cuff which is attached to the upper arm. This can be inflated (actuated) from an on-board pump, controlled by a microcontroller, when a signal is received from UltraLYNX™. When inflated the intervention (caffeine patch) is brought into contact with the skin.
6. Caffeine patch – a commercially available patch which sticks to the skin and delivers the caffeine transdermally.
7. Heart Rate Monitor (HRM) - A device which accurately measures the beats per minute (BPM) of the wearers heart. Data from this is sent to ATAK-CIV.
8. Power supply

Sweat Sensing

Ion selective sweat sensors are fabricated by modifying flexible screen-printed electrode chips. Firstly, a transducing layer is electrochemically deposited to reduce potential drift. Secondly, an ion selective cocktail is drop-cast onto the working electrode and a solid-state reference electrode cocktail onto the reference electrode. Once dry, the sensors are calibrated using potassium chloride solutions at various concentrations.

This architecture will enable various other analytes of interest to be measured. It is possible to produce an array of different sensors ready to “plug and play” for specific scenarios.





Additional Analytes of Interest	
Analyte	Condition
Na^+	Dehydration
Cl^-	
Zn^{2+}	Stress
Cortisol	
NH_4^+	Shift from aerobic to anaerobic metabolic conditions
Lactate	
Glucose	Blood sugar levels
Alcohol	Inebriation

Future developments could also target the production methods for sensors. Screen printing the relevant ion selective layers directly would streamline the production process resulting in sensors with increased reliability. Furthermore, this would enable custom electrode designs to be fabricated. Multiple working electrodes could be incorporated onto a single sensor paving the way for multi sensing and the exploitation of cross-sensitivities for biomorphic sensing.

Additional developments could include sensors into fabrics, textiles and even disguised in temporary tattoos.

Biomorphic Sensing

The ability to monitor the performance/degradation of a sensor and adapt accordingly.

Simulate & Feel

Injecting electrical only test pulses through a sensors bias chain and filtering the response from the output – a measurand free, on-line test method:

- Electrical only Stimulus
- Engineer so response is a function of material and structural parasitics
- Apply on-line
- Filter the output to achieve a structural / integrity measurement

Probe & Compare

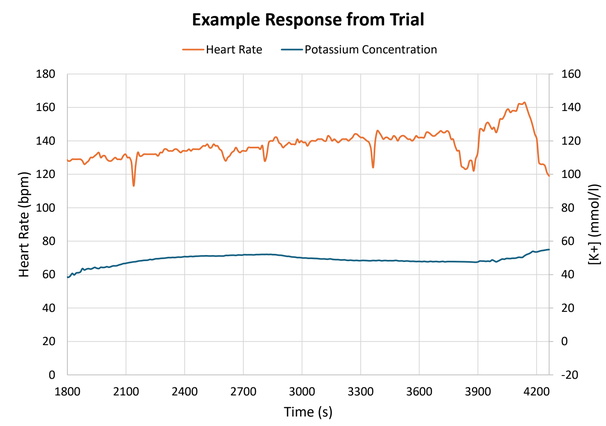
We can use cross-sensitivities to make rough validations of a sensors primary data.

- Monitor key hardware parameters
- Cross-correlate or compare with other indicators
- Compare or correlate with trends

Real-World Testing

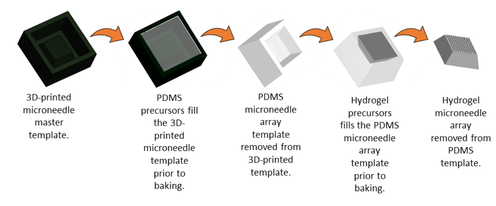
The aim of human trials is to demonstrate that a closed loop system can sense changes in physiology, send/receive physiological data, and upon activation remotely deliver an intervention. The purpose of the trial is to test the usefulness of the system, and no clinical decision-making takes place.

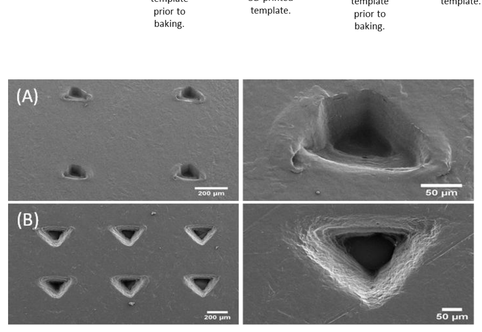
Participants complete a simulated march and running protocol on a treadmill, designed to mimic the load carriage of fast marches in the British Army and offensive/defensive fire and manoeuvre-based tasks.

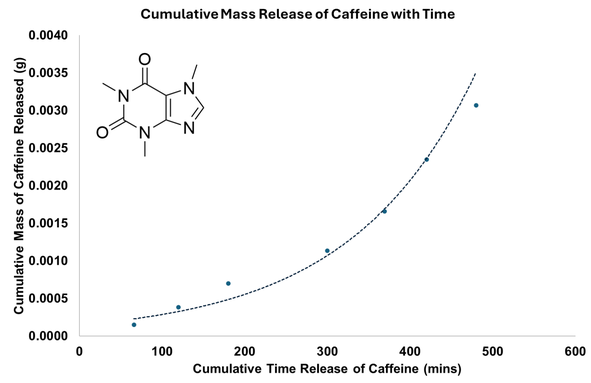


Microneedles & Caffeine Delivery

Poly(2-hydroxyethyl methacrylate), pHEMA, hydrogel-based microneedle patches were produced with mechanical properties such that they would penetrate skin (insertion force of a single microneedle to be ca. 40 N, assessed using a multilayer film composed of 8 layers of Parafilm ® (previously used to mimic microneedle array penetration into skin). Caffeine release from the pHEMA hydrogel-based microneedles was demonstrated over a period of hours in a model release system. Such pHEMA microneedles have potential application for transdermal delivery of a variety of other molecules.







Towards Active Release Systems

Electroactive films for stimulated delivery of: **Left)** Melatonin (sleep hormone) release from electropolymerised films. a) Continuous stimulation. b) On/off stimulation. c) Passive release. **Right)** Pemetrexed (anticancer) release from solution processed electroactive polymers.