Seizure detection with integrated sensor garments

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The project focus is on three common neurological disorders

- Epilepsy – 60 000 persons in Sweden have epilepsy
- Parkinson's disease – 20 000 persons in Sweden have Parkinson's disease
- Stroke – 20 000 persons yearly are afflicted by stroke

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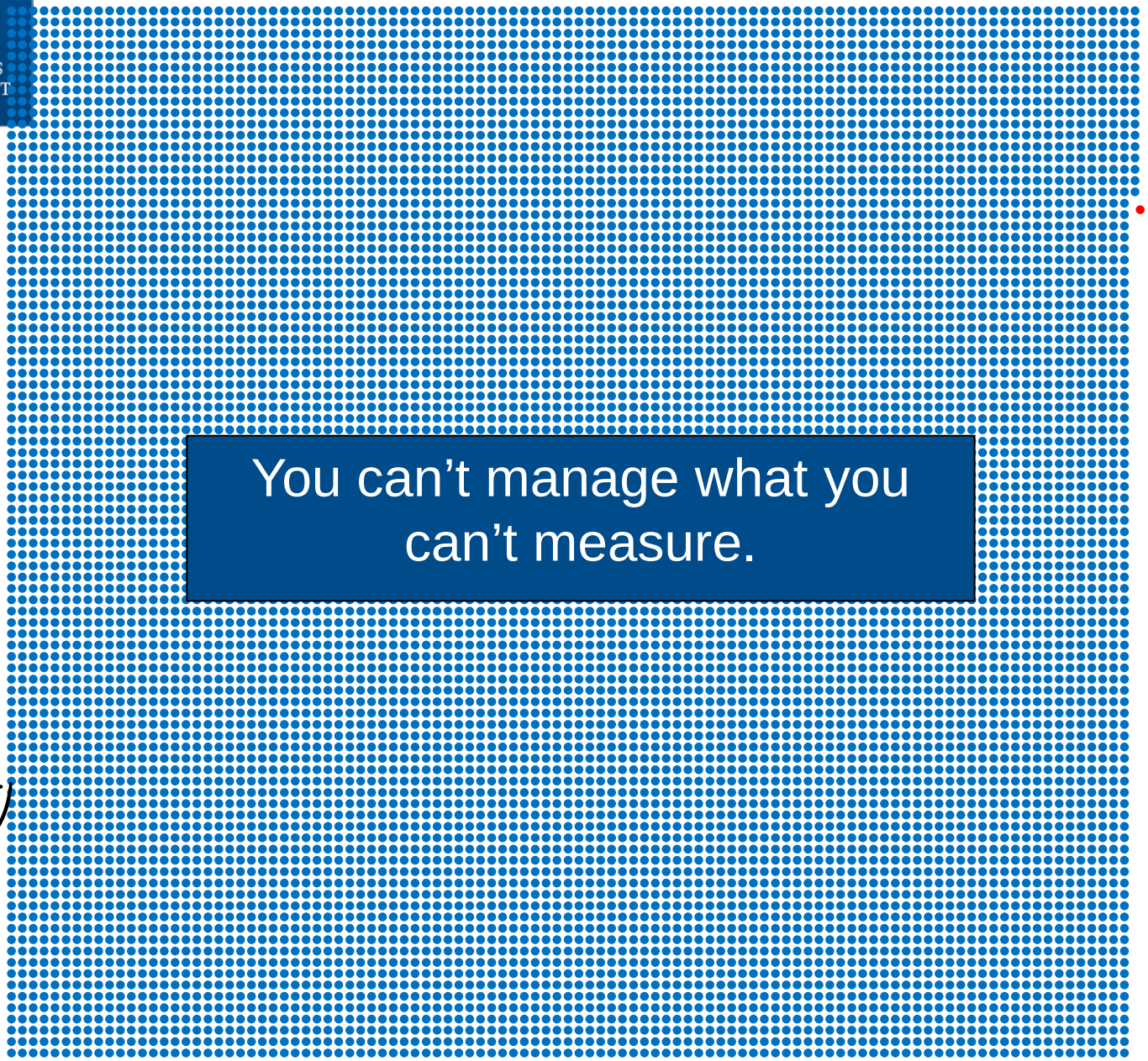
Aims of wearITmed

- To measure relevant movement patterns
- To select other physiological variables relevant to measure in the neurological disorders in question
- To develop measure systems enabling continuous measurements IRL
- To improve diagnosis, follow-up and thereby treatment of these disorders



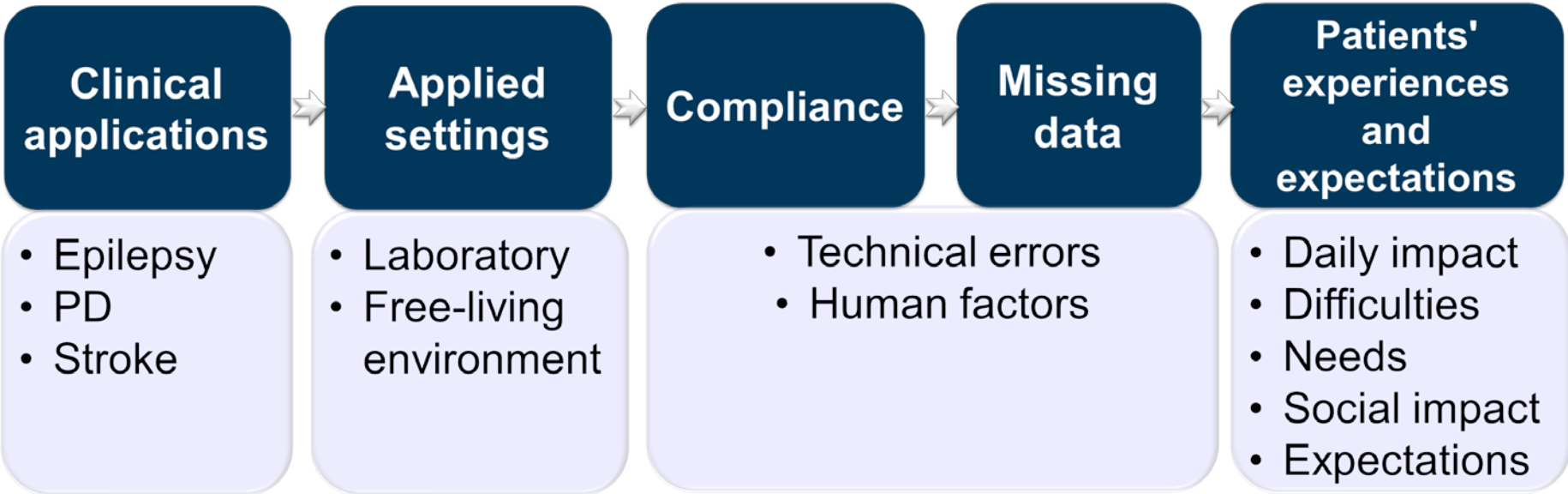
Adapted from Sara Riggare

Physiological variables of interest to wearITmed

- First priority:
  - motor symptoms and patterns
  - pulse
- Second priority :
  - oxygen saturation
  - heart rate variability
  - change in blood pressure
  - electrodermal activity
- The combination of these variables will enable more specific differentiation of and characterisation of the symptoms of the disorders

A mixed methods systematic review

- 50 studies included
- Synthesis of quantitative and qualitative studies of clinical applications of wearable sensors



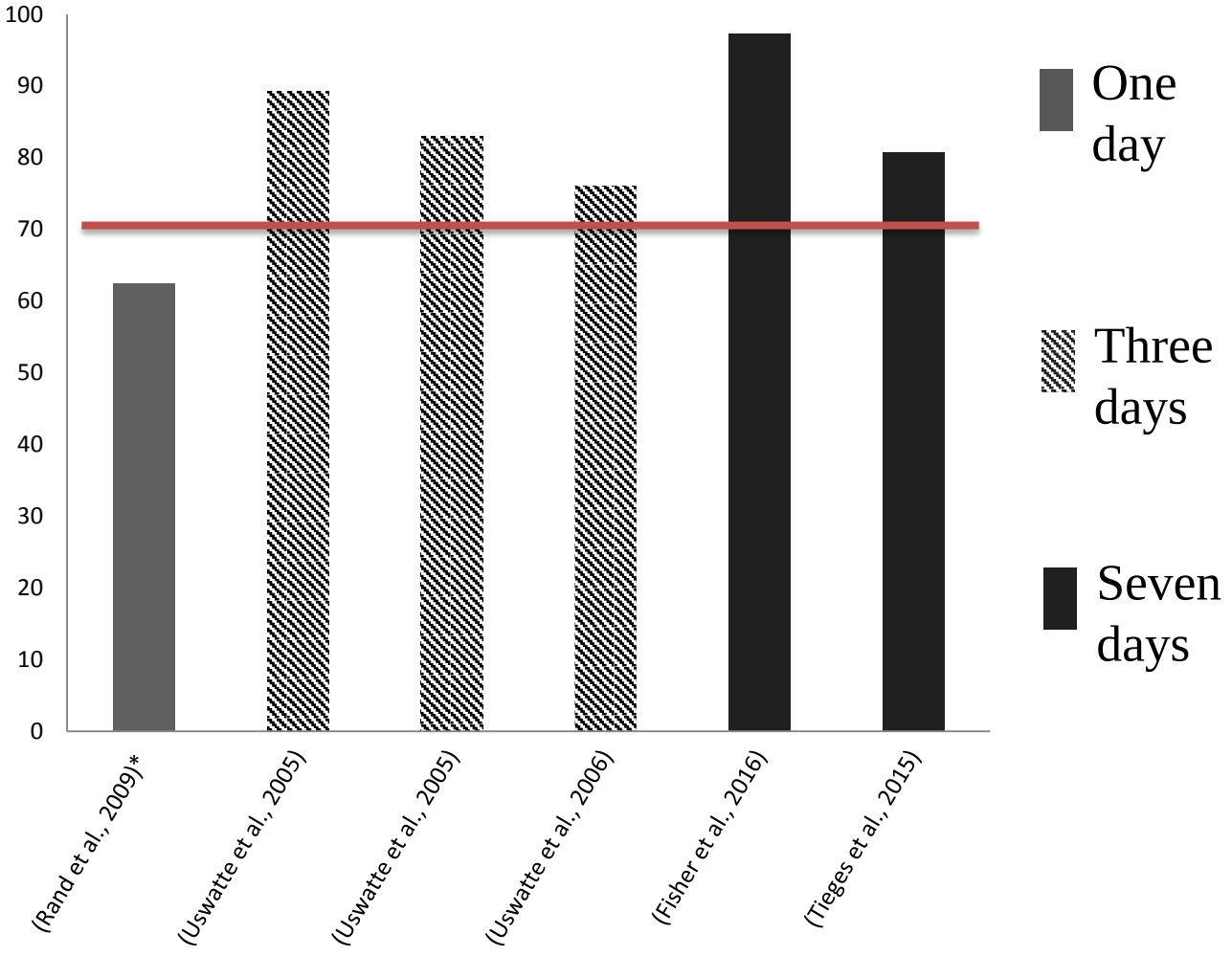
Dongni Johansson et al manuscript

Missing data when using sensors (non-garment integrated)

- **Ca 10-20% technical failure**
  - Malfunctioning of one or more sensor units
  - Bluetooth communication
  - Memory card
  - Battery
  - Data transfer
- **Ca 10-20 % human failure**
  - Configuration failure
  - Miscommunication
  - Forgot to use, not used for sufficient time, wrong placement, device was lost

How is compliance during continuous monitoring using wearables

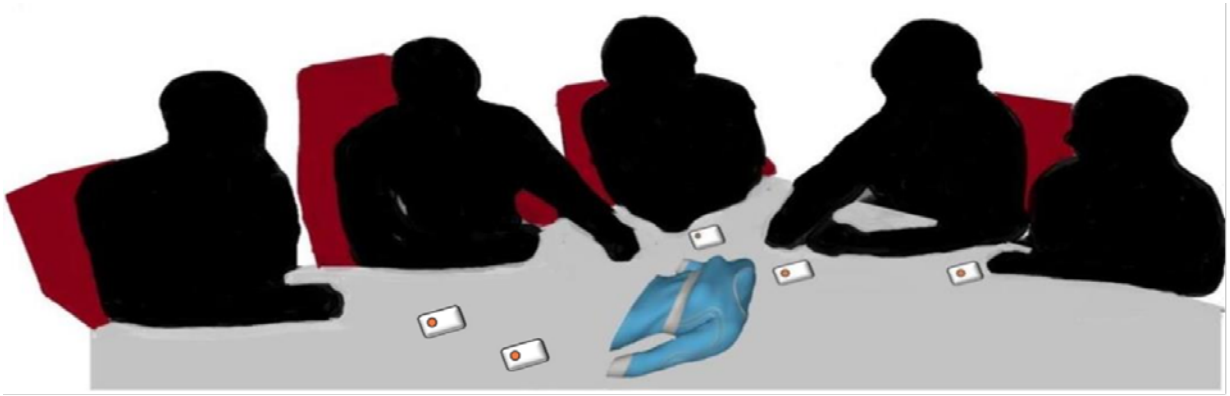
Ca 70%



Preliminary results from Mixed-methods review

Focus group interviews

- To explore perceptions of wearable technology
- Qualitative content analysis



Women with epilepsy 1 group n=4	Men with epilepsy 2 groups n=6	Health professionals in epilepsy 1 group, n=7
Women with PD 1 group n=6	Men with PD 2 groups n=9	Health professionals in PD 1 group, n=8

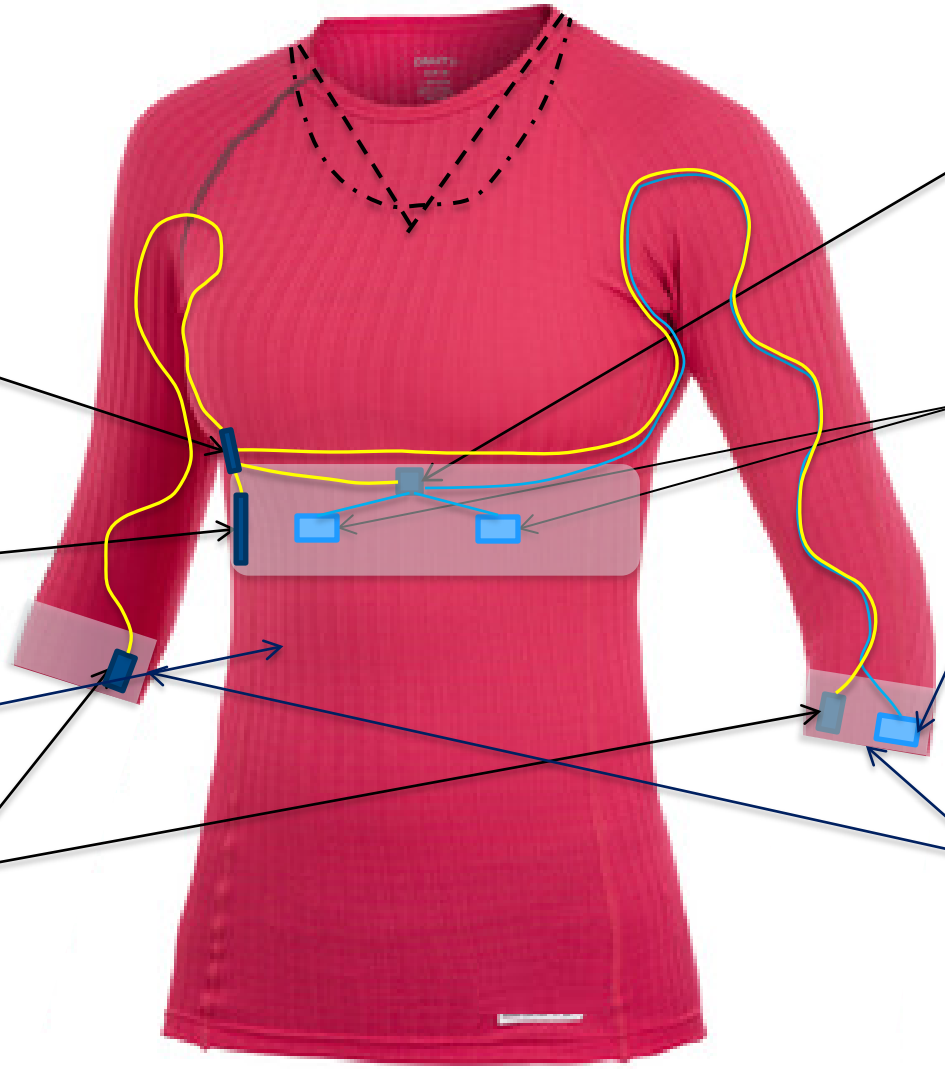
Johansson et al Acta Neurol Scand 2017

M16 – second version of garment with integrated sensors

Smart phone app for start-stop and configuration

V necked: male
U necked: female

Three-quarter long sleeve



Motion and ECG measurement

Central unit
- Micro controller
- Radio
- Memory
- USB contact

Electrodes

Battery

Reference electrode

Tight sensor zone

Motion and PPG measurement

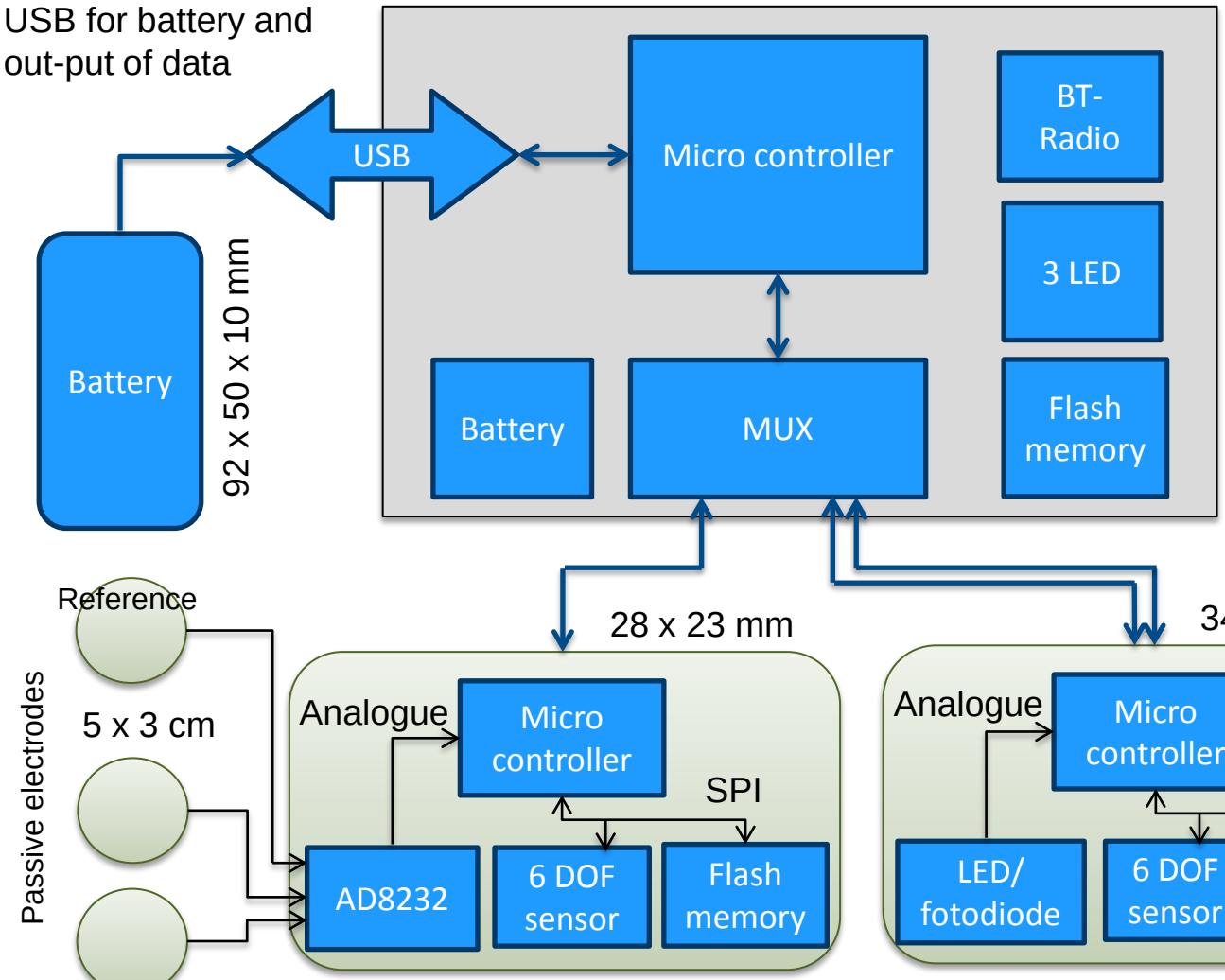
Tight sensor zones

Electronics and Sensor units

BLE for start-stop and configuration

Central unit 54 x 44 mm

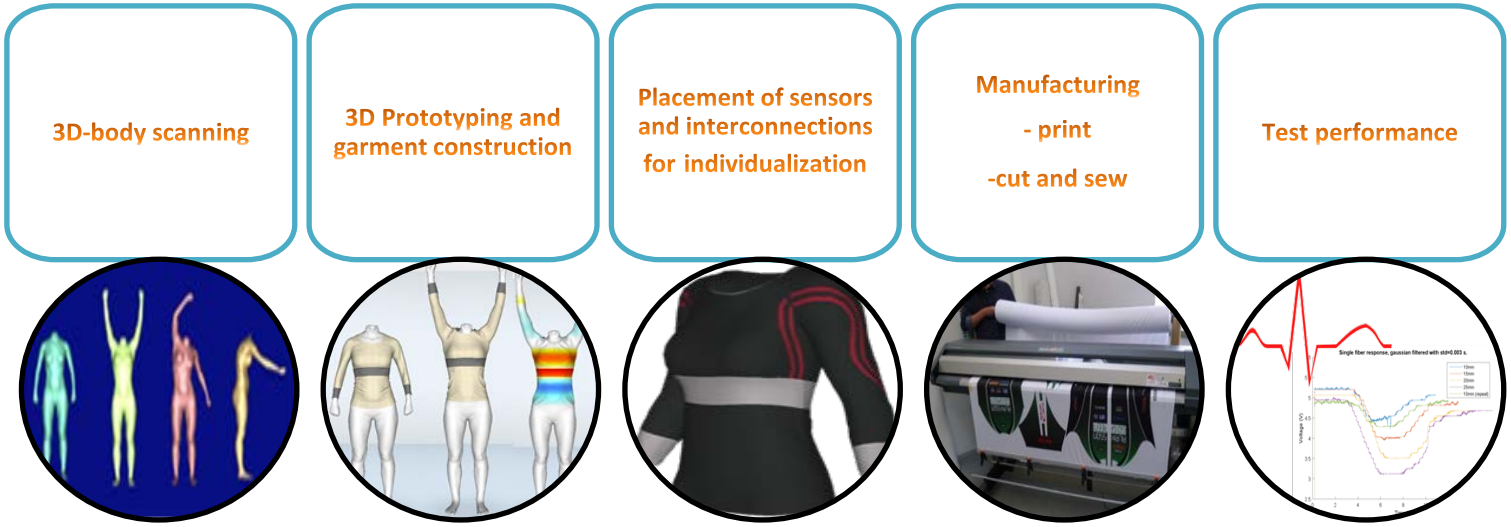
USB for battery and out-put of data



ECG + motion sensors, x1

PPG sensor + motion sensors, x2

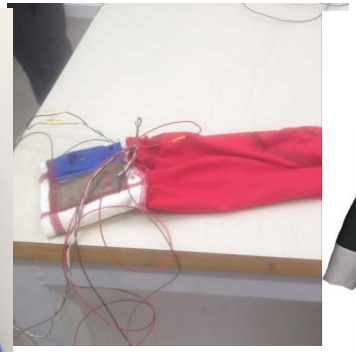
The Swedish School of Textiles is developing a production flow for individualised sensor garments

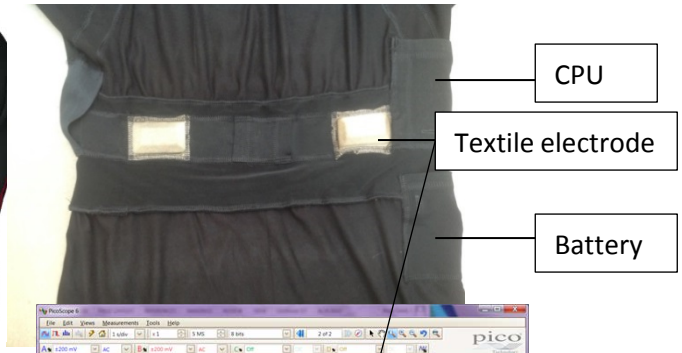


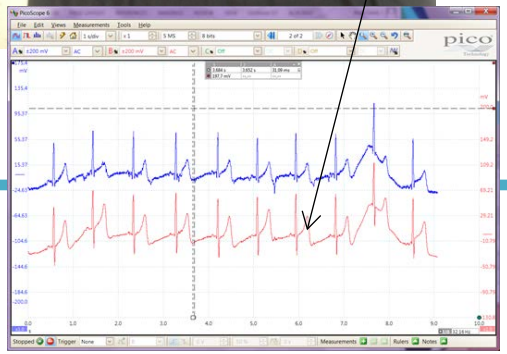
Ongoing work:

- Garment development and fabrication
- Garment fit and sensor position based on 3D-modelling
- Piezoelectric sensors for movement and their modelling
- 3D-printed strain sensors – modelling and experimental

Garment development and fabrication





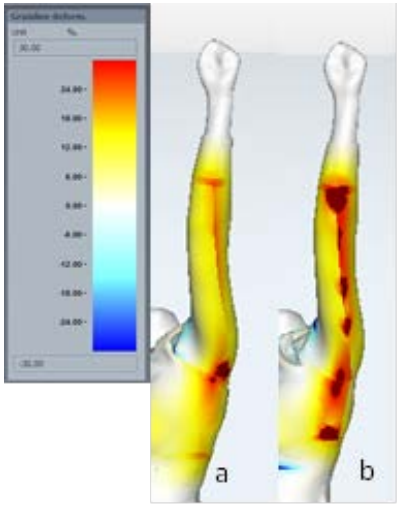


Challenges addressed:

- Comfort versus functionality
- Integrating electronics and wiring

A method is developed which includes an operational construction line where textile sensors and wires are integrated by printing, knitting, sewing.

Garment fit and sensor position based on 3D-modelling

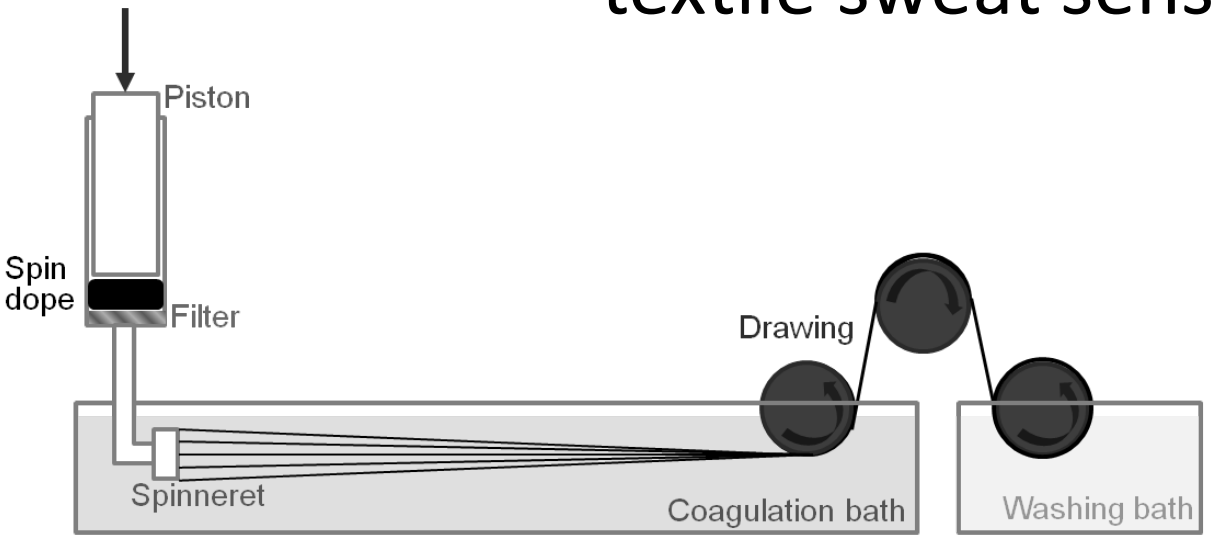


Challenges addressed:

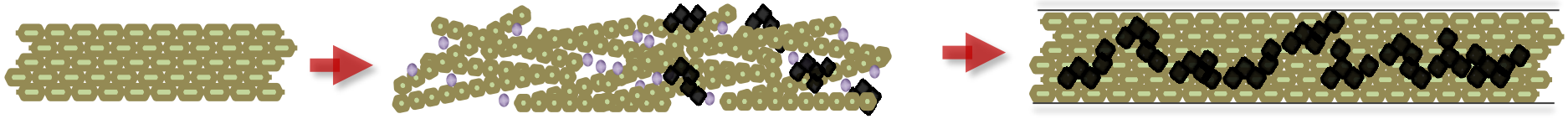
- 1 size does not fit all

After 3D-scanning, a virtual mannequin is created on which garment construction and sensor position can be evaluated before production.

Wet-spinning of conductive cellulose fibers for textile sweat sensor



- Dissolving cellulose in ionic liquid
- Addition of carbon black with different structures
- Wet-spinning process
- Characterisation



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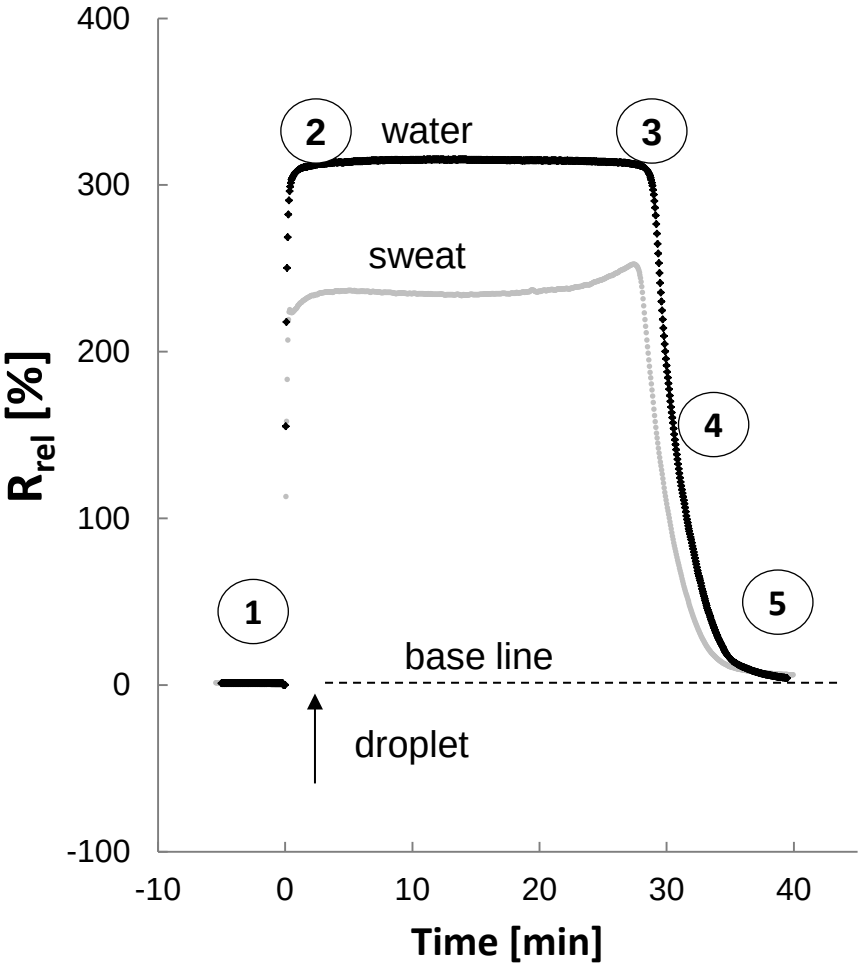
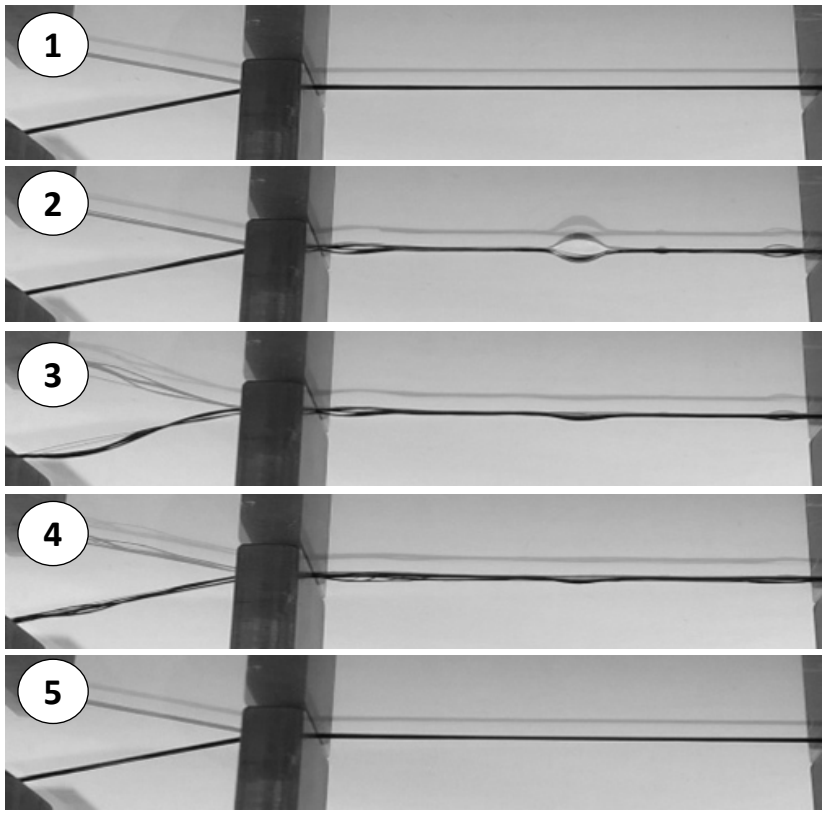
Electrical resistance of yarn increases when subjected to water/sweat and returns on drying





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Patient data

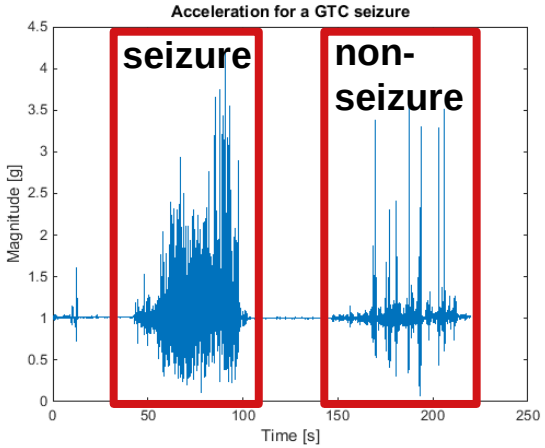
Measurements from 87 patients in the EMU

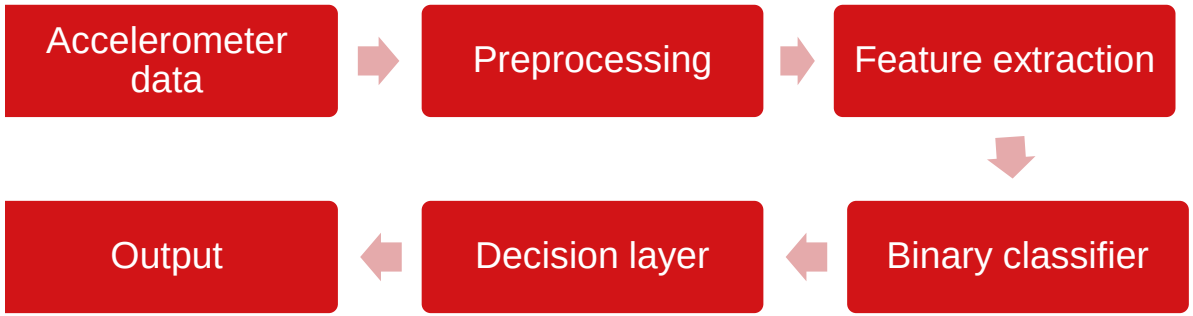
- 22/87 patients had 68 GTCS
- 36 seizures from 11 patients used for development
- Loss of data due to technical failure (11 seizures)
- Loss of data due to human failure (21 seizures)

- 5/87 patients had 48 HMS
- 30 seizures from 4 patients used for development
- Data from low-activity periods used but not only nocturnal
- Loss of data due to technical failure (2 seizures)
- Loss of data due to human failure (8 seizures)

EPILEPSY

- The overall aim is to detect epileptic seizures with high sensitivity and specificity.
- We have designed a generic detection algorithm focused on GTCS using machine learning methods. A number of commonly used classification methods have been evaluated.
- The performance is improved by more complex non-linear classifiers. They appear to improve algorithm generalizability and robustness against high frequency non-seizure movements





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Further development

- Further work on signal processing algorithms
- Improvement of the integration of electronics and sensors in the textile.
- Improve the robustness of the garment
  - Manage 40 C machine wash
  - Manage normal handling (dressing/undressing)
- Improve the production of the garment

Conclusions

- wearITmed is a cross-scientific project with close collaboration between the partners
- Input from patients and health professionals is essential
- Challenges span from practical aspects such as washability to advanced technical development
- As yet we have no commercial partners, but we are currently taking several contacts

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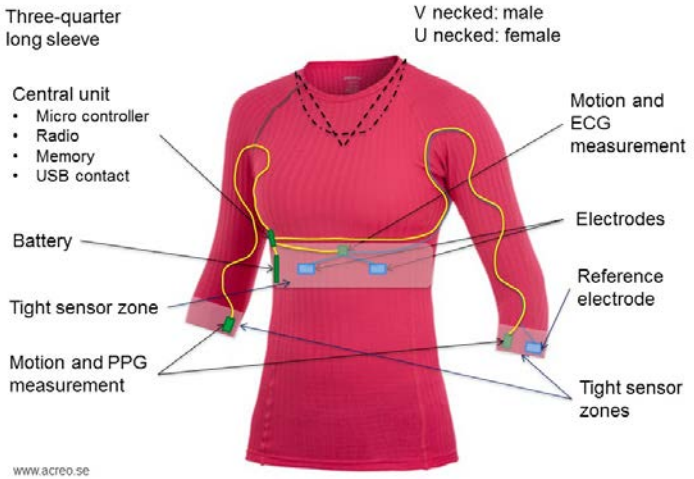
Thank you for your attention!



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