# Estimating Cognitive State with Physiological Sensing: Opportunities and Challenges in Digital Manufacturing

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## Introduction

As industrial work activities become increasingly cognitive, management of operator mental workload, situation awareness, and decision making is critical for ensuring safe, effective system operation. Physiological sensing technologies, such as functional near infrared spectroscopy (fNIRS), show promise in terms of assessment of cognitive state and may offer less-invasive ways to assess performance.

To this end, DigiTOP's Work Package 3 is focused on:

- Identifying relationships among human performance/behaviour, cognition, and physiological responses
- Exploring applications for physiological sensing in factory environments
- Demonstrating continuous near-real-time human performance estimation in connection with Digital Twin research activities

### DigiTOP Objectives

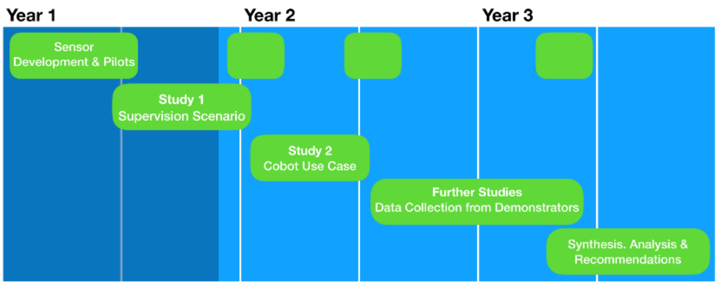
DigiTOP is an EPSRC-funded, 3-year (2018-2021) project that seeks to enable industrial decision making through improved understanding of the impact of digital technology on humans involved in manufacturing operations. Through this work, DigiTOP will:

- Deliver an open-access digital toolkit to support implementation of digital manufacturing technologies (DMTs) and prediction of their impact on humans in manufacturing systems
- Identify human requirements for tool design that supports operator workload, situation awareness, and decision making
- Explore ethical, organisational and social impact of DMT introduction into workplaces

### Research Challenges

- Identifying the mapping between operator cognitive states and physiological response
- Developing a framework for multi-sensor integration
- Effective detection and filtering of the motion artefacts present in the physiological data, especially fNIRS data

## WP3 Roadmap and Contributions




- Integration and validation of physiological sensor systems within DigiTOP industrial use cases
- Framework for collecting and analysing physiological data for real-time performance evaluation
- Improved understanding of the relationship between physiological patterns associated with variations in mental workload, situation awareness states, sensemaking and decision making

## Acknowledgements

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## Study 1: Physiological Response to Variations in Perceptual Demand, Fatigue, and Task-Unrelated Thoughts

### Research Objectives

To investigate the effects of perceptual demand and cognitive fatigue on physiological response, including oxyhemoglobin (HbO2) and deoxyhemoglobin (HHb) concentrations in the medial prefrontal cortex (mPFC) and middle temporal gyrus, blink rate, heart rate, breathing rate, and facial skin temperature.

### Study Design

The study adopted a two-factor within-subjects approach to investigate the effects of varying perceptual demand (low vs. high perceptual demand) and mental fatigue (low vs. high fatigue) on physiological response during a visual search task inspired by Forster & Lavie (2009)[1]. The task was built in PsychoPy[3] and designed in line with Figure 1.

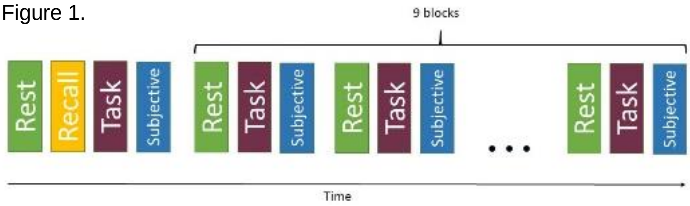


Figure 1: Task timeline

Task blocks were of low or high perceptual demand and were randomly presented .During each of these blocks, participants were presented with 50 cork coaster images (1.9 seconds each) followed by a 0.9 seconds blank screen.

During the low perceptual demand block, each image presented contained only one coaster with one of the two defects they were asked to identify (Figure 2) while during the high perceptual demand block, four cork coasters were presented, only one having one of the two defects (Figure 3).

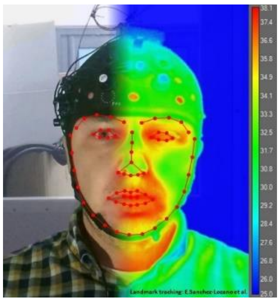

Figure 4: Visual-thermal fused image showing a participant wearing the fNIRs head cap as well as the landmark tracking[2]

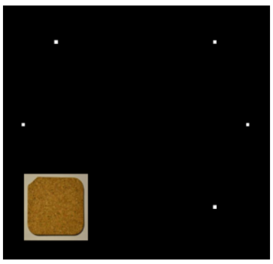

Figure 2: Low perceptual demand sample

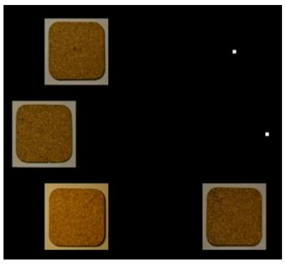

Figure 3: High perceptual demand sample

### Sensors

- Artinis Octamon+ fNIRS
- Zephyr Bioharness 3
- FLIR A65sc Thermal Camera
- Visual Camera

## References

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3. Peirce, J. W. (2007). PsychoPy—Psychophysics software in Python. Journal of Neuroscience Methods, 162(1), 8-13.