Operator tracking for fighter pilots: review of sensing technologies for flexible cockpit automation

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Problem

- Today’s pilot environments are *blind* to the operator:
  - Fatigue level
  - Cognitive control: workload (information overload)
  - Attention level
- Hypothesis: Having knowledge of the operator could improve *human-automation collaboration*
  - HMI could provide info when the operator is *not* busy
  - Know what the operator has seen
  - Pilot´s current tasks

Agenda

Work in progress

- Operator tracking – research aim
- Physiological signs and cognitive processes
- Candidate sensing approaches
  - Pros and cons
- Our approach – current work
- Conclusion

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Operator tracking – research aim

- Workload and stress levels
- Situation awareness and attention
- Fatigue
- Analytics pipeline
  - Model of the operator's health
    - Physical state (workload, fatigue etc.)
    - Short term and current tasks (i.e., observed objects)
      - Attention guidance
    - Cognitive control level (metrics)

Human states and responses

- **General state**
  - Arousal (activity level)
  - Fatigue etc
  - Workload and stress levels

- **Situation-specific response**
  - Startle respons (direct threat)
  - Orienting respons (OR)
  - Defensive respons (DR)

Signs and cognition

State	Signal	Reference
Cognitive workload/stress	**HRV – heart rate variability, EEG alpha decreases**	Mulder et al., 1993 Hjortskov et. al., 2004
Inattentiveness	EEG-DELTA	Harmony, 2013
Attention	**Respiratory rate**	Harver, Lorig 2000
Frustration	Camera data	Kapoor et. al., 2007
Fatigue	EEG-DELTA, EEG-ALPHA, EEG-BETA. EEG-GAMMA, **Eye blink frequency**	Papadelis et. al., 2007
Cognitive activity/drowsiness	EEG-GAMMA, **Eye blink frequency**	Merker, 2013
Distraction/poor performance/Disengagement/task switching behavoir	**High levels of locus coeruleus tonic activity**	Kane et al., 2017
Fatigue	Increasing mental fatigue coincides with diminished stimulus-evoked pupil dilation	Hopstaken et al., 2015
Task difficulty	Harder task implies pupil dilation	Gabay et al., 20xx

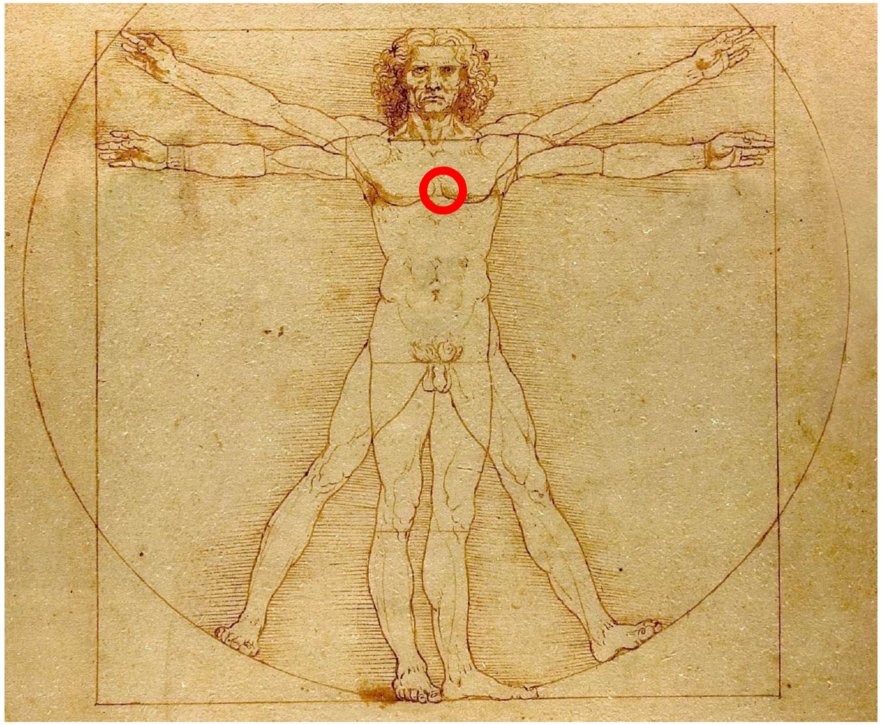
Eye and pupil behavoir

State	Signal	Reference
Task difficulty	Pupill dilation	Hess & Polt, 1964, Klingner et al., 2011, Krejtz et al., 2018, Granholm, Asarnow, Sarkin, & Dykes, 1996, van der Wel et al., 2018, Gabay et al., 2011
Tasks and goals	Fixation time increase	Hannula et al., 2010
Attention, object interest	Fixation time	Eckstein et al, 2017
Fatigue	Blink frequency	Papadelis et. al., 2007, Merker, 2013
IQ	Pupil dilation	Ahern & Beatty, 1979; Beatty, 1982
Cognitive control	Blink frequency	Van Bochove et. al., 2013
Task flexibility		Sherman et. al. 1998
Sleep deprevation	Blink frequency	Barbato et al., 2000
Distration, unusual auditory tones	Pupil dilation	Wetzel et al., 2012
Fatigue	Lessed stimlulus-induced pupil dillation	Hopstaken et al., 2015
Loss of visual information	Blink frequency	Hoppe et al., 2018
Distration/under achievment	General pupil dilation	Kane et al., 2017
Task difficulty	Number of blinks/contextual	Hoppe et. al., 2018
Cognitive flexibiity	Sponteneous eye blinks	Chermahini and Hommel, 2010

What is a suitable approach for tracking general states and situational-induced states of pilots?

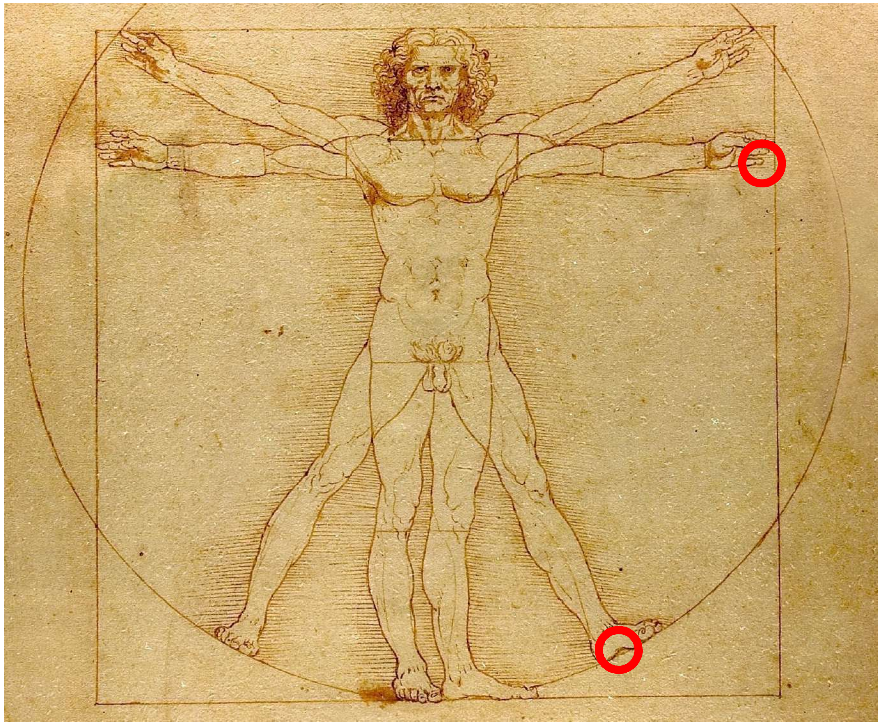
Physiological signs and cognitive processes (1)

- Cardiovascular signs
  - **HR/HRV**
  - Peripheral blood flow
- Pletysmography
- fNIR
- Chest bands
- Cognitive workload
- De-acceleration-acceleration pattern
  - OR response



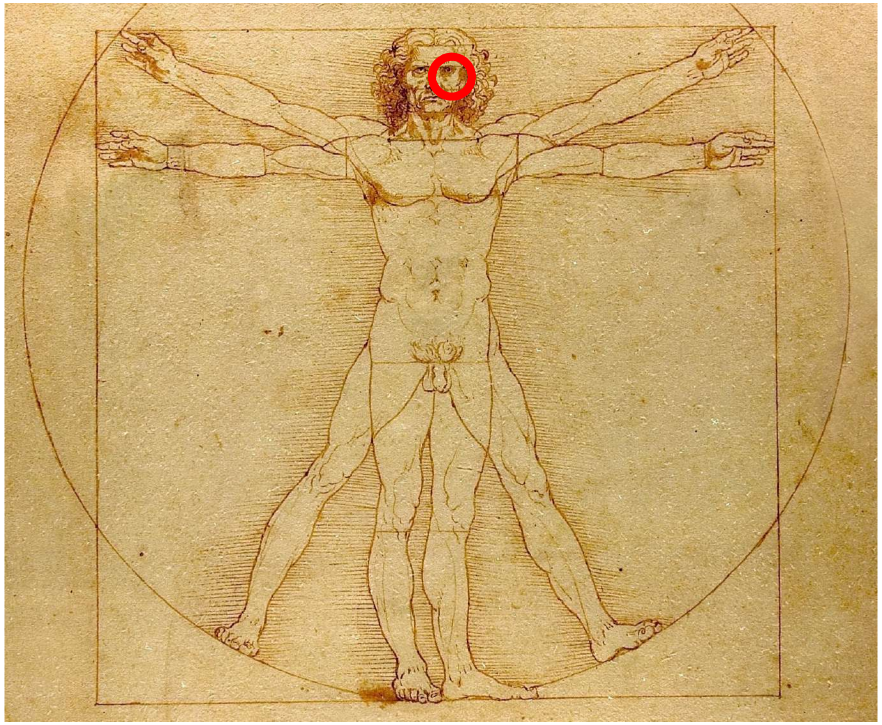
Physiological signs and cognitive processes (2)

- **Electrodermal response**
- General activation level
  - Arousal (tonic signal level)
- OR response (phasic response)
  - Threat
  - Object significance
- Slow transient response



Physiological signs and cognitive processes (3)

- **Eye and pupil response**
  - Fatigue
  - Attention (general and specific)
  - Object interest (threat level)
  - Fast response
  - OR response
- 60 Hz cameras
  - Suitable for helmets



Problems

- Human phsisological responses are individual
  - Individual baselines
- Some signals not detectable
  - EDA
- Delayed responses
  - EDA (0,5 s)
- Artefacts
  - Light conditions
- Practical aspects (rules our EEG, also, blinks a problem)

An experiment: Infrared

- Heat camera (FLIR)
  - Face temperature -> workload
- ML-algorithm – facial features
- 25 Hz measurements
  - Skin temperature and breathing rate
- FLIR camera->expensive
- Not practical


SHUTTER TEST CAM #1
R101=8.2KΩ
with ATFI T128168A
Adhesive - No shims
13 mm

Conclusion

- Integrated multisignal approach suggested
  - Combine HR/HRV, EDA, advanced eye tracking
  - Machine learning with sequential real time inference
    - Hypotheses of the operator state
    - Later responses in the pipeline may validate/falsify faster ones
- Sensors should be comfortable, be built into the flight suit and helmet
- No calibration

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