Measuring behavior, perception, attention and mental state

New sensors, tools and analytics support data-driven training and assessment

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NextGen Training Technologies – Industrial Conference

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Company information

Noldus Information Technology

- Developer of software, hardware and integrated solutions for measurement and analysis of human behavior
- Founded in 1989
- Headquarters in Wageningen, The Netherlands
- Offices across Europe, North America, Asia
- 165 employees
- Clients: universities, research institutes, industry (automotive, aerospace, maritime, tech companies, etc.)

Human factors and interactive systems

Background and scope

- **Human factors**: application of **psychological** and **physiological** principles to the engineering and design of products, processes, and systems
- **Goal**: better understanding how humans can work in harmony with technology
- **Application**: system design, procedures, **training** to reduce human error, increase productivity, enhance safety, optimize comfort when operating an interactive system
- **Examples**: aircraft, car, train, ship, control room, or any other mission-critical system

Human factors approach to training and assessment

Processes to be addressed

- **Behavior**
- **Perception**
- **Attention**
- **Situational awareness**
- **Mental state**
- **Task performance**

Data-driven training and assessment

Evolution of assessment methods

Observation
Note taking
Qualitative analysis

Measurement
One or a few modalities
Single subject
Post-session analysis

Complex measurements
Multiple modalities
Multiple subjects
Real-time analysis and feedback

Human-system interaction

Measurement and analysis challenges

- What to measure?
- Which sensors to use?
- Synchronizing data streams
- Integrating data
- Analyzing data
- Obtaining insights

The Observer XT

Measuring human-system interaction

Technical trends

- Sensors become smaller, less expensive
- Sensor resolution goes up (e.g. video)
- Sensors become less invasive
- More computing power, cheaper storage
- Data integration: from offline to real-time
- Deep learning: automated pattern recognition

Measuring behavior, perception, attention and mental state

Eye tracking

Tobii Pro Spectrum

Tobii Pro Nano

Tobii Pro Glasses 3

Smart Eye Pro

Screen-based eye tracker
Contact-free
Fixed to one screen

Eye tracking glasses
Use anywhere
Operator free to move

Multi-camera eye tracker
Largest tracking distance, motion box, view angle

Measuring behavior, perception, attention and mental state

Physiological sensing

- Cardiac activity - ECG (HR, HRV) or Pulse (HR)
- Skin conductance - GSR
- Muscle tension - EMG
- Respiration rate
- Brain activity – EEG, fNIRS

Multi-sensor wristbands

EMG

GSR – Galvanic skin response

Pulse rate

fNIRS

EEG

EEG

Measuring behavior, perception, attention and mental state

Facial imaging

Basic expressions

- Happy
- Sad
- Angry
- Surprised
- Disgusted
- Scared
- Contempt
- “Neutral”

Affective states

- Interest
- Confusion
- Boredom

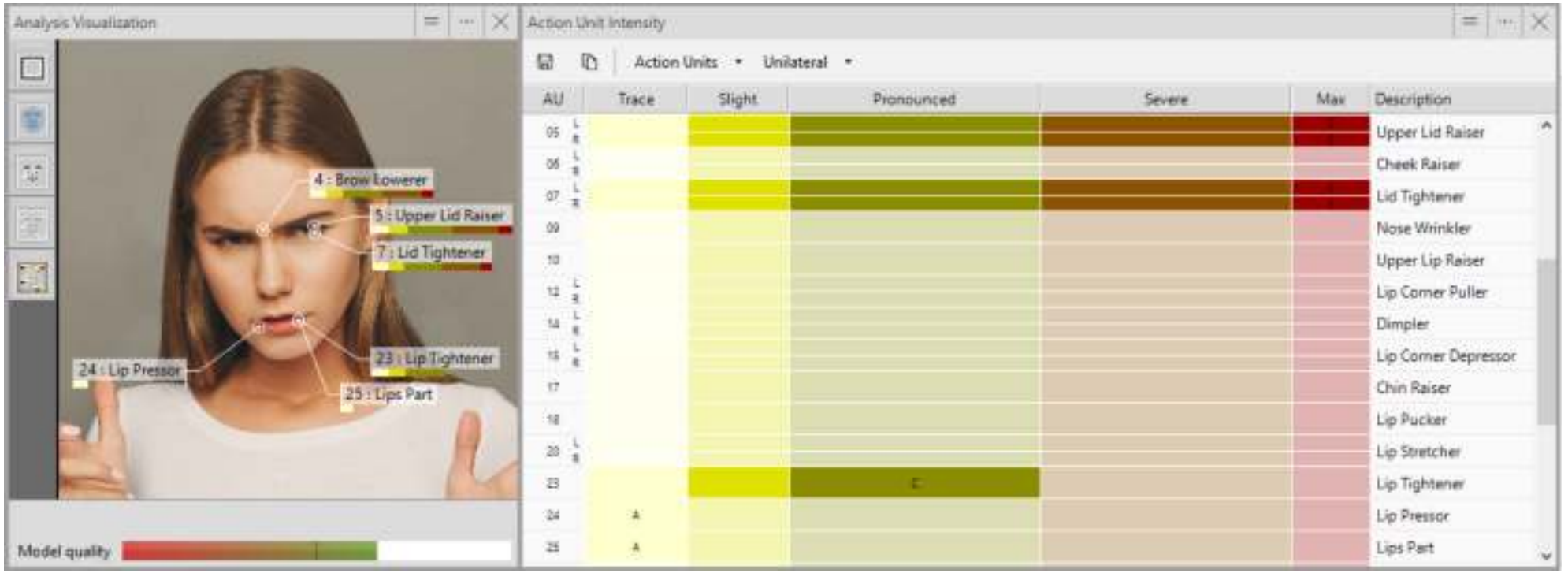
Heart rate

- Remote PPG

FaceReader

Facial imaging

Facial action units



- FaceReader recognizes 20 facial action units
- See them in action on https://www.noldus.com/facereader/facial-action-units

Facial imaging

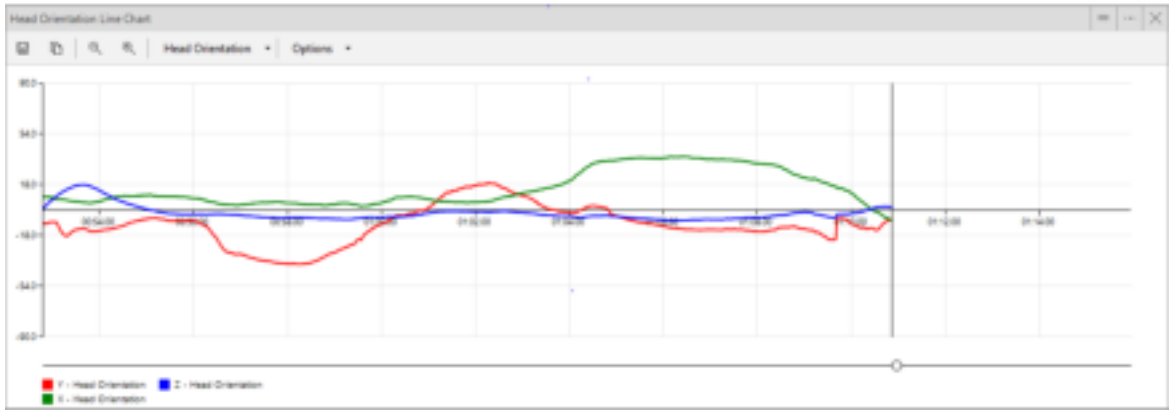
Beyond basic expressions

- Interest
- Boredom
- Confusion
- Attention
- Blink (AU45)
- Smiling
- Laughing
- Leaning Backward
- Leaning Forward
- Head turn left (AU51)
- Head turn right (AU52)
- Head up (AU53)
- Head down (AU54)

Highly relevant for human-system interaction

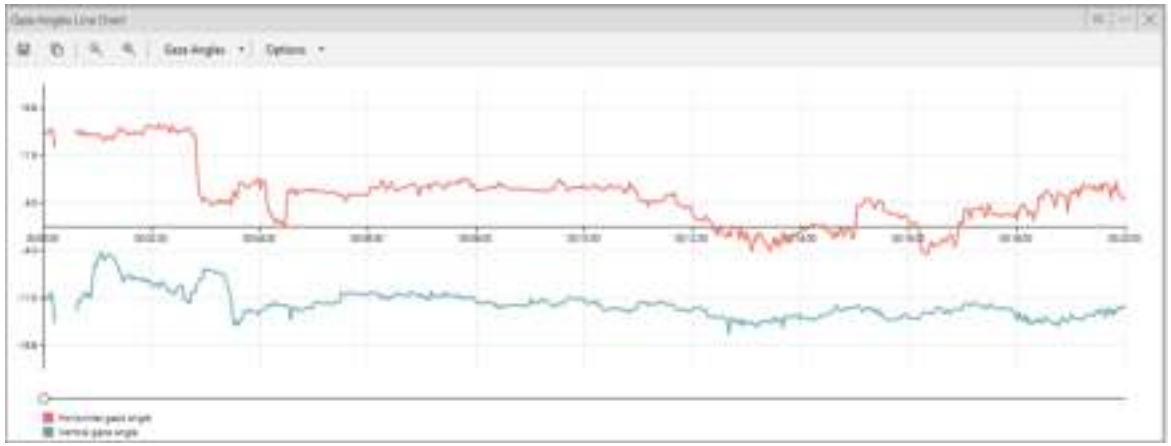
Facial imaging

Head orientation and gaze direction



Head orientation: recorded in three angles (X, Y and Z direction).

Detect nodding (drowsiness), turning (distraction)



Gaze direction: left-up, left, left-down, up, forward, down, right-up, right, right-down. Average error of ~7 degrees (~5 degrees or less for frontal faces~).

Detect areas of visual focus (not as accurate as an eye tracker)

Remote photoplethysmography

Reading your heart rate from a distance

- Blood pressure pulses → changes in blood volume → small changes in skin color, in sync with heart rate
- Software computes heart rate and heart rate variability
- Measure stress level, cognitive workload

Facial imaging

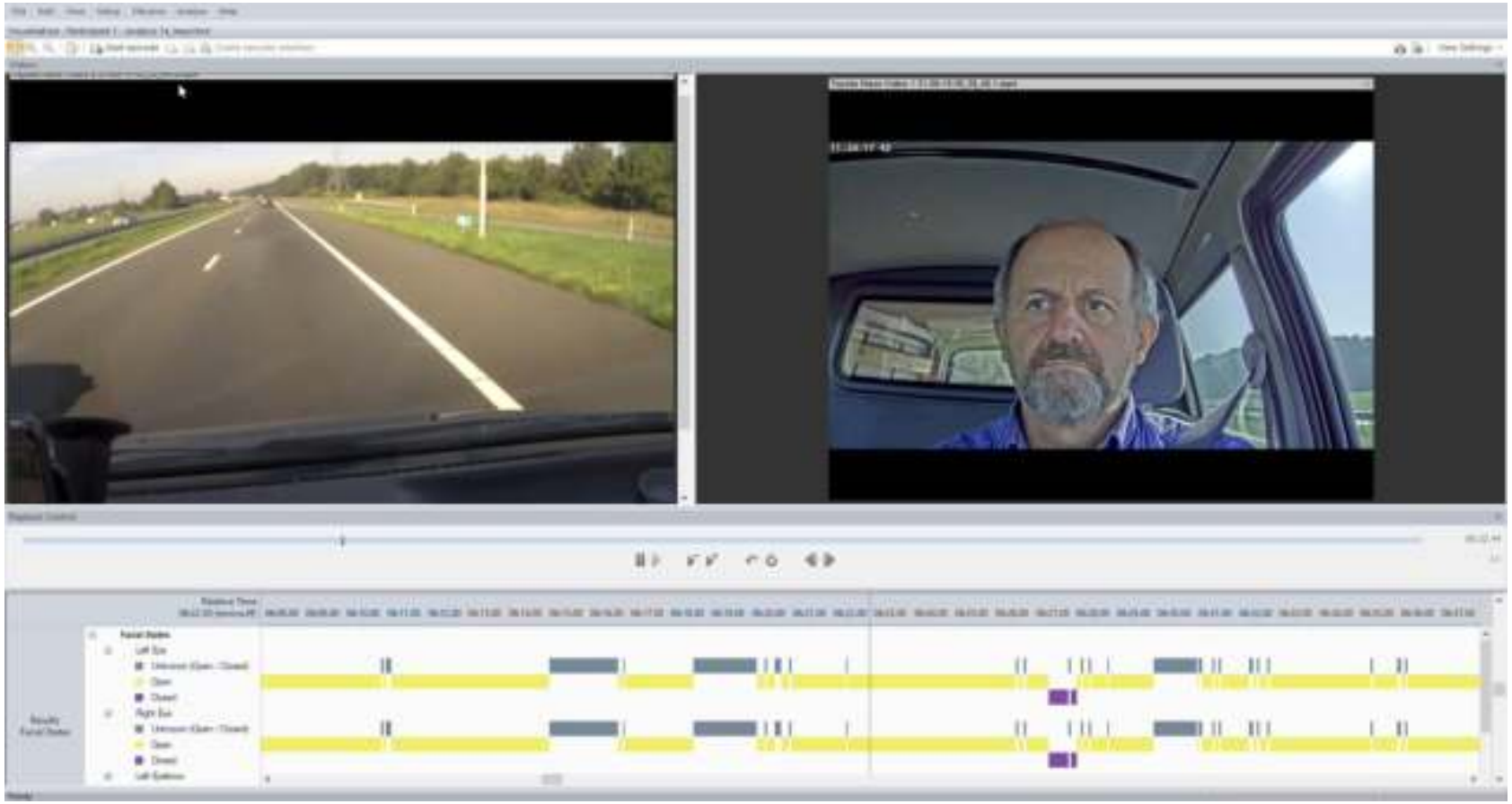
Test in real-world driving scenario

Daylight camera setup

Infrared camera setup

Facial imaging

Usage in car



- Driving context: Day
- Video camera: Daylight camera
- What this video tells us: FaceReader can detect driver drowsiness (eyes closed)

Facial imaging

Usage in car

- Driving context: Day
- Video camera: Daylight camera
- What this video tells us: FaceReader can detect driver drowsiness (forward head rotation)

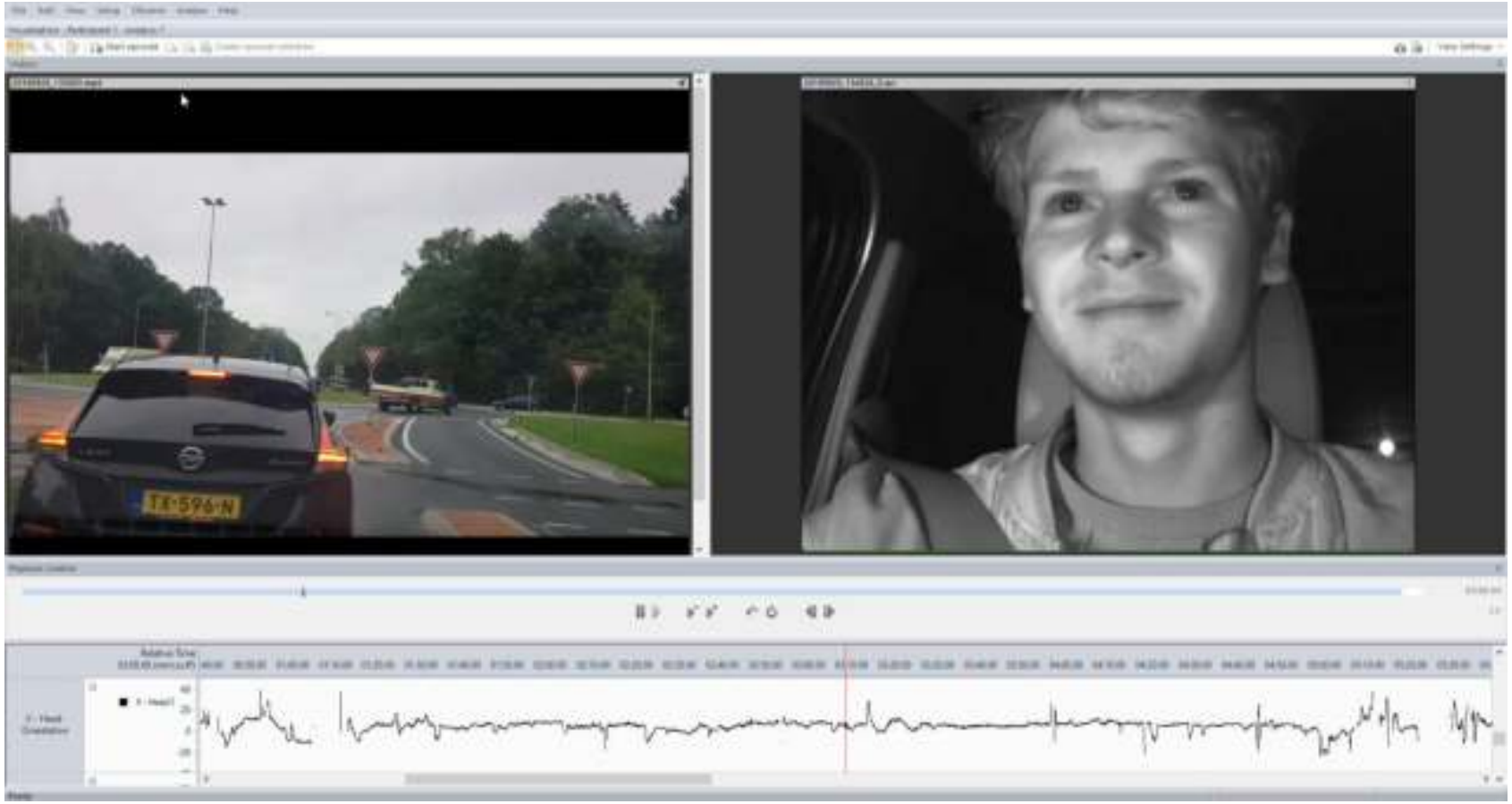
Facial imaging

Usage in car

- Driving context: Day
- Video camera: IR camera
- What this video tells us: FaceReader can detect the facial expressions “happy” and “surprised” in IR images captured in daylight

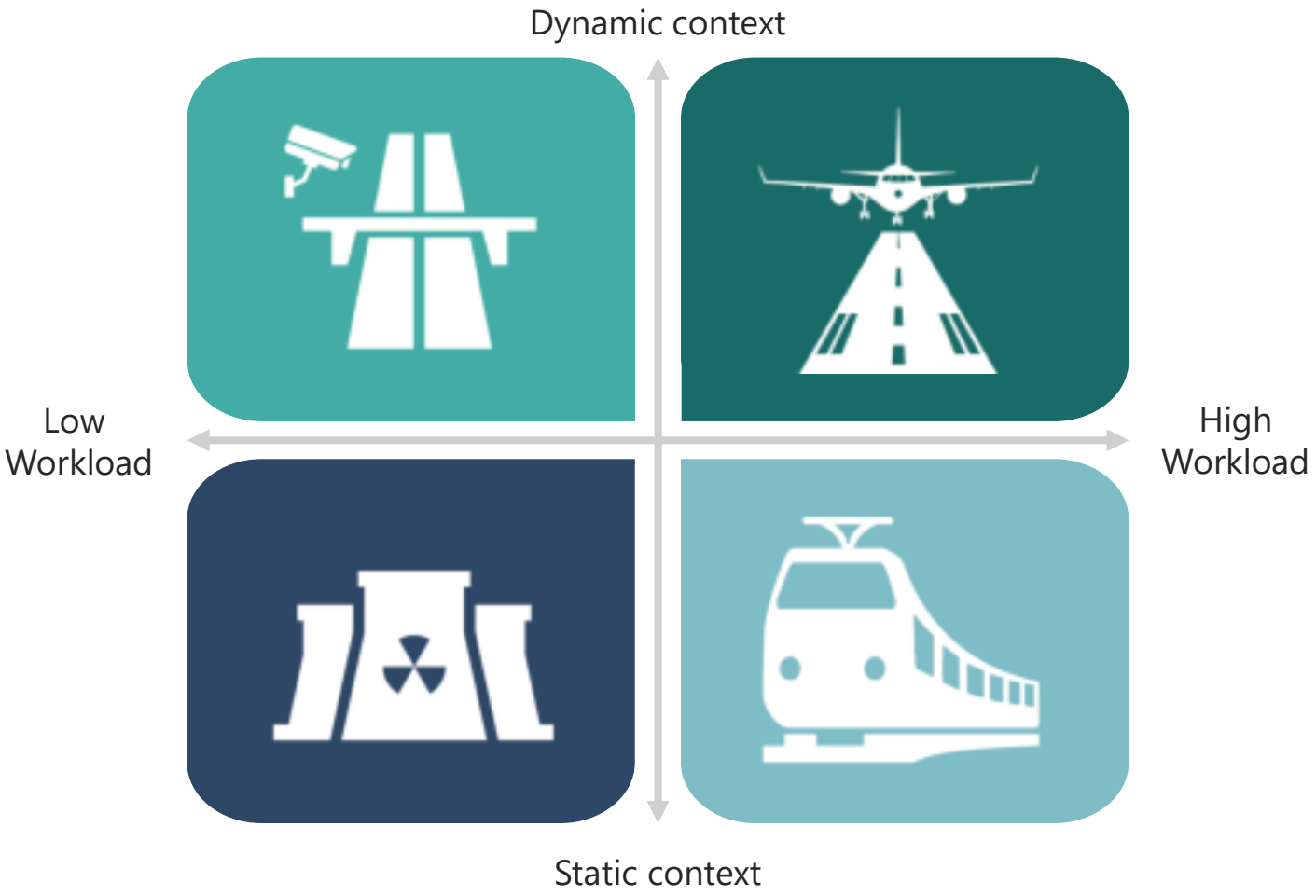
Facial imaging

Usage in car



- Driving context: Day
- Video camera: IR camera
- What this video tells us: FaceReader can detect head rotation (looking in external mirror) in IR images

Training operators, pilots and drivers
A multidimensional challenge



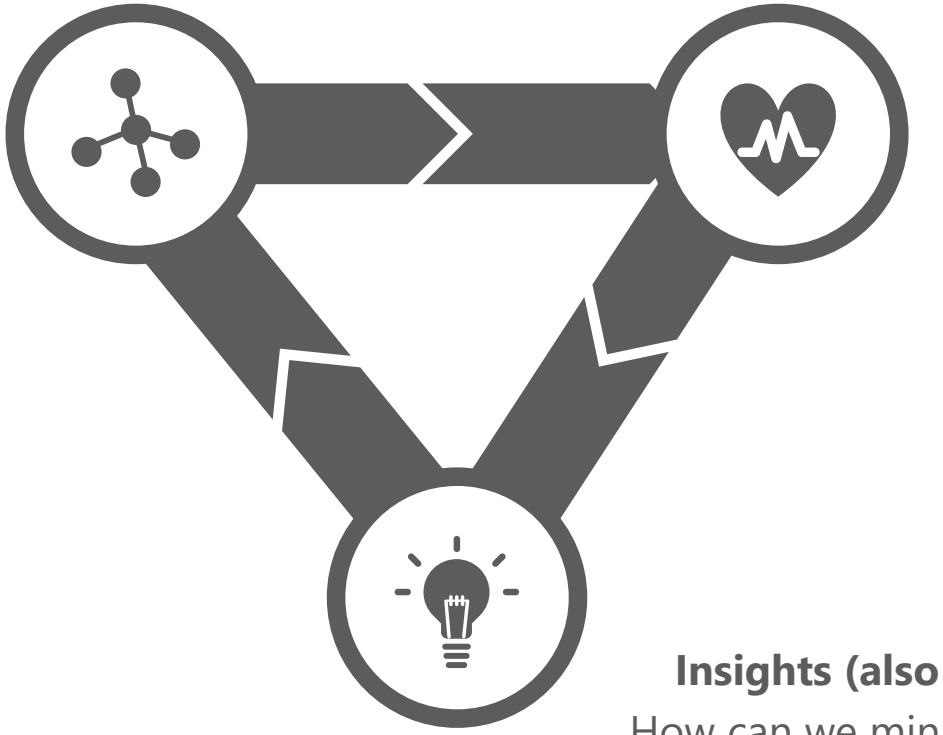
Requirements for assessment system

- Flexible: support many different scenarios, static/dynamic context, high/low workload
- Multimodal: different sensors
- Multiple subjects: interaction
- Real-time analysis and feedback
- Ease of use for the trainer

How to approach this challenge?

Context of the behavior

What is happening around the subject? Which factors are affecting him/her?



Measures representing behavior

Which data can be recorded that helps measure and understand the operator's actions?

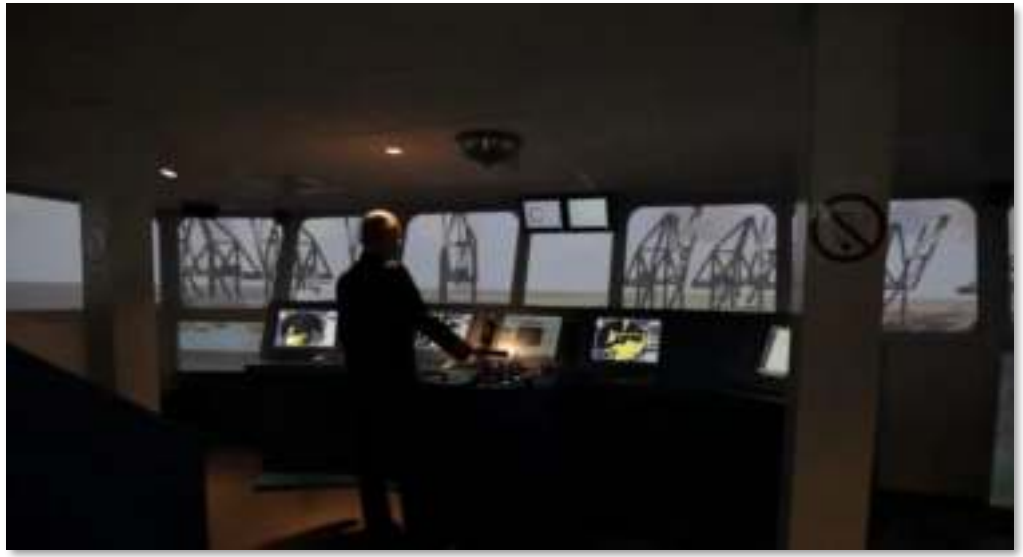
Insights (also during the session)

How can we minimize the delay in a live feedback loop? Or how can we reduce time interpreting data?

Multimodal measurement

Concept validation

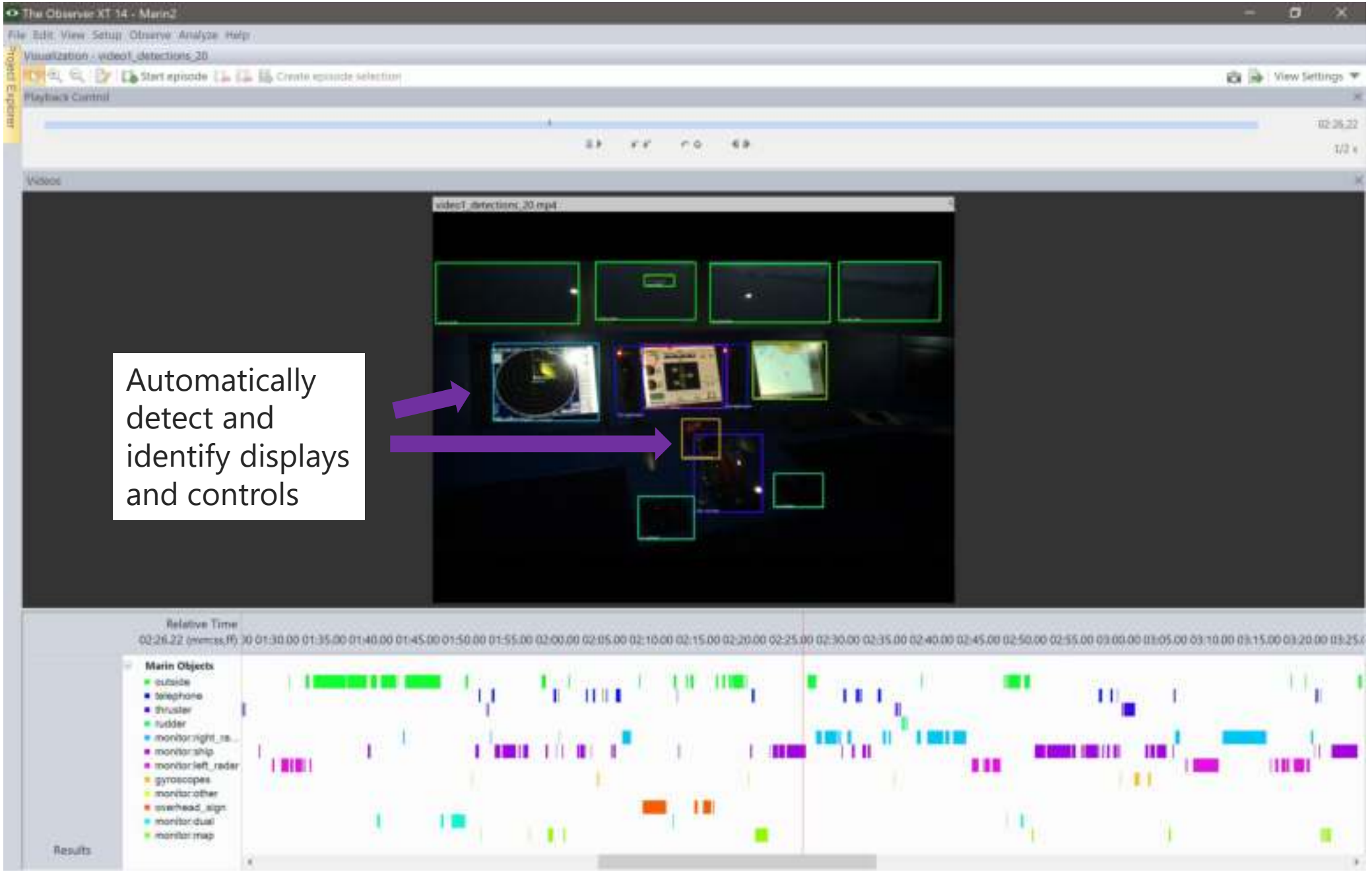
- Industry: Maritime (offshore)
- Use case: Operator in high-risk environment
- Simulation scenario: Tug boat captain has to go to an oil rig and position his barge to allow people to be lowered from the rig onto the deck of the barge.
- Measurement and analysis goals:
  - Where is he looking? Behavior (wearable eye tracking)
  - What is he looking at? Context (automated object detection)
  - Can he manage the task? Insight (cognitive load analysis)
- Technical challenge: automatic object / AOI labeling



The concept

Real-time contextual workload assessment by combining **attention**, using automated object labeling and gaze mapping, and **mental effort**, based on pupil-size change.

- Single sensor (head-mounted Eye Tracking)
- Automatic compensation of light intensity changes
- Real-time data processing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Playback Control
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Automatically detect and identify displays and controls
Relative Time
Marin Objects
outside
telephone
thruster
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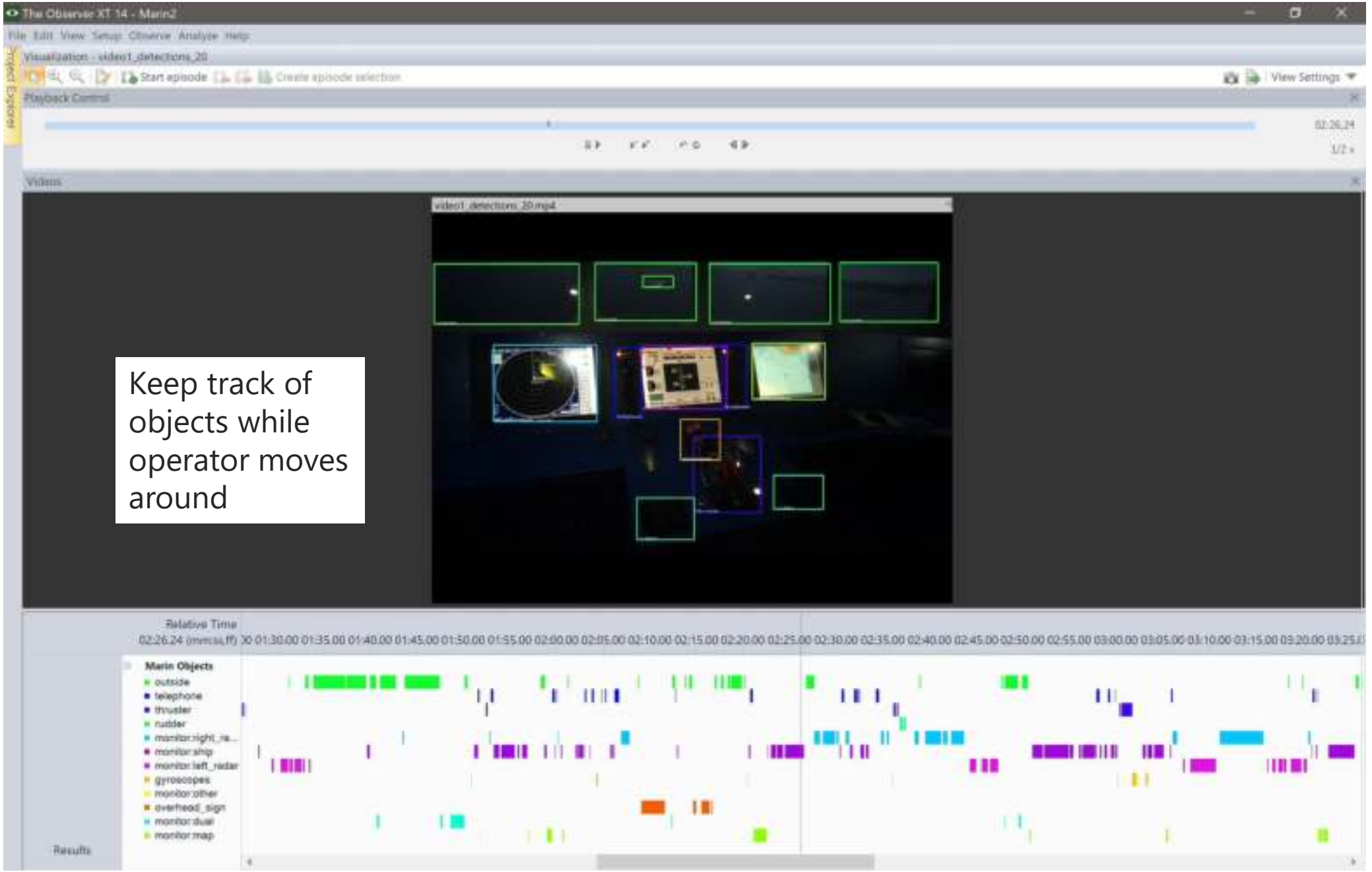
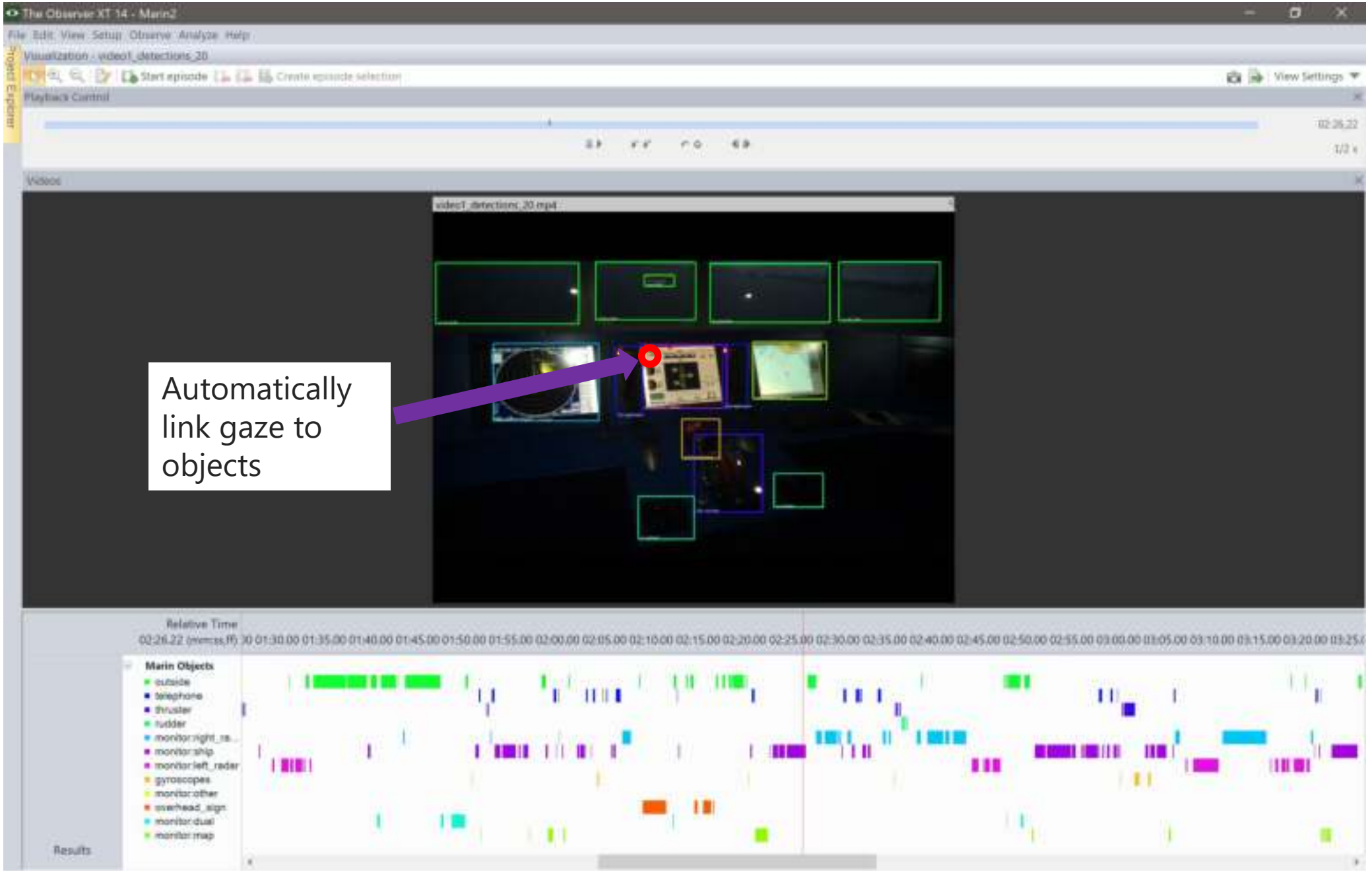
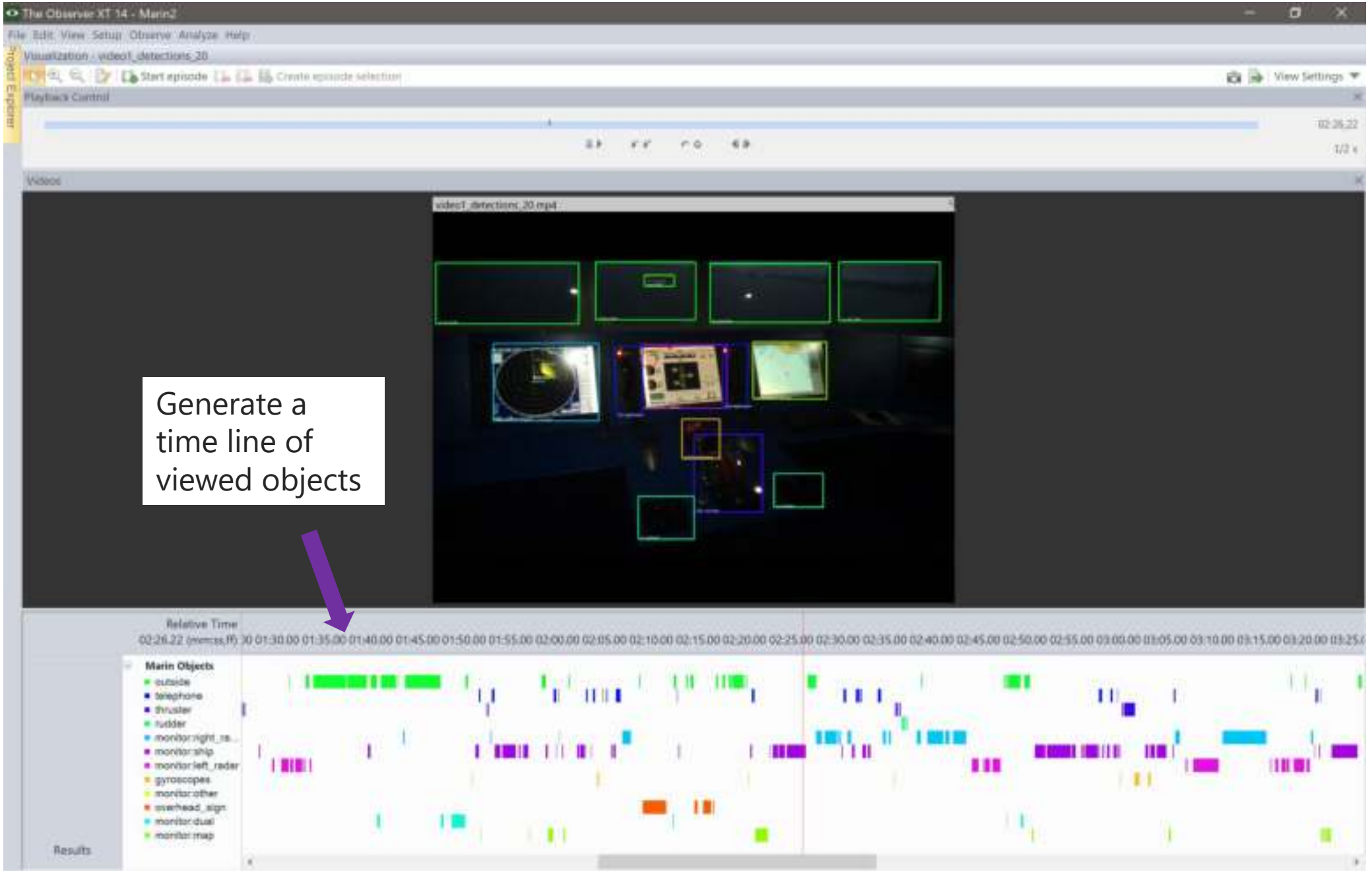
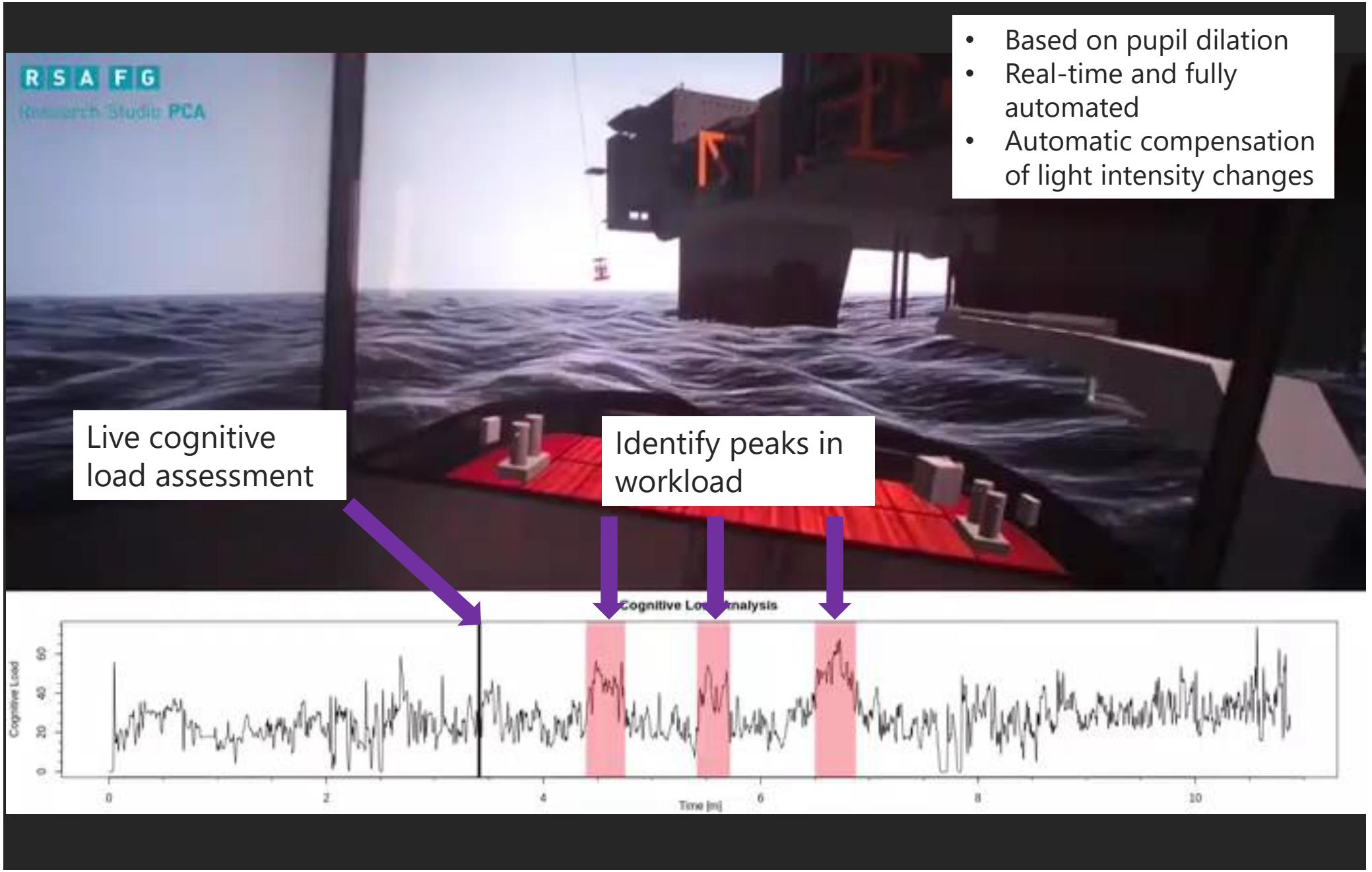
monitor:left_radar
gyroscopes
monitor:other
overhead_sign
monitor:dual
monitor:map
Results

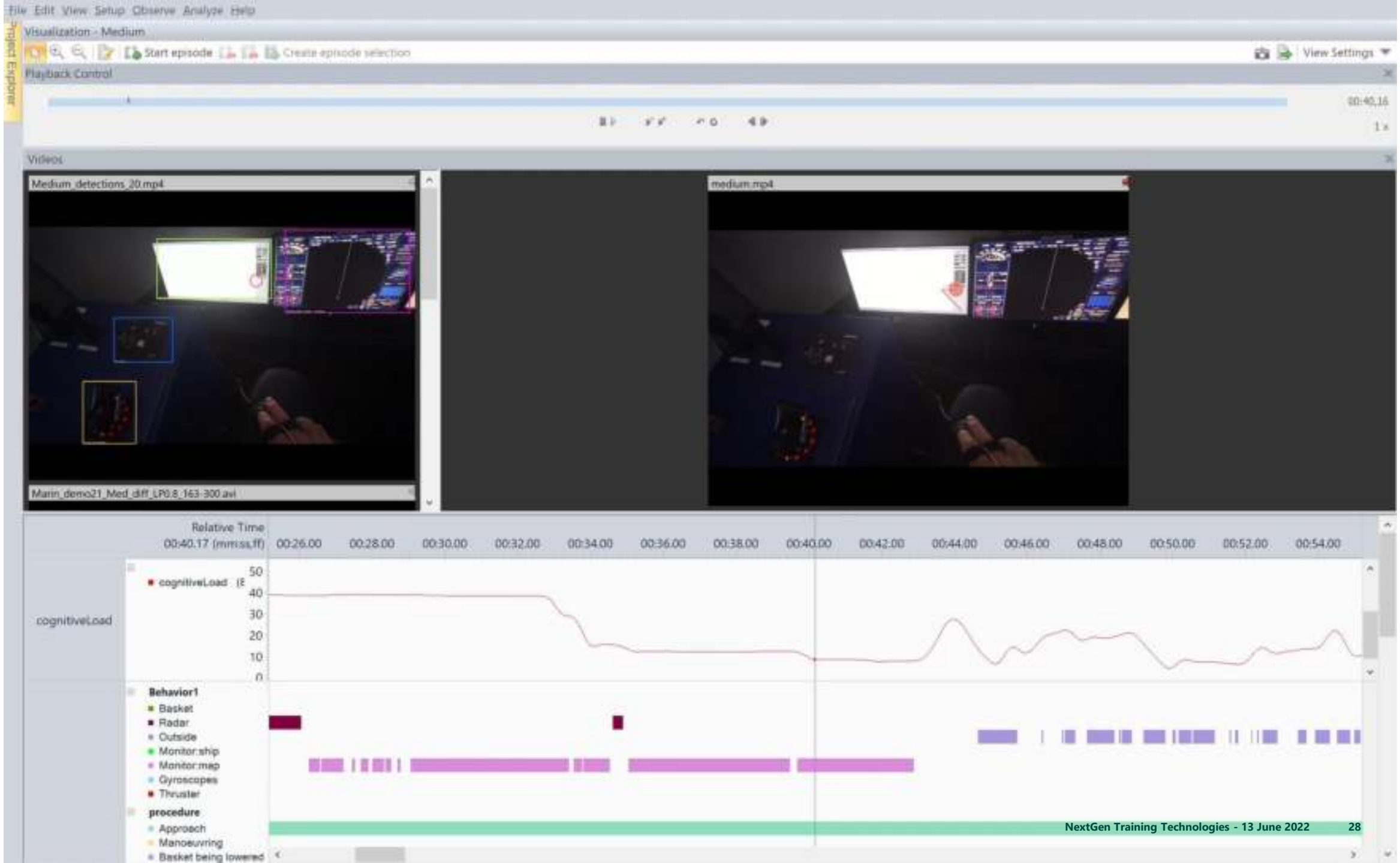

Keep track of objects while operator moves around


Automatically link gaze to objects


Generate a time line of viewed objects



- Based on pupil dilation
- Real-time and fully automated
- Automatic compensation of light intensity changes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Project Explorer
Visualization - Medium
Start episode
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Videos
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Marin_demo21_Med_diff_LP0.8_163-300.avi
medium.mp4
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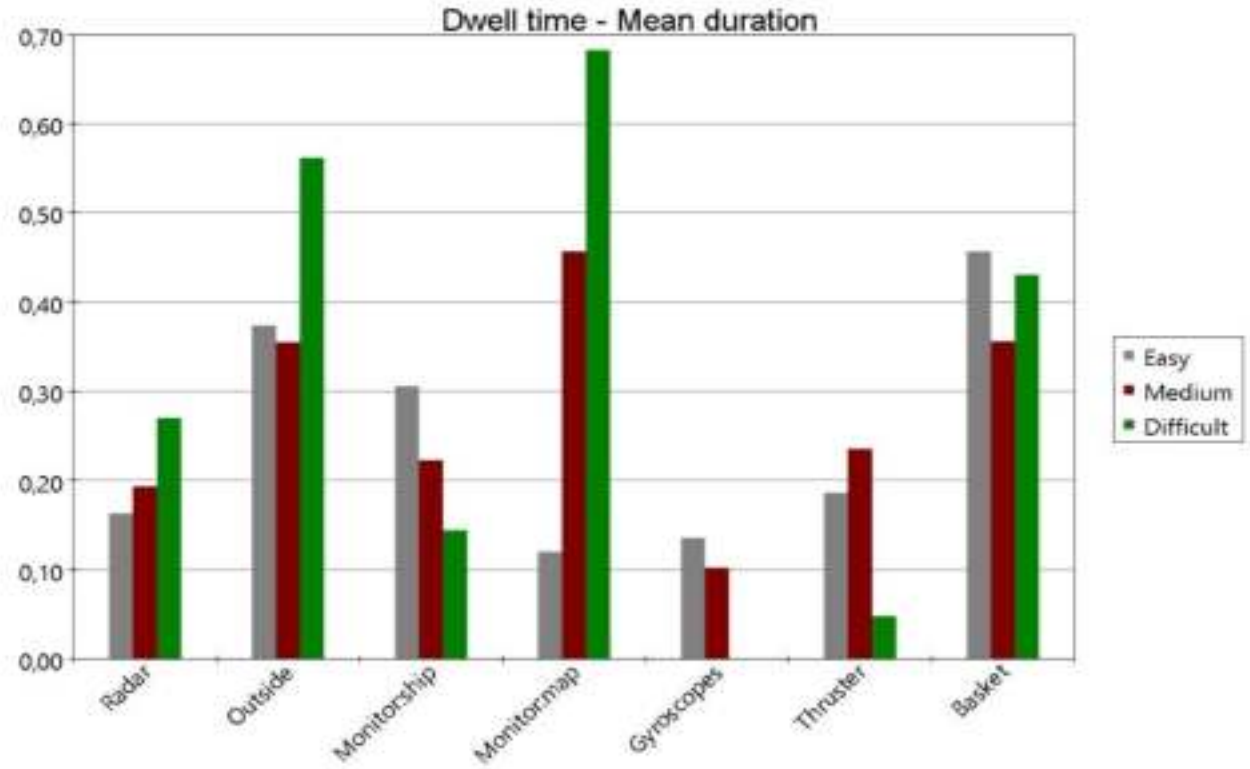
00:44.00
00:46.00
00:48.00
00:50.00
00:52.00
00:54.00
cognitiveLoad
50
40
30
20
10
0
Behavior1
Basket
Radar
Outside
Monitor:ship
Monitor:map
Gyroscopes
Thruster
procedure
Approach
Manoeuvring
Basket being lowered

Multimodal measurement and analysis

Preliminary results: attention

- 3 different levels of complexity:
  - Easy: low wind & current
  - Medium: average wind & current
  - Hard: strong wind & current

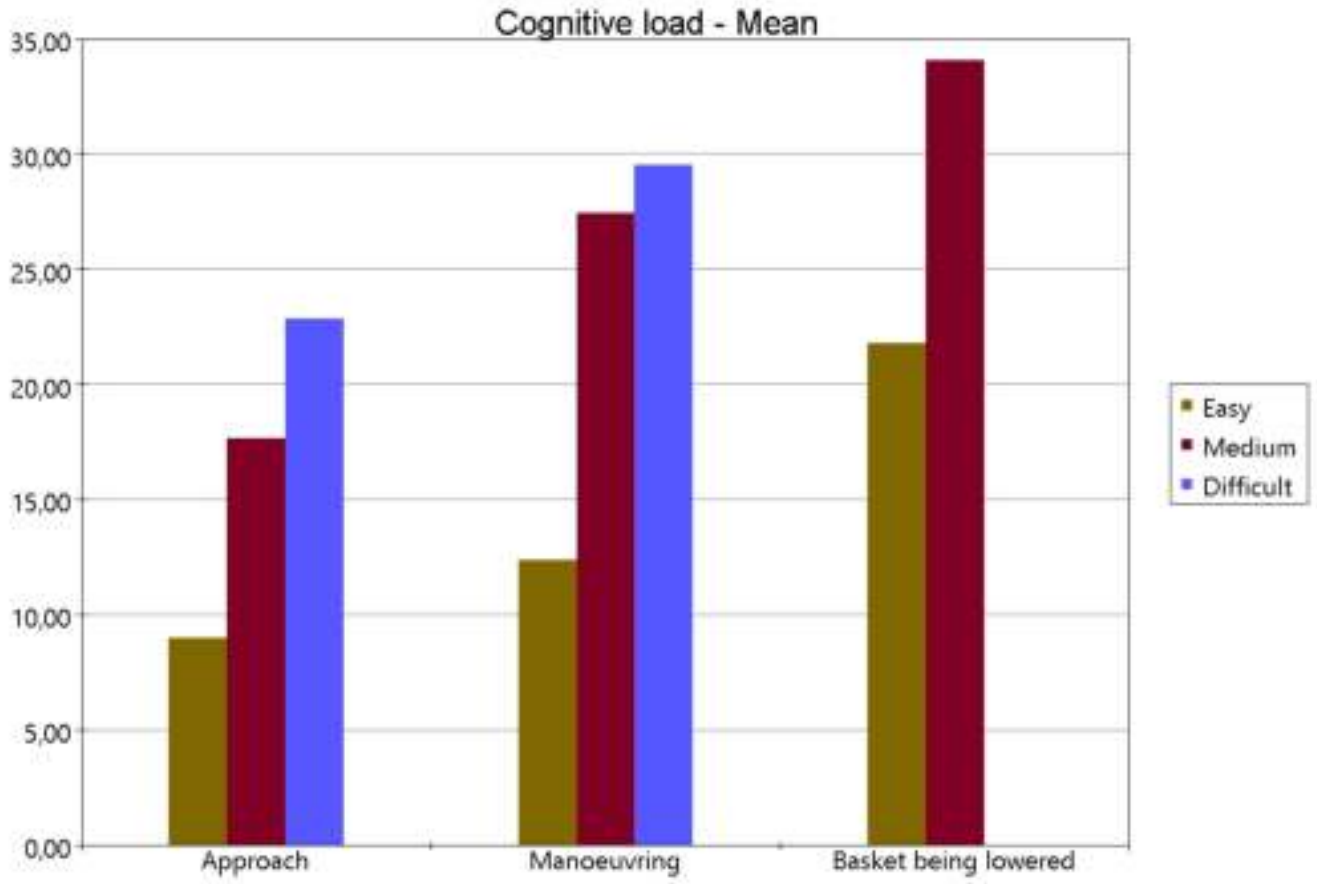
- 3-stage task:
  - Approach
  - Maneuvering: positing the deck of the barge below the basket
  - Basket lowering: keep the deck at the right position & make sure the timing of the basket lowering is in sync with the waves



Multimodal measurement and analysis

Preliminary results: Cognitive load

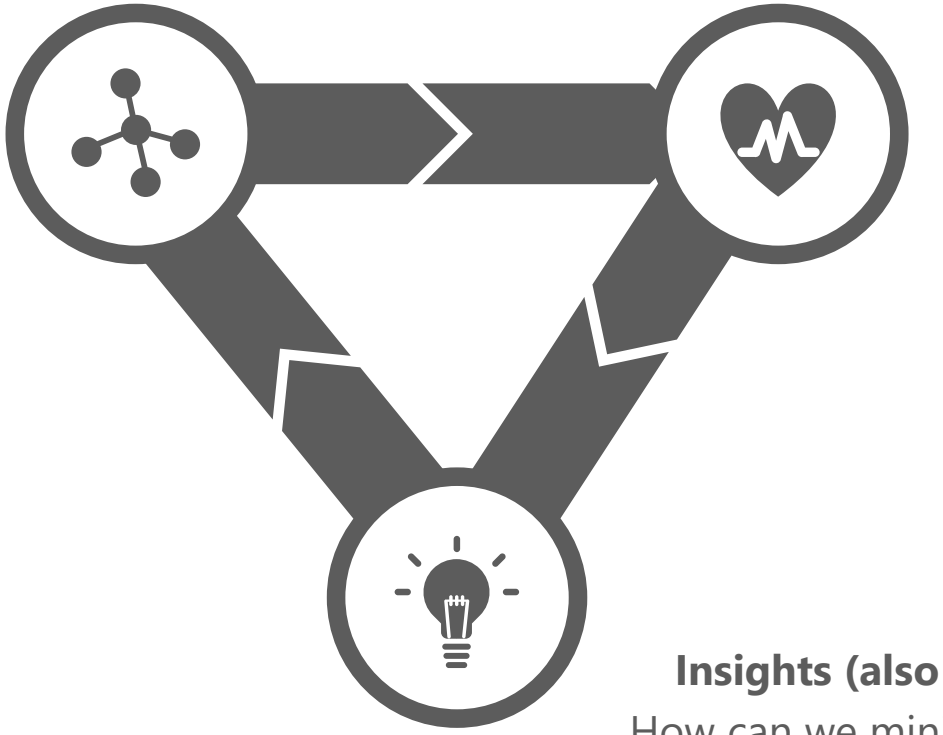
- Cognitive load derived from pupil dilation
- Corrected for changes in light exhibited by the displays



Where do we go from here?

Context of the behavior

What is happening around the subject? Which factors are affecting him/her?



Measures representing behavior

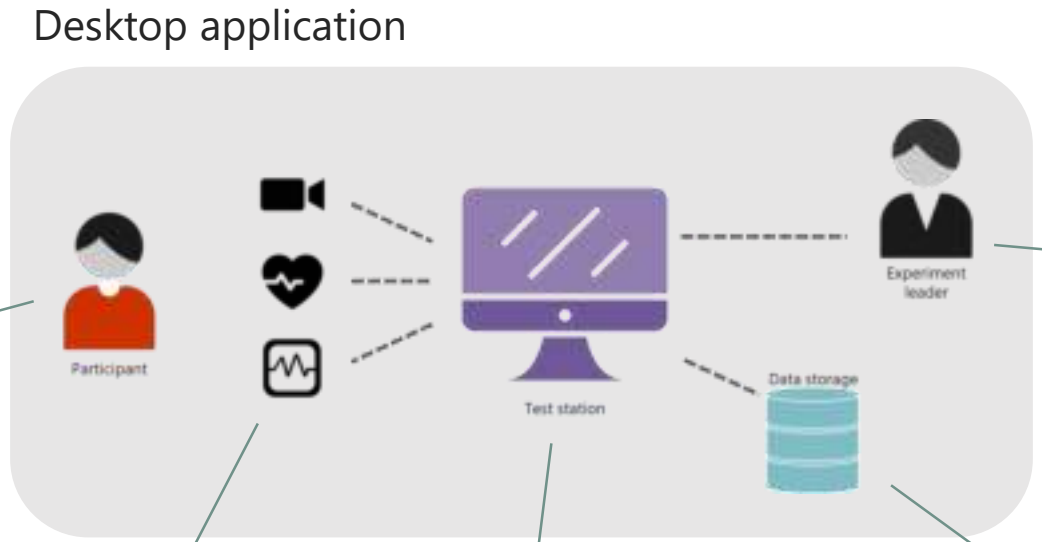
Which data can be recorded that helps measure and understand the operator's actions?

Insights (also during the session)

How can we minimize the delay in a live feedback loop? Or how can we reduce time interpreting data?

Human factors research and training

Traditional measurement setup



Single participant at a time
(how to study interaction?)

Device-specific software
(how to control acquisition?)

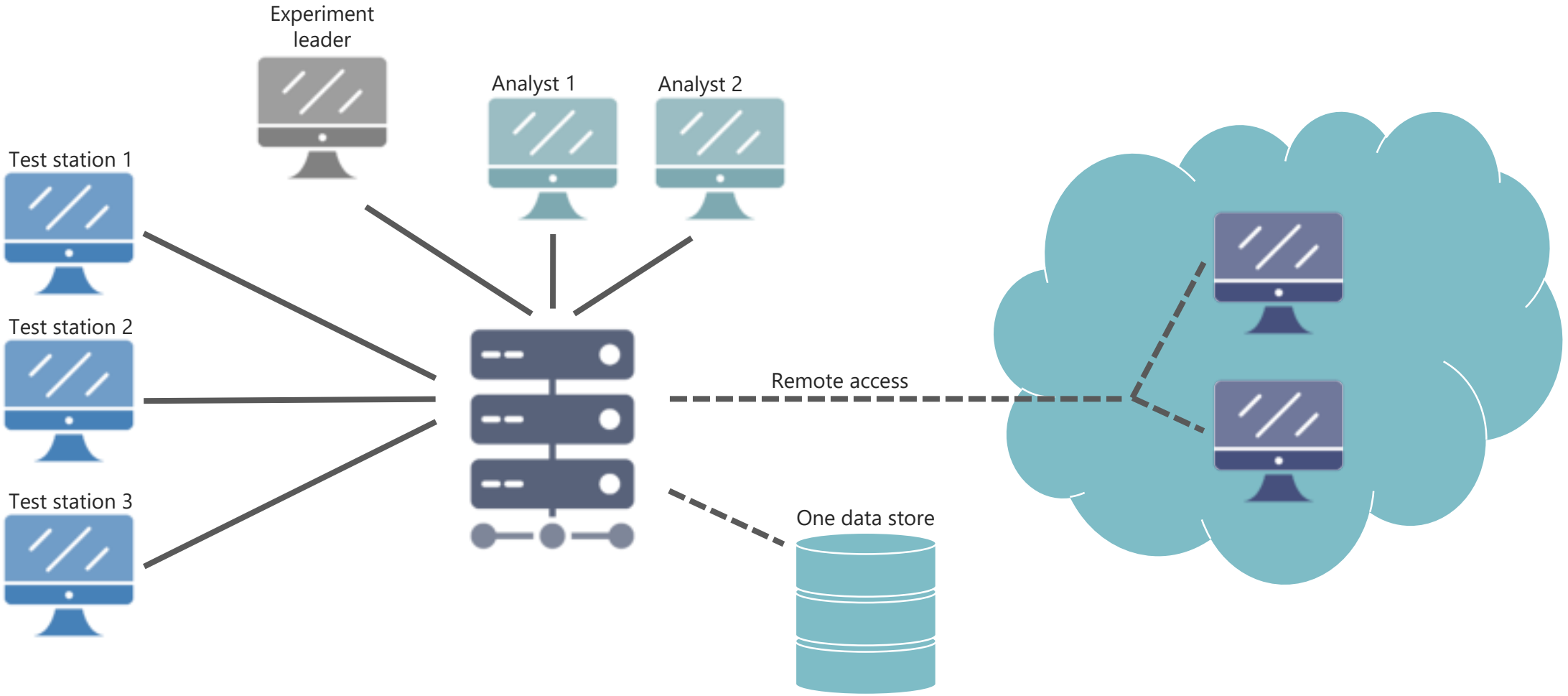
One local PC per participant
(how to organize several recording sessions?)

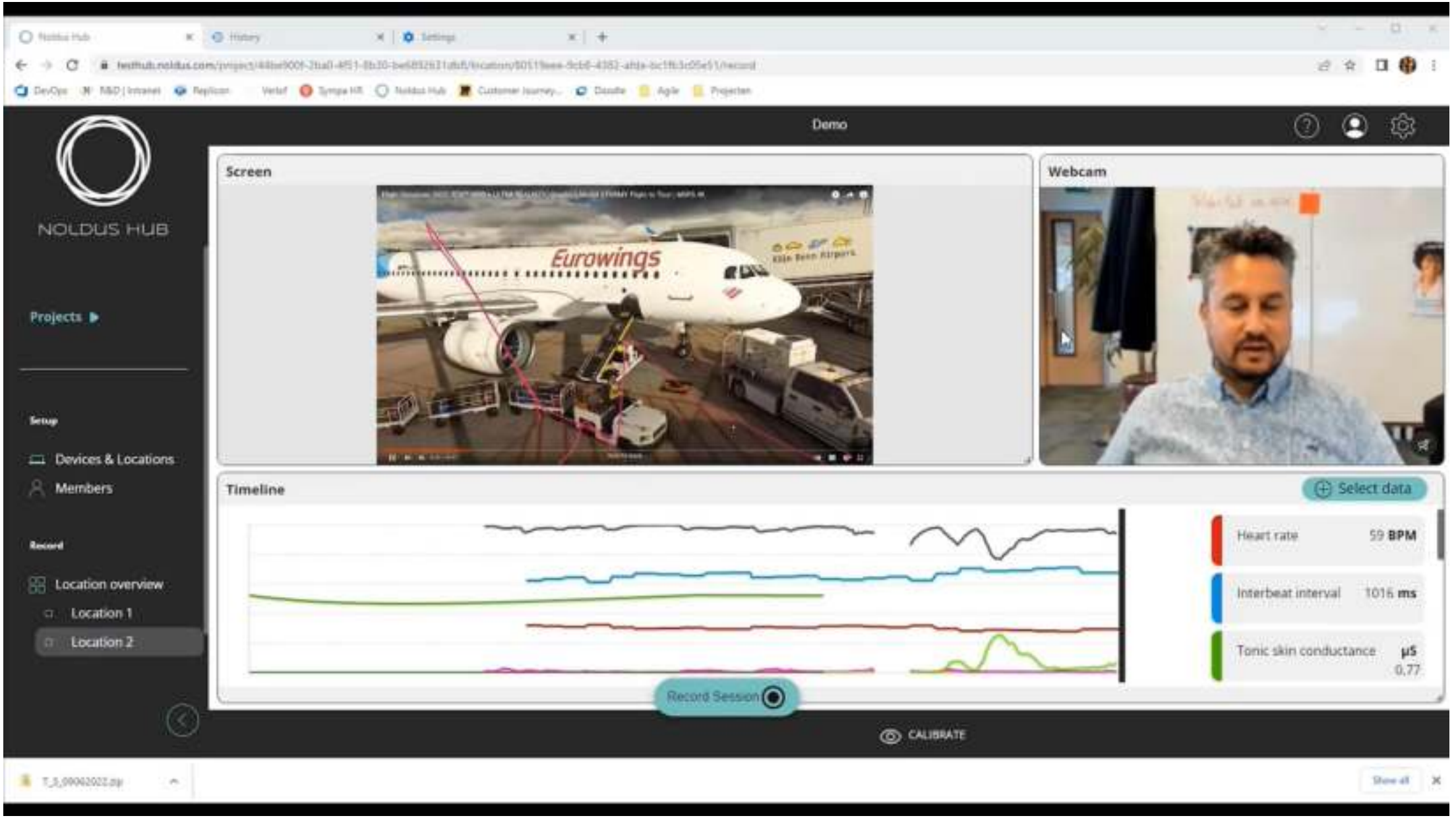
Data storage on every local PC
(how to share, access, and scale up?)

Single user accessing single PC at a time
(how to combine & synchronize data from several test stations)

New: networked research and training platform

Noldus Hub




Demo
NOLDUS HUB
Projects
Setup
Devices & Locations
Members
Record
Location overview
Location 1
Location 2
Screen
Eurowings
Webcam
Timeline
Select data
Heart rate
59 BPM
Interbeat interval
1016 ms
Tonic skin conductance
µS
0,77
Record Session
CALIBRATE

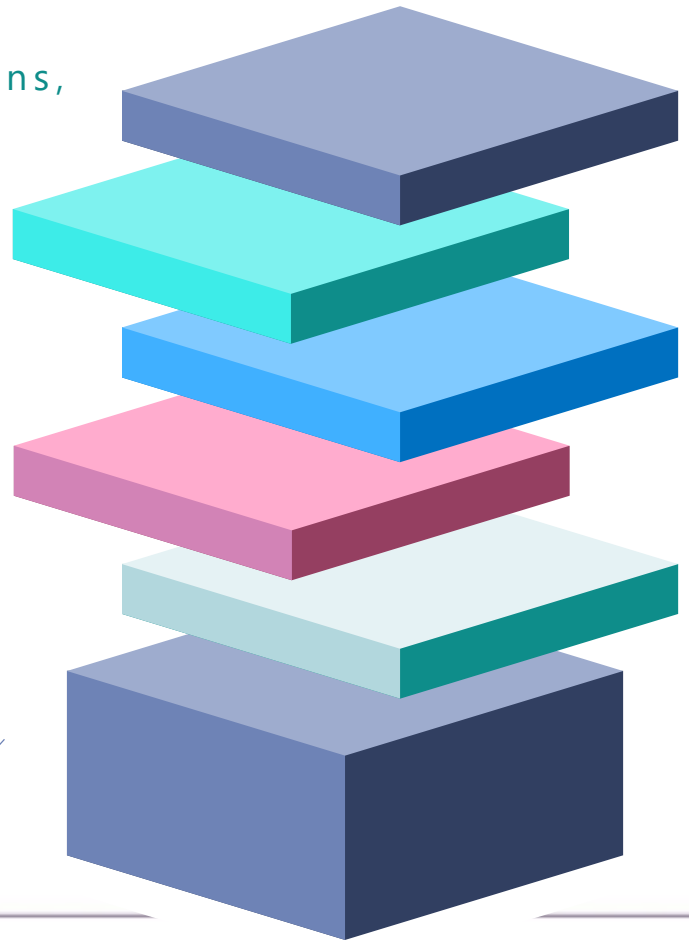
Platform for data-driven training and assessment

Wrapping up: key benefits

Scalable (multiple stations, multiple subjects)

Real-time quality control ("system heartbeat")

Solid IT architecture



Instant playback and data visualization

Insights and transparency

Multimodal measurements made easy

Noldus Hub: work in progress

How can we work together?

Step 3
Let's design the approach

Step 2
Share your needs

Step 1
What is your challenge?

Thank you

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