CogPhys: Assessing Cognitive Load via Multimodal Remote and Contact-based Physiological Sensing

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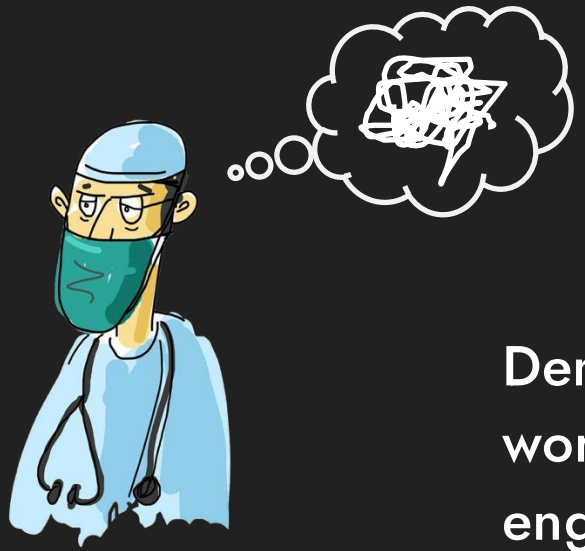
Cognitive load—demand on working memory—impacts performance in critical domains



Cognitive load:

Demand imposed on our working memory when engaging with tasks

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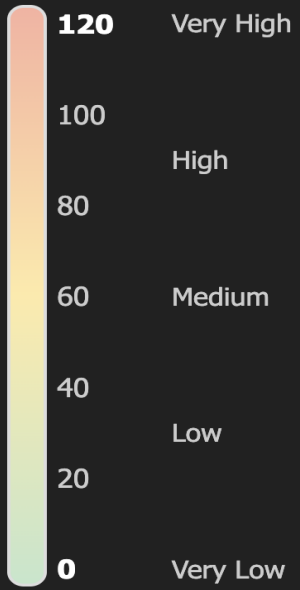
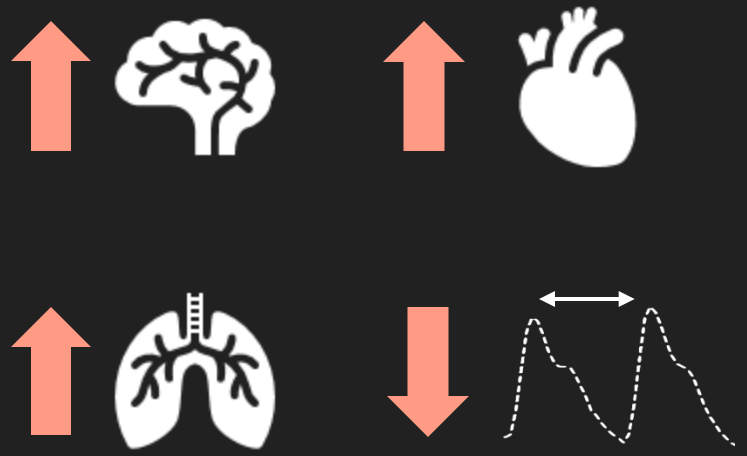
Typical methods to quantify Cognitive Load

NASA Survey Scale
Total Score: 120



Popularly, using contact sensors:
EEG, ECG, chest bands, pulse, etc.



Typical methods to quantify Cognitive Load

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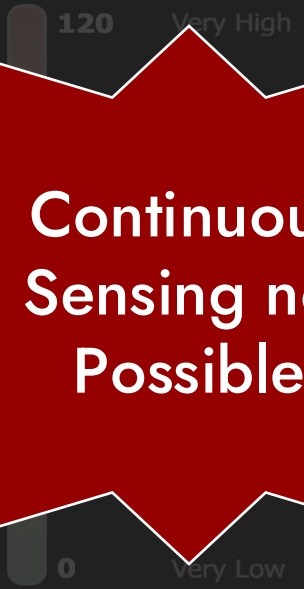
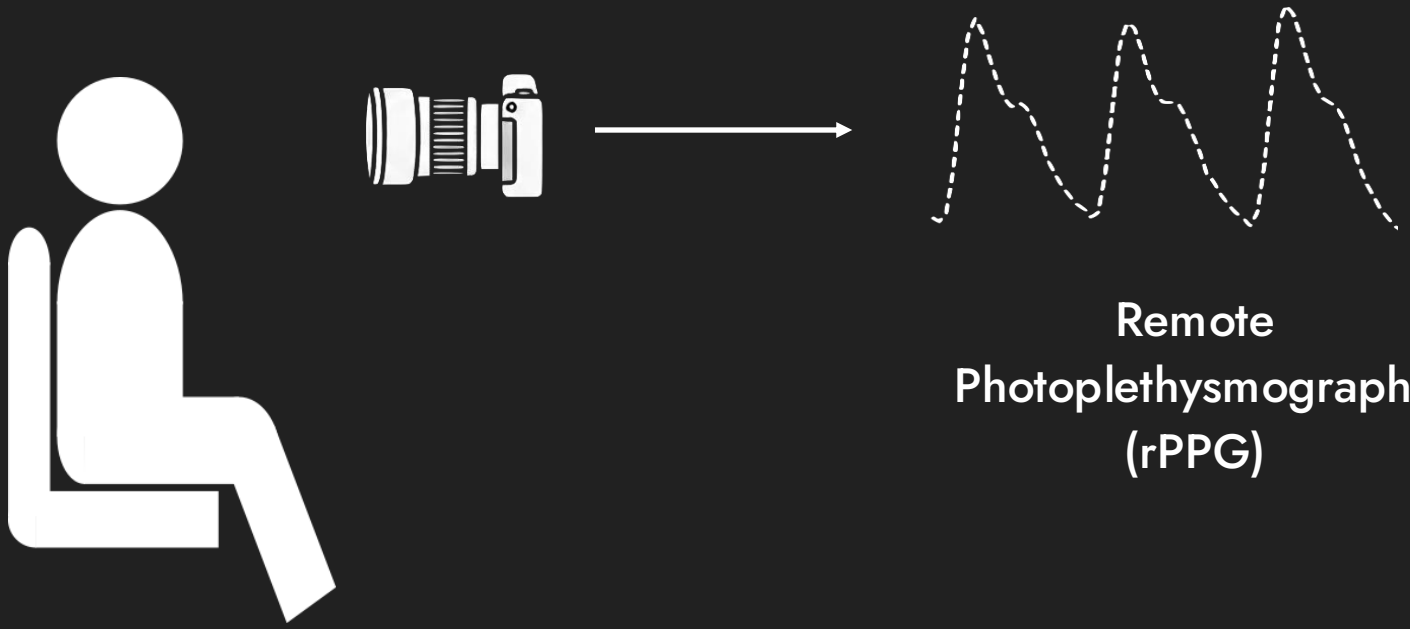


Continuous Sensing not Possible

Popularly, using contact sensors:
EEG, ECG, chest bands, pulse, etc.

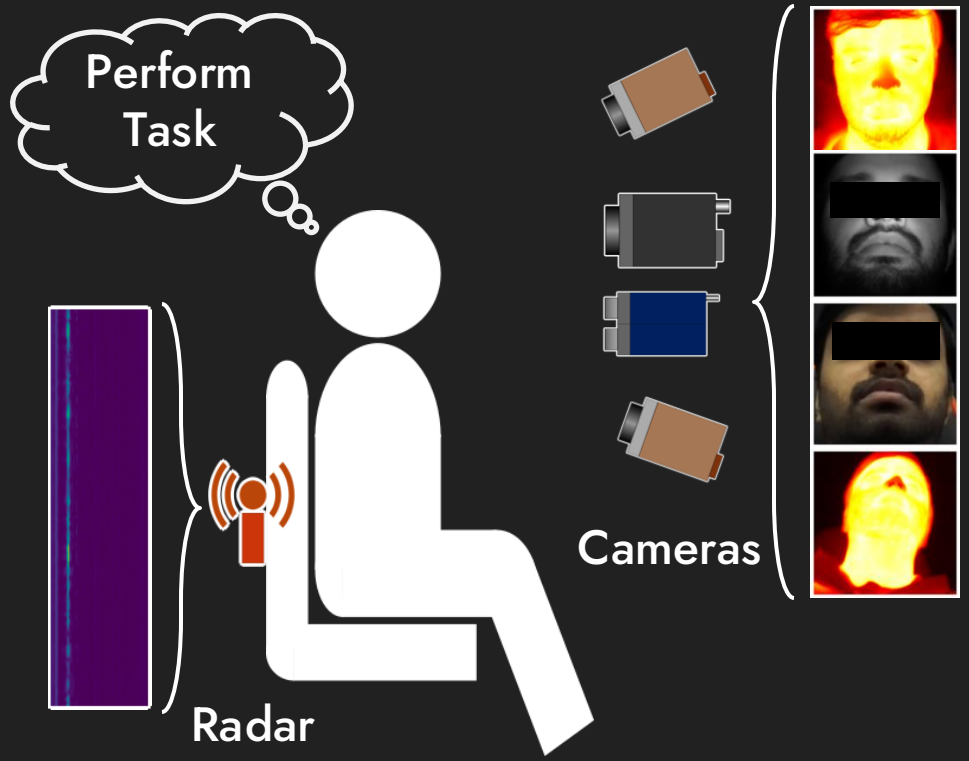
Intrusive and Unwieldy

Remote physiological sensing is a solution



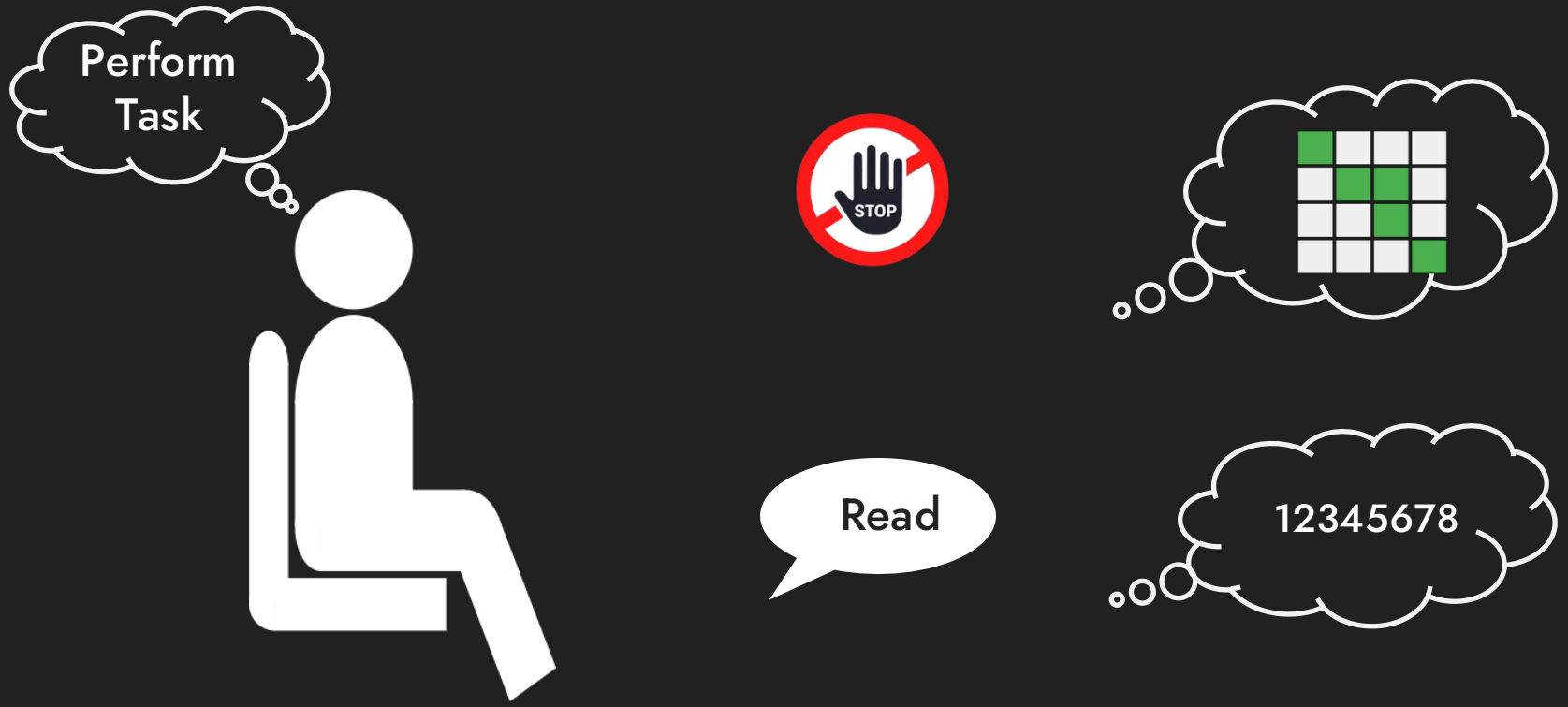
Remote Photoplethysmography (rPPG)

Our Solution: CogPhys - a first-of-its-kind dataset for multimodal remote cognitive load estimation.



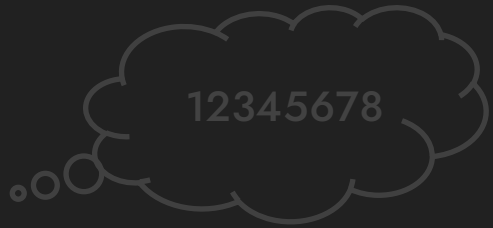
- ✓ *Size:* 37 participants
- ✓ *Remote Sensors:* 5 sensors for remote vital sign and cognitive load estimation
- ✓ *Contact Sensors:* 2 sensors as GT for validation
- ✓ *NASA-TLX:* Cognitive load labels. Raw scores are binarized

Inducing cognitive load and collecting labels



Inducing cognitive load and collecting labels

Sitting still (baseline)



Inducing cognitive load and collecting labels

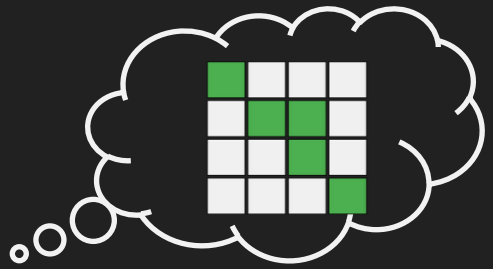
Reading random passages

Read

12345678

Inducing cognitive load and collecting labels

Memorize + Solve Math (x2)

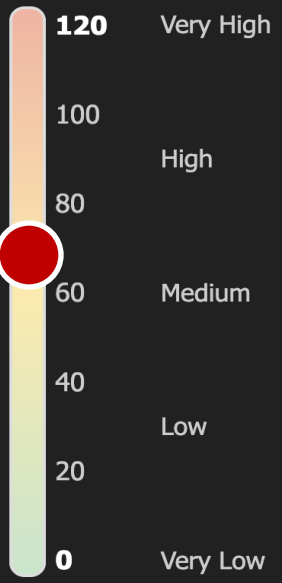


Read

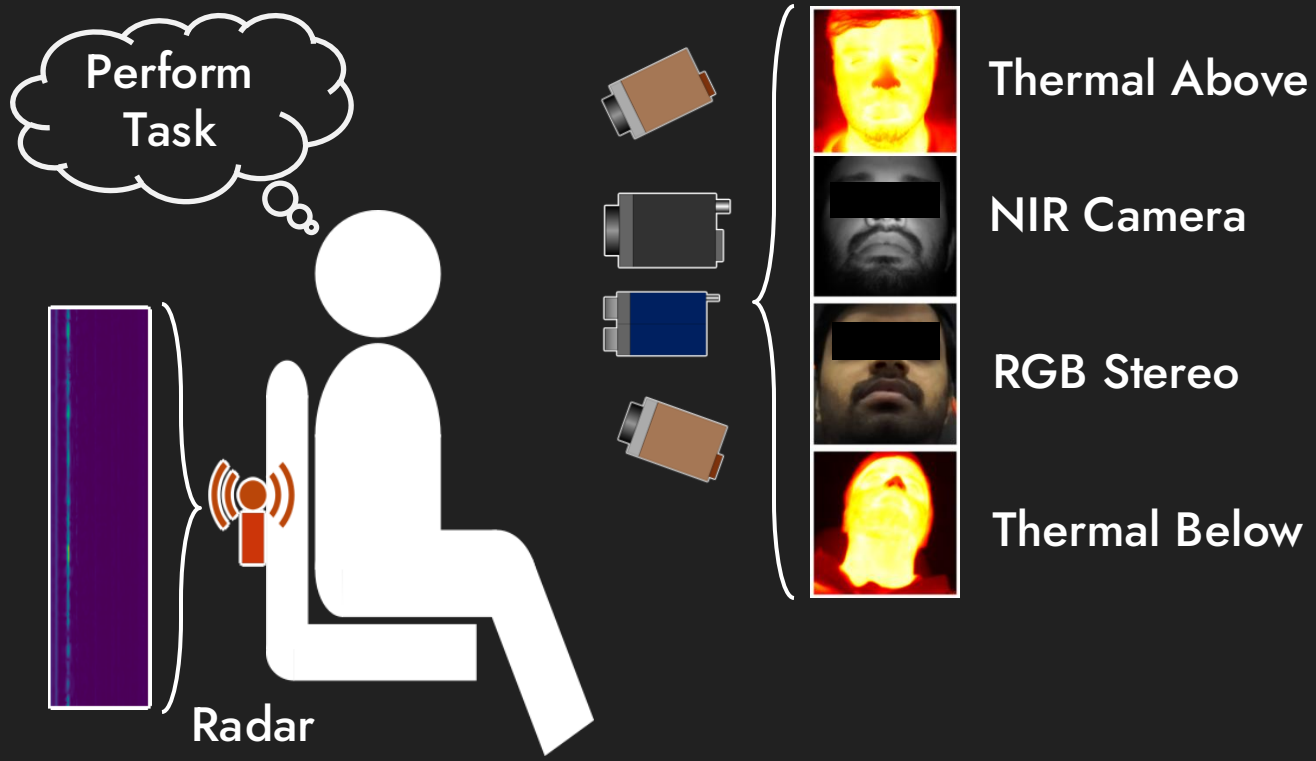
Inducing cognitive load and collecting labels

NASA-TLX collected for each task

Survey Score



CogPhys Setup: Multimodal Remote Sensing



CogPhys Setup: Multimodal Remote Sensing

RGB Stereo and NIR Cameras

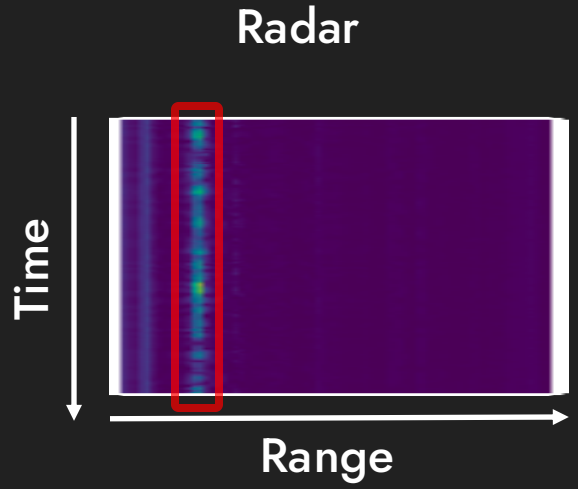
We track subtle color changes in the face to obtain HR, HRV signals

CogPhys Setup: Multimodal Remote Sensing

RGB Stereo and NIR Cameras

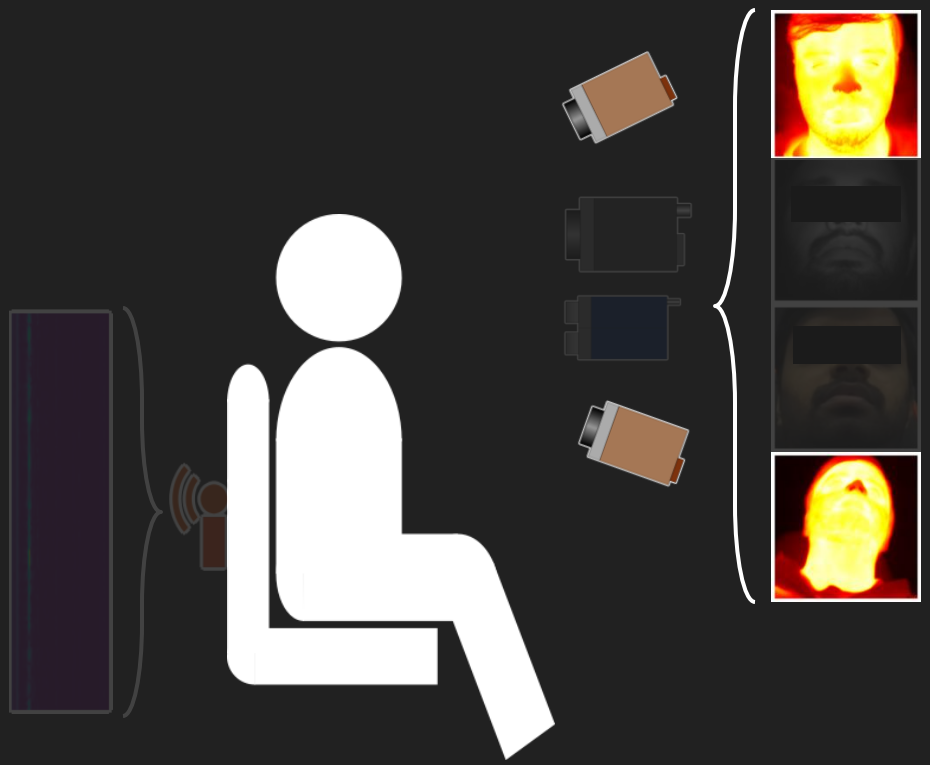
The RGB camera also gives us blinking patterns

CogPhys Setup: Multimodal Remote Sensing

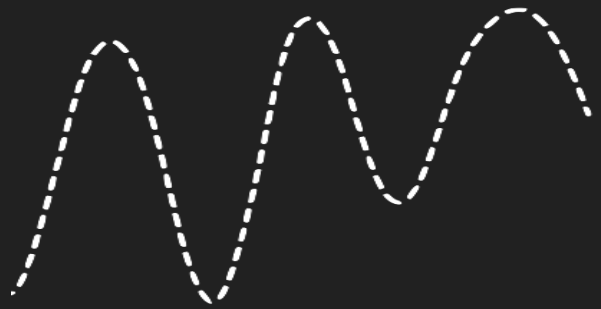


Radar detect vibrations such as those induced by breathing

CogPhys Setup: Multimodal Remote Sensing

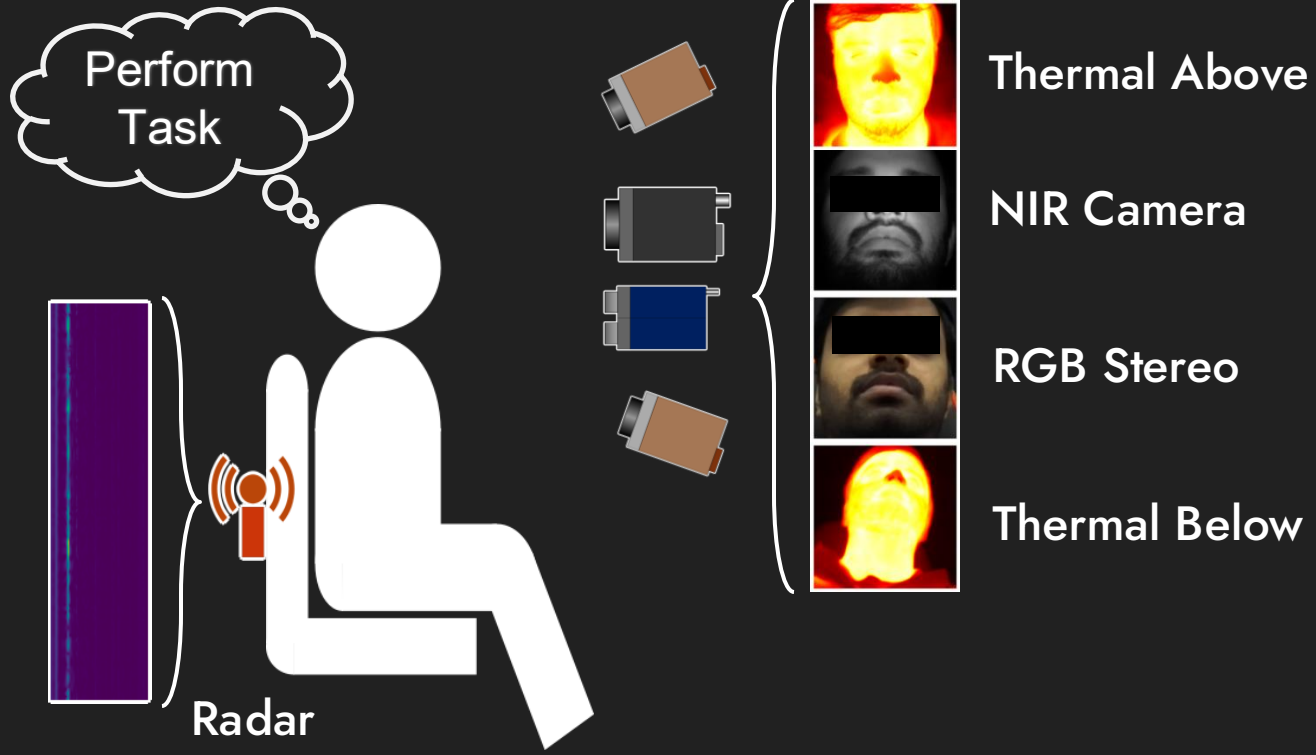


Two Thermal Cameras



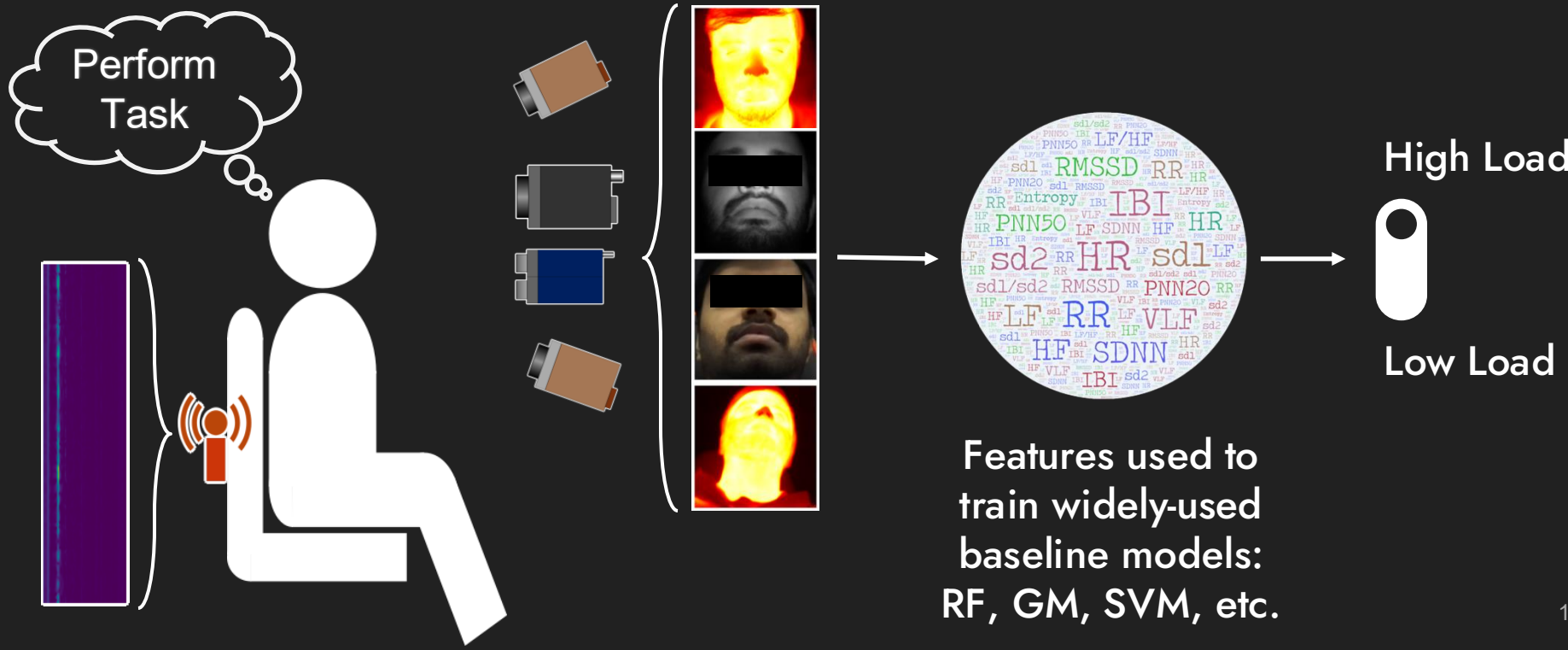
We track intensity changes near the nostril to obtain RR signals

Database with remote multimodal data and cognitive load labels



N = 37 Participants

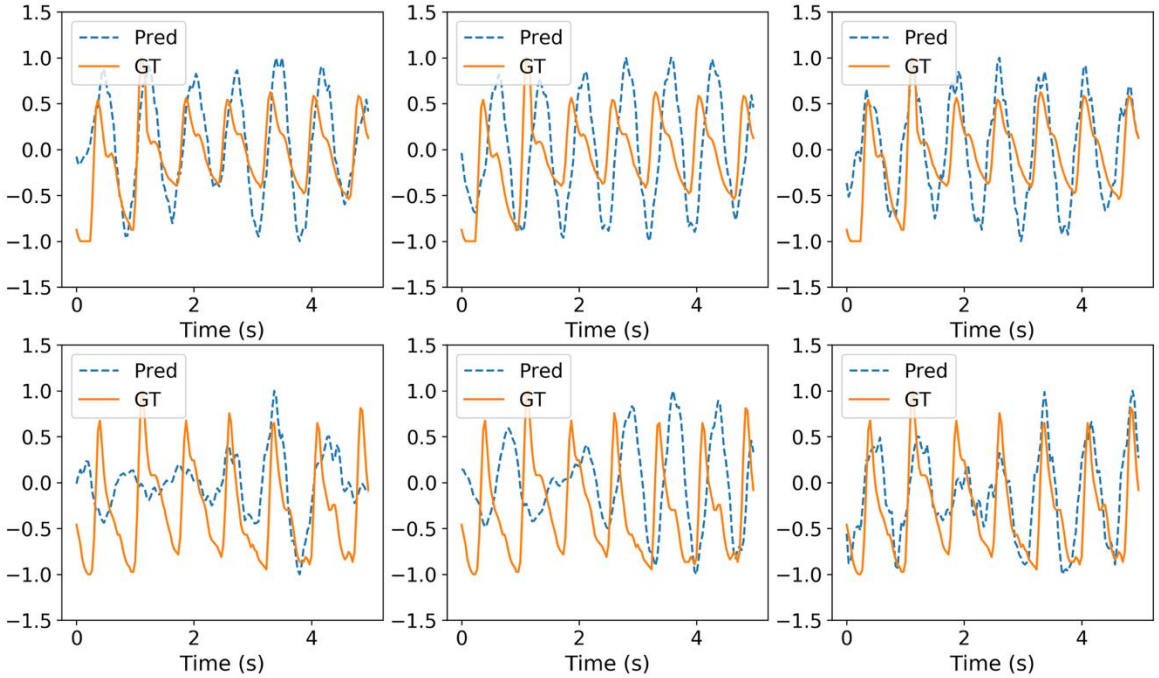
Remote vital signs bridge sensor data to cognitive load estimation



Validate CogPhys

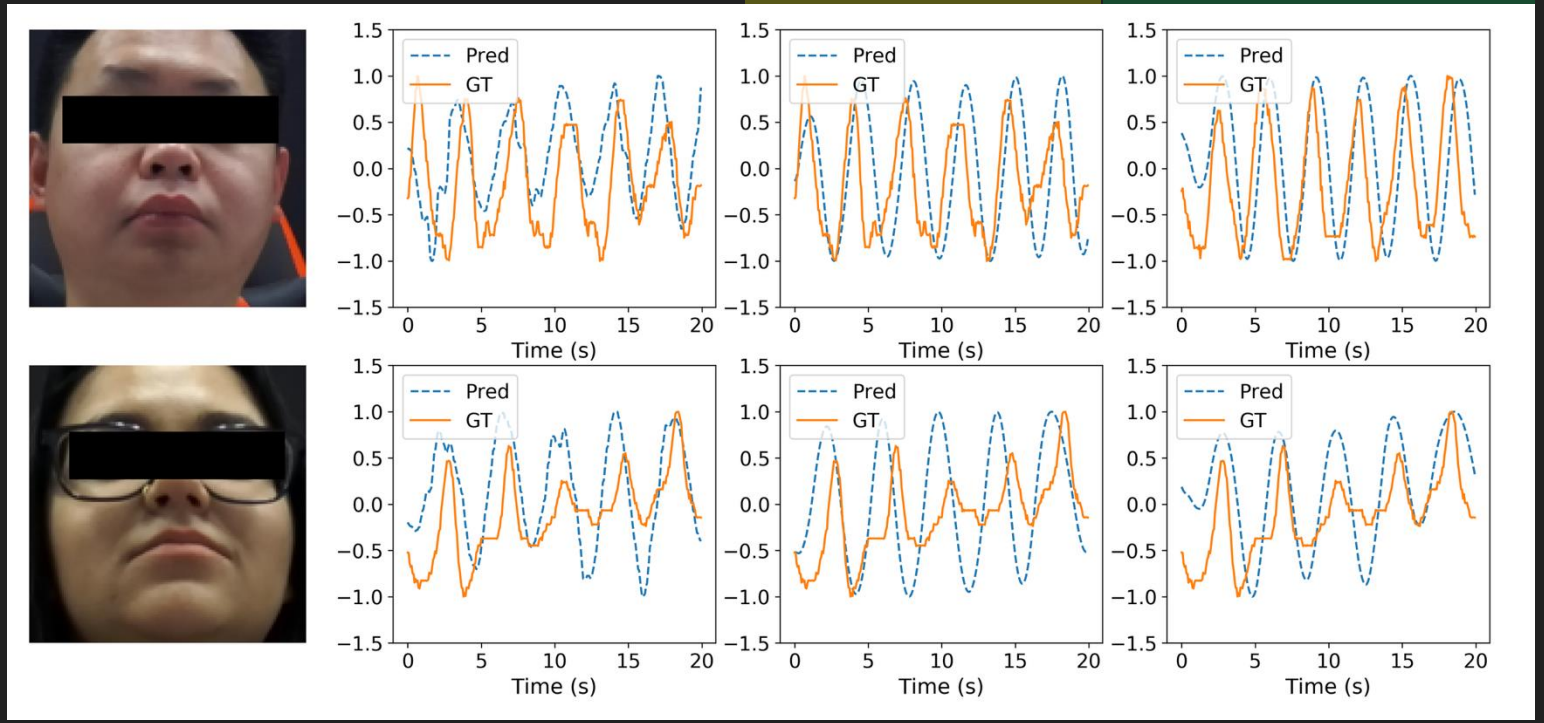
Validate CogPhys: Heart Rate Estimation

NIR MAE:	RGB MAE:	Fusion MAE:
4.77 BPM	3.75 BPM	2.94 BPM



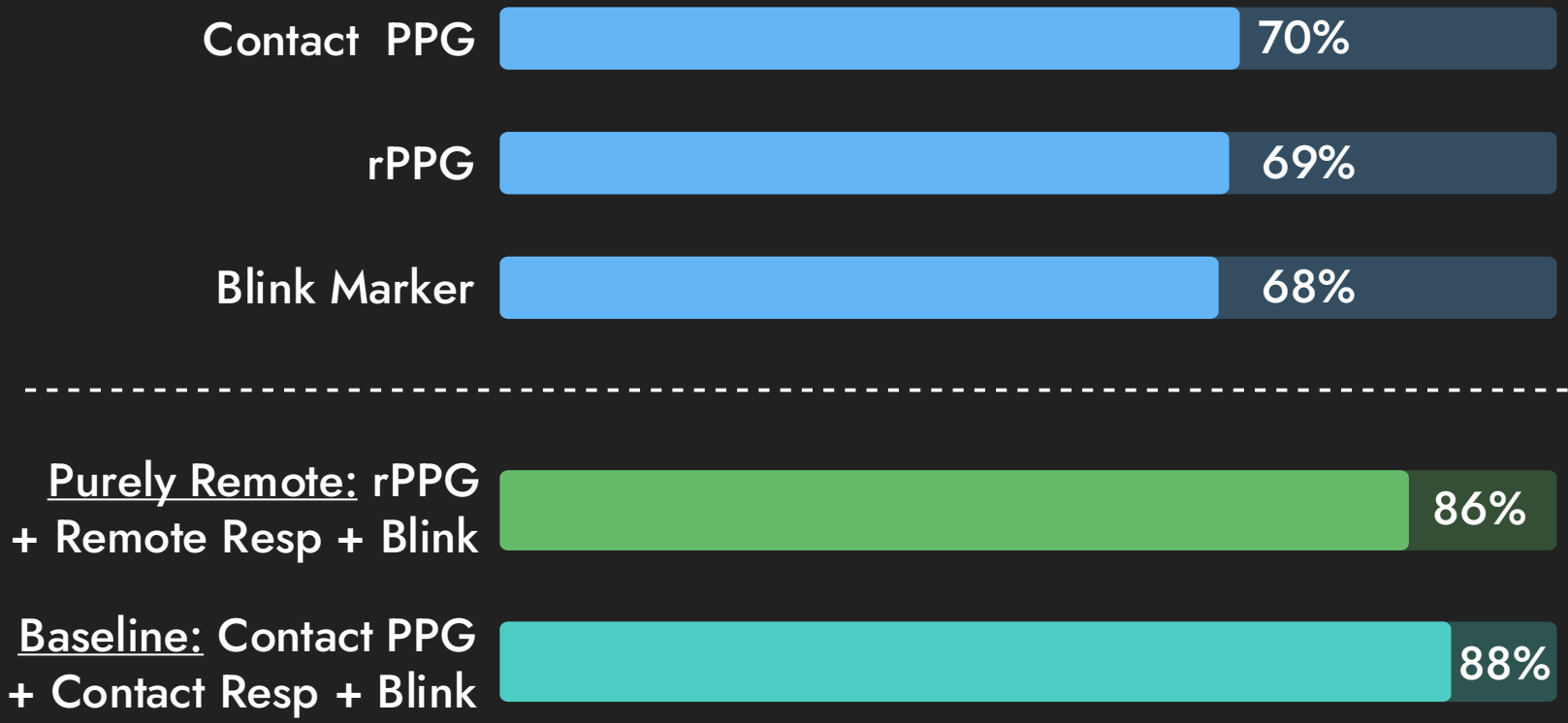
Validate CogPhys: Respiratory Rate Estimation

Thermal MAE:	Radar MAE:	Fusion MAE:
2.41 RPM	2.32 RPM	2.25 RPM



Validate CogPhys: Cognitive Load Estimation

Validate CogPhys: Cognitive Load Estimation



Summary & Impact

- First multimodal remote sensing dataset for cognitive load estimation
- Demonstrates viability: A purely remote approach has 86% accuracy, while contact sensors with blink achieve 88%
- A foundation for future remote sensing and cognitive load research
- Applications:
  - Driver state sensing (e.g. , drowsiness and distraction)
  - Healthcare – hospitals and clinics