Human Interaction with Complex and Autonomous Systems and Vehicles

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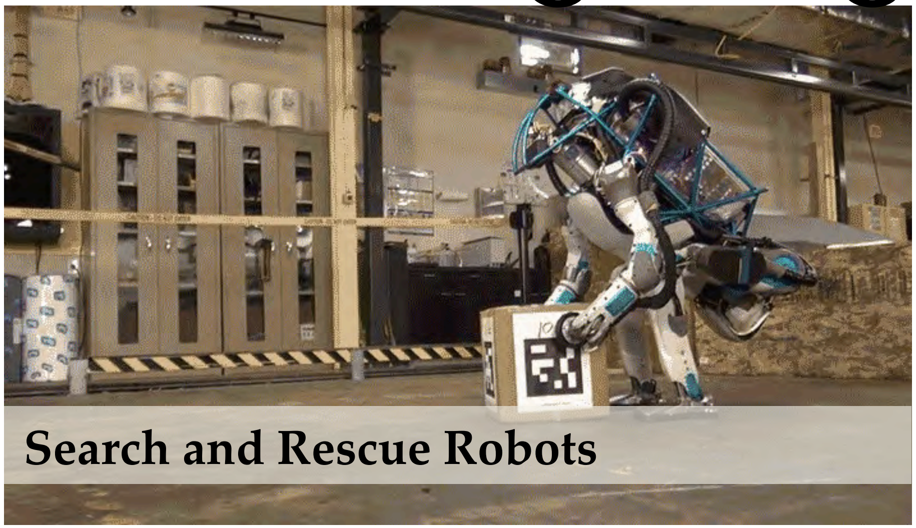
Increasing Usage of Automation


Search and Rescue Robots

Artificial Intelligence


UAVs


Self-Driving Cars


Manufacturing

Human + Autonomy

Human Strengths:

- Inference
- Adaptation
- Intuition
- Judgment
- Morality

Autonomy Strengths:

- Fast
- Does not get bored
- Consistent
- Good for Predictable cases

Human Limits:

- Response Time
- Bandwidth
- Cognitive Capacity
- Inconsistency
- Endurance
- Training

Autonomy Limits:

- Adaptability
- Data requirements
- Interface with System
- Need Rules

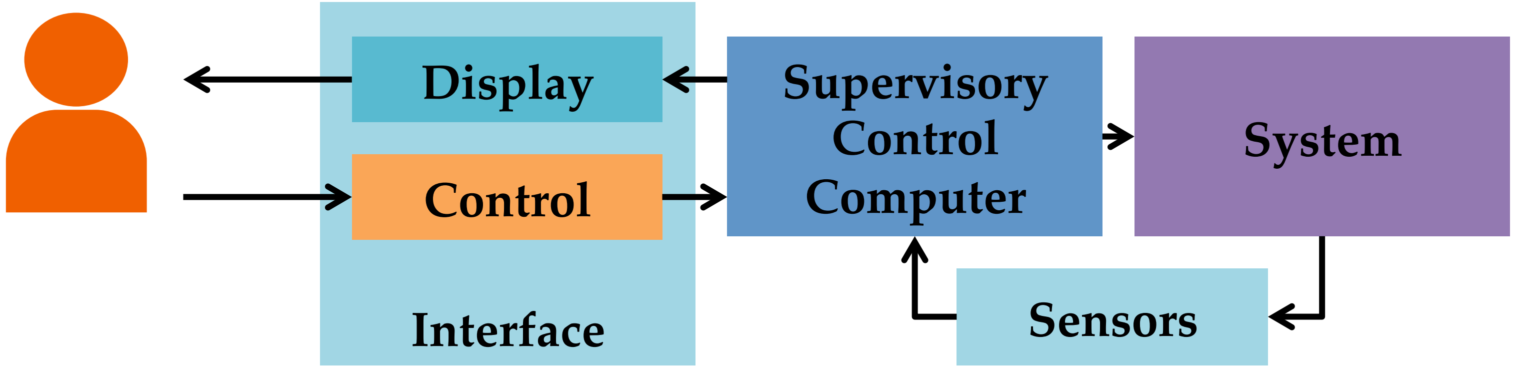
Using brain and body sensing for implicit interfaces

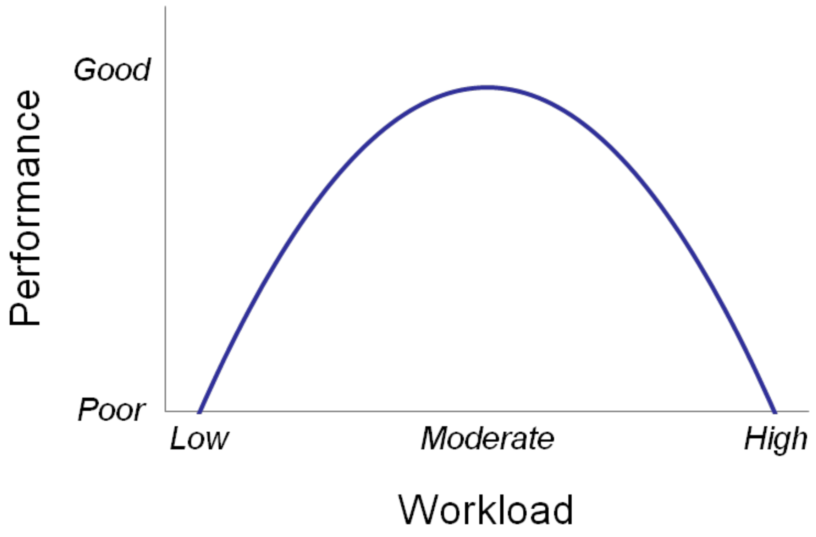
Goal: expand bandwidth between human & computer

Approach: identify signals people naturally give off and adapt systems appropriately

When are these signals useful in human supervisory control?
How do you use them effectively?

Human Supervisory Control





The brain as explicit and primary input

BrainGate System at Brown University

Brain & body as implicit, supplementary input

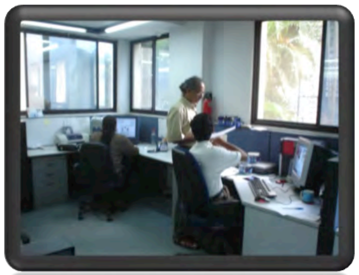
Brain & body as implicit, supplementary input

- **Augment** traditional input devices
- **Wider group of users**, beyond disabled
- **Passive, implicit** input channel
- Capture **subtle** cognitive state changes
- Input to **adaptive** interactive system
- **Real-time**, continuous data

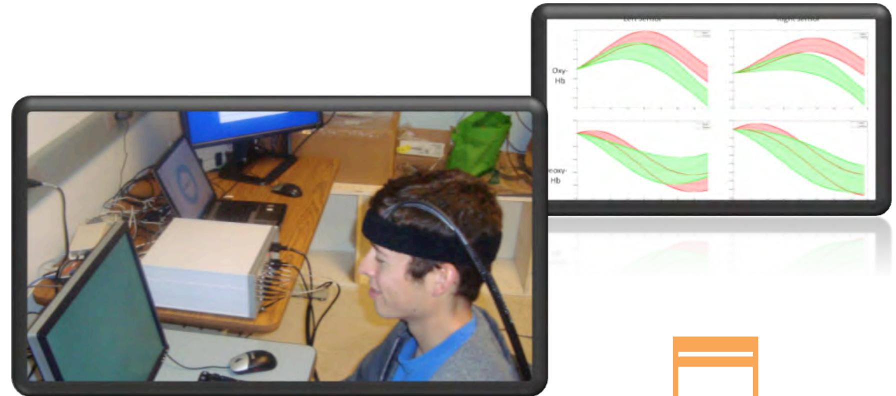
Examples

- Adapting **autonomy** levels
- Modifying **quantity** of information
- Transform **modality** of info presentation
- Task **allocation,** manage **task load, difficulty**
- **Offline evaluation** of user interfaces, systems

Brain & Body Signals as Input

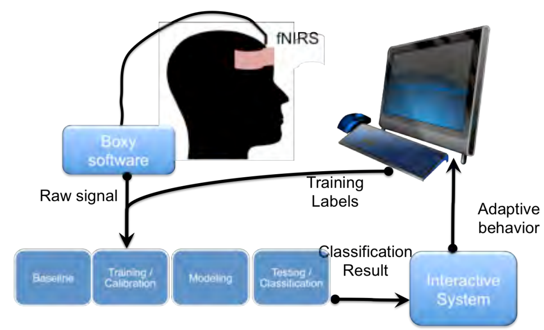


Practical Considerations

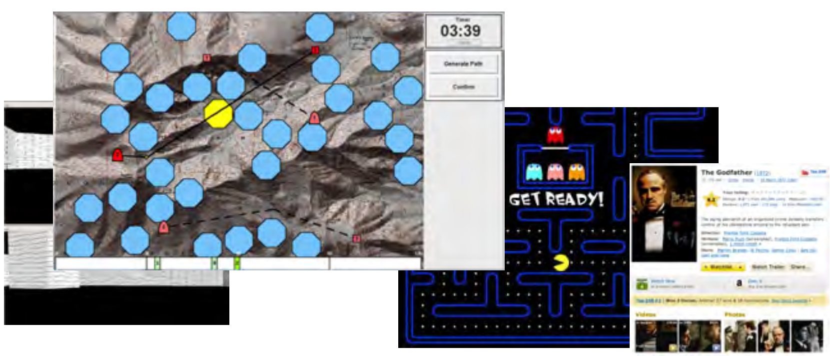


Offline cognitive state studies

Real-time System

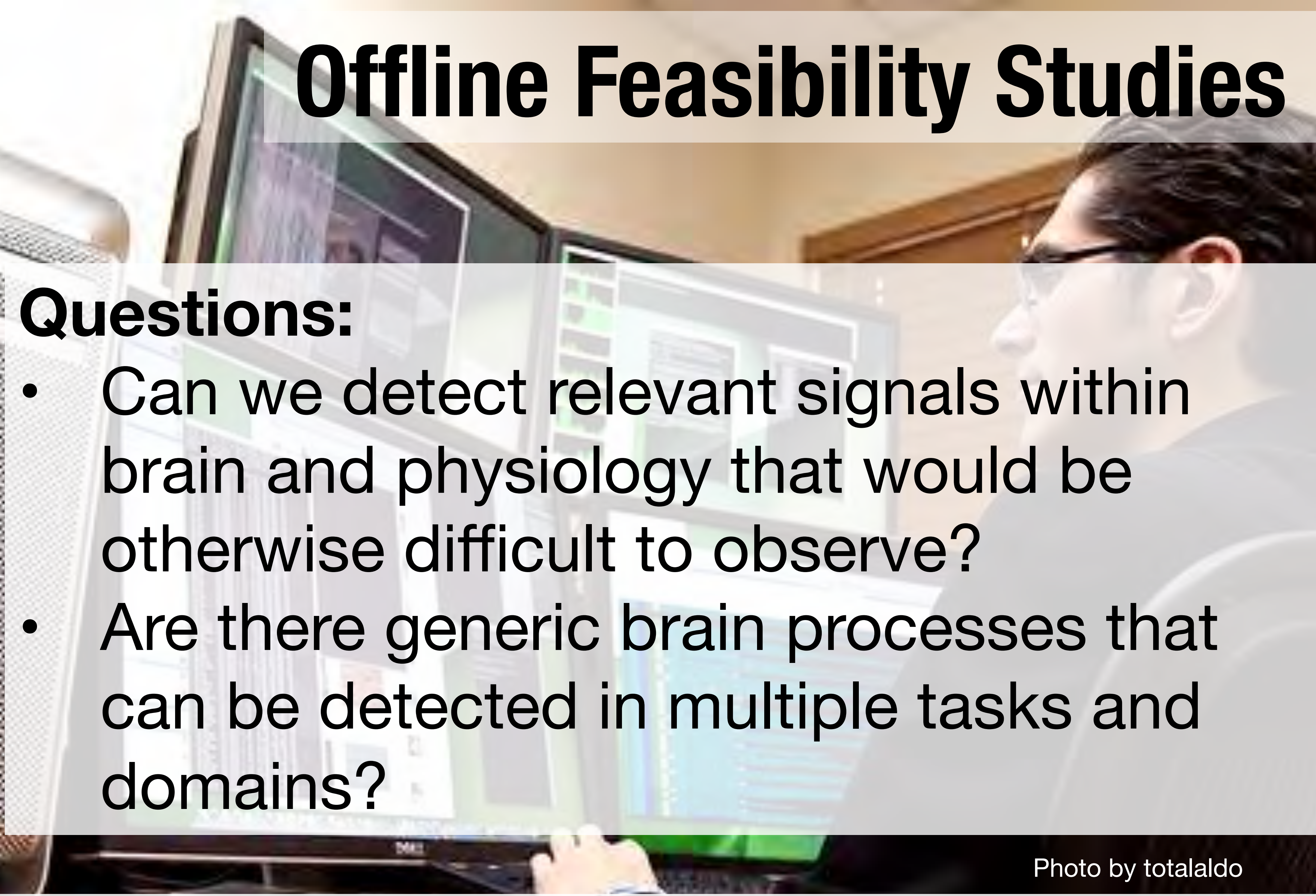


Interface Design & Evaluations



E.T. Solovey, et al. Designing Implicit Interfaces for Physiological Computing: Guidelines and Lessons Learned using fNIRS. *ACM Transactions on Computer-Human Interaction*. Vol. 21, Iss. 6. 2015x.

Offline Feasibility Studies



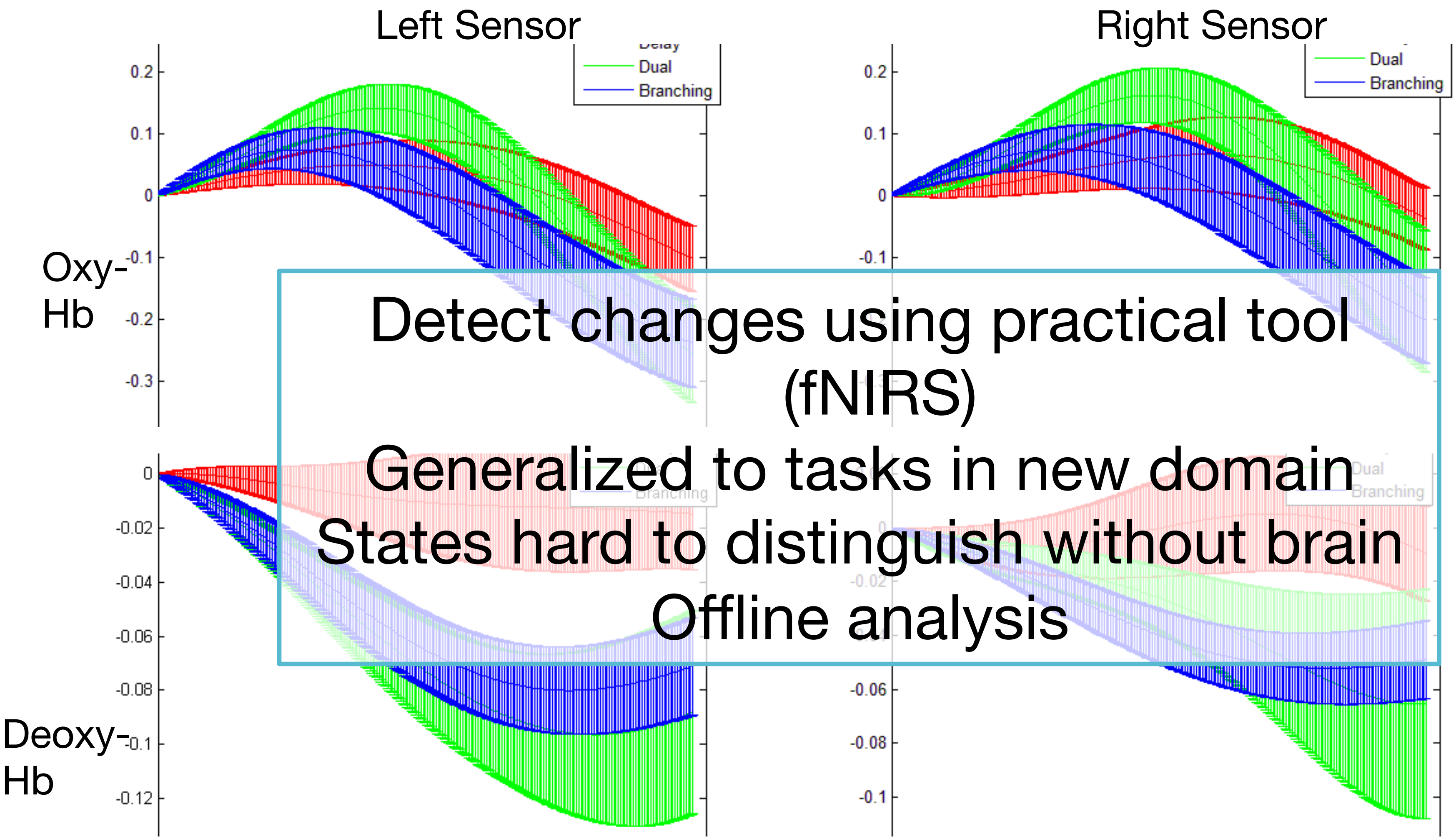
Questions:

- Can we detect relevant signals within brain and physiology that would be otherwise difficult to observe?
- Are there generic brain processes that can be detected in multiple tasks and domains?

Photo by totalaldo

E.T. Solovey, K. Chauncey, F. Lalooses, M. Parasi, D. Weaver, M. Scheutz, P. Schermerhorn, A. Sassaroli, S. Fantini, A. Girouard, R.J.K. Jacob, "Sensing Cognitive Multitasking for a Brain-Based Adaptive User Interface," Proc. ACM Conference on Human Factors in Computing Systems CHI'11, ACM Press (2011).

Different Activation Patterns



Detect changes using practical tool (fNIRS)

Generalized to tasks in new domain

States hard to distinguish without brain

Offline analysis

Solovey, et al., CHI 2011

Feasibility Studies on the Road

1) Within Individuals

- Natural driving
- 2-back task
- Physiological and vehicle data
- 20 subjects

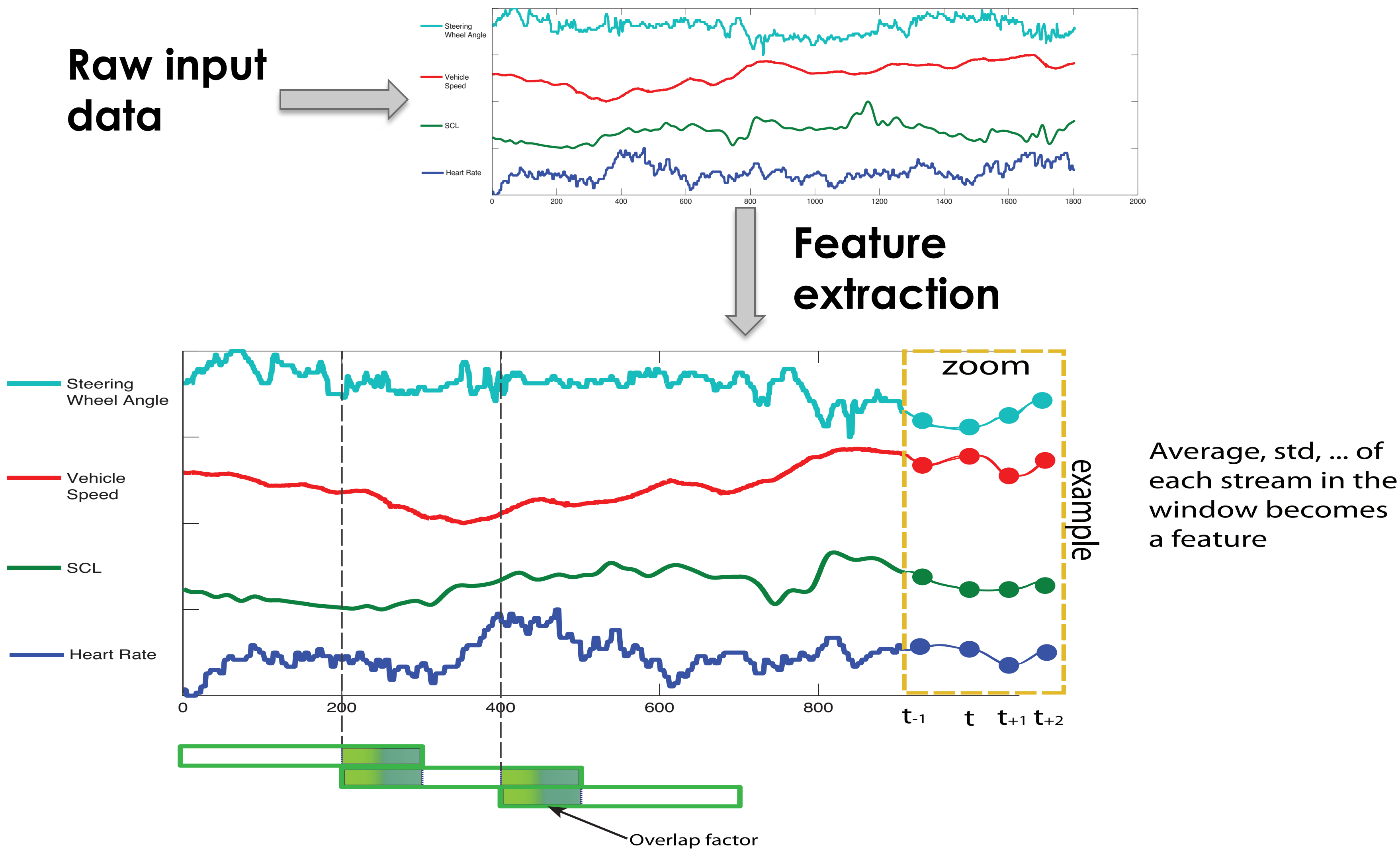
2) Across Individuals

- Natural driving
- n-back tasks
- Physiological and vehicle data
- 99 subjects

3) Experiment 3: Brain Sensing

- Simulator driving
- Simple driving, Blank-back, 0-back, 1-back, 2-back tasks
- 3 blocks of these tasks
- 19 subjects

Feature extraction

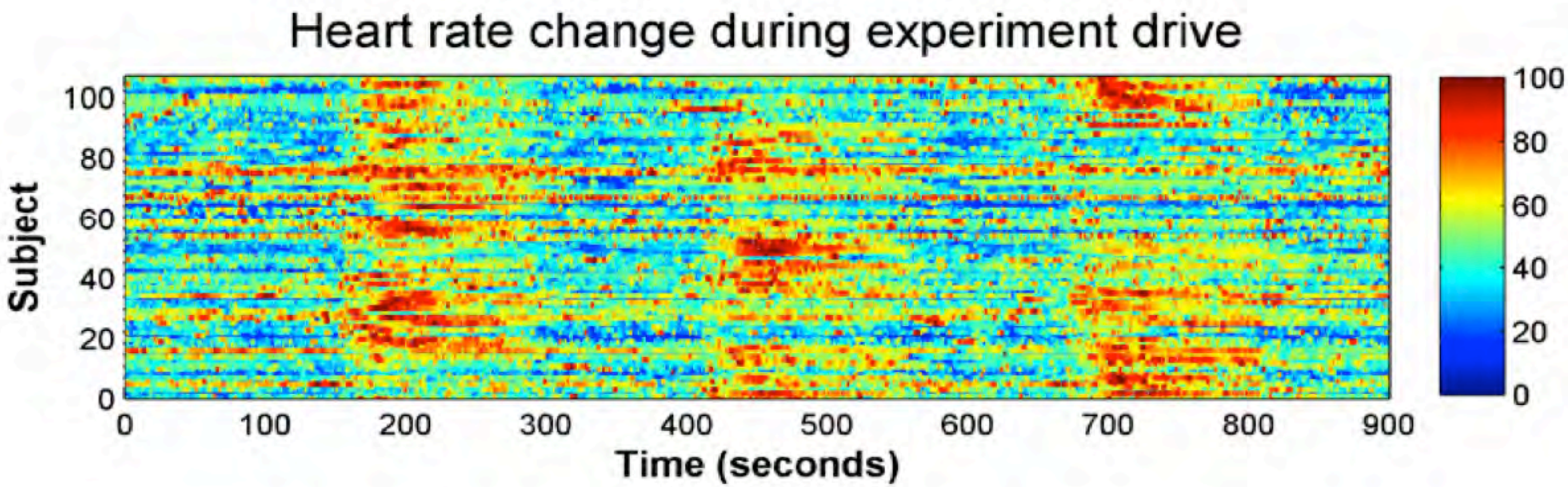


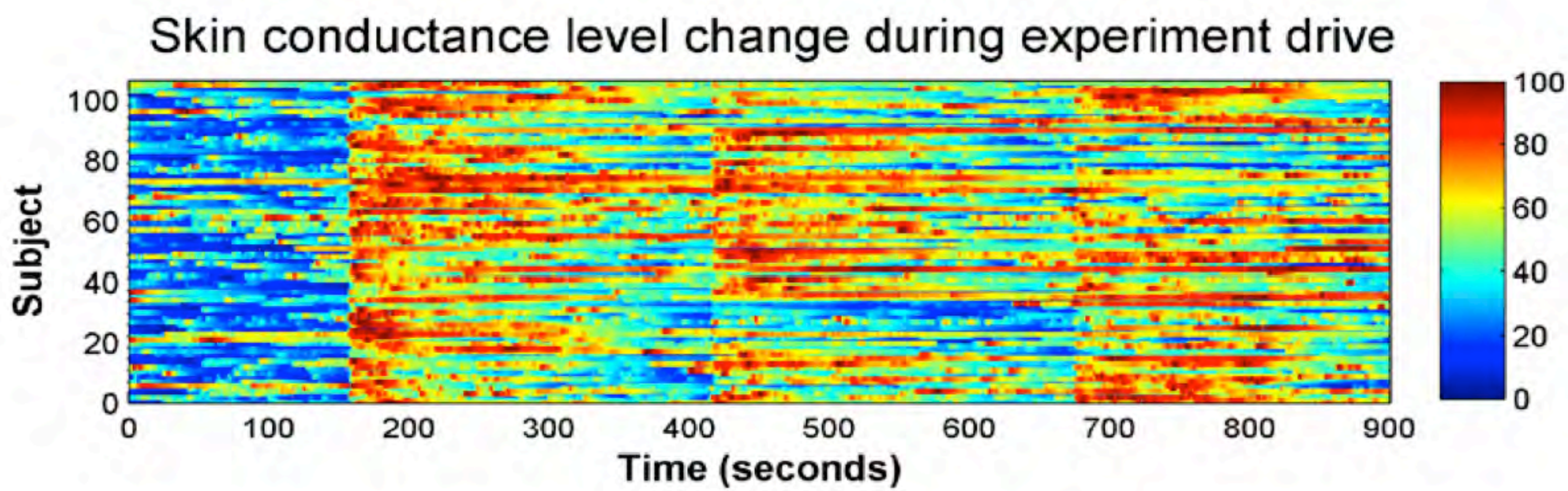
Experiment 1 results

	All Features		Heart Rate	
	Mean	S.D.	Mean	S.D.
Decision Tree	75.0	10.8	72.8	12.8
Logistic Regression	75.5	10.9	73.9	11.3
Multilayer Perceptron	75.7	10.9	74.0	12.4
Naïve Bayes	75.0	12.5	74.1	11.8
Nearest Neighbor	69.4	11.6	71.5	10.3

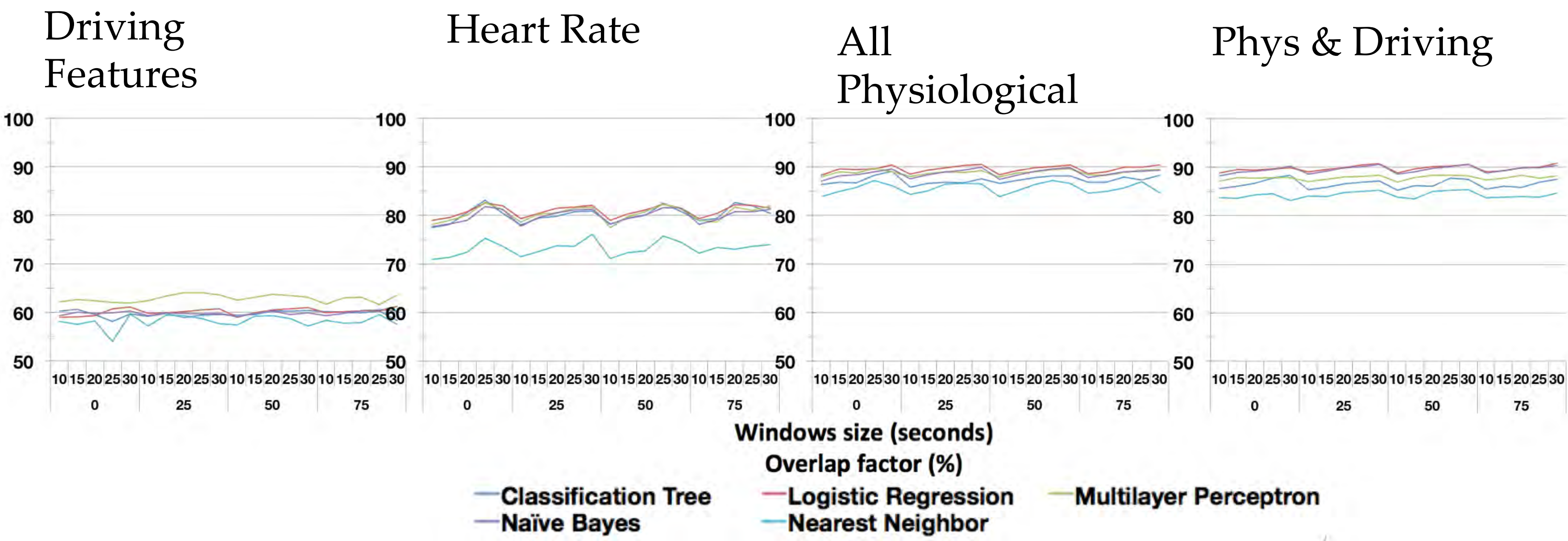
- Reasonable accuracy, using simple features and classification methods, HR alone even has promise
- 24 trials = ~48 minutes of data, training on 43 minutes
  - Okay for proof-of-concept, not ideal for real-world
  - Future: improved methods to shorten this
  - Classification across individuals may reduce/eliminate this training time (Exp 2)

Experiment results



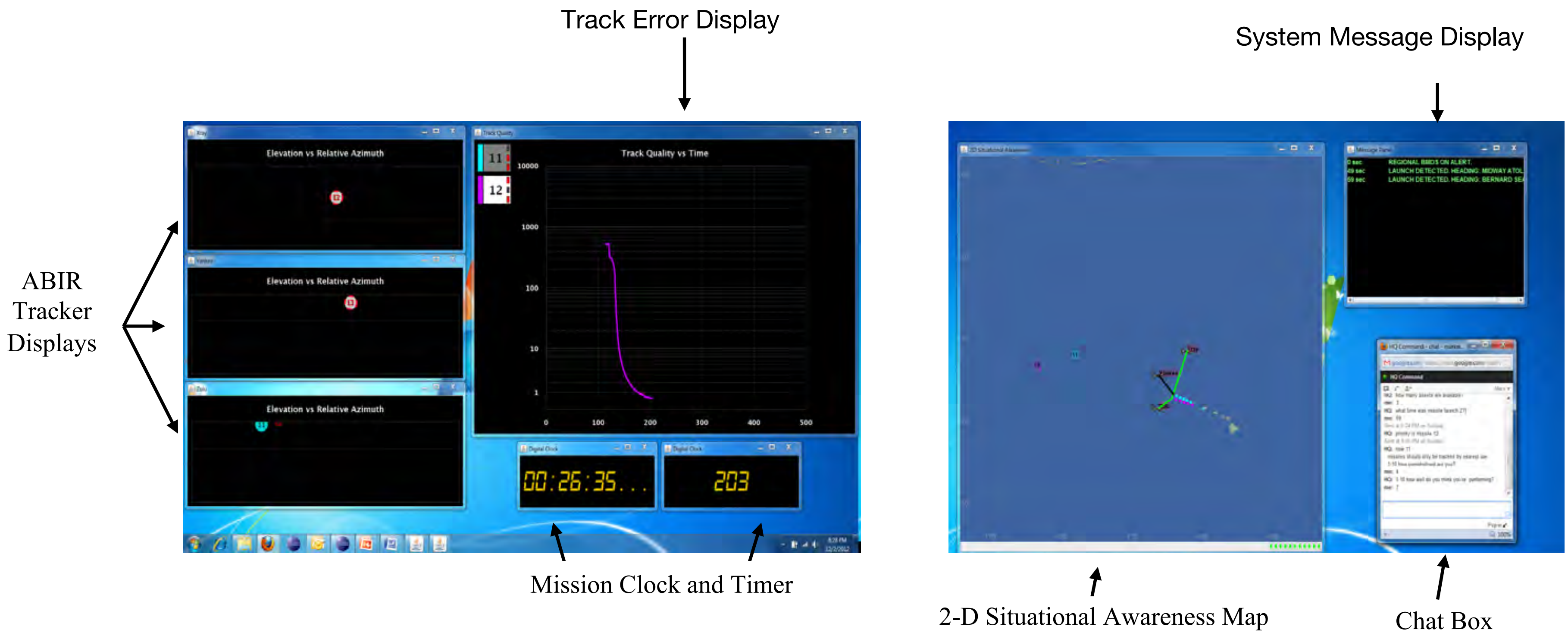


Experiment 2 Classification Results

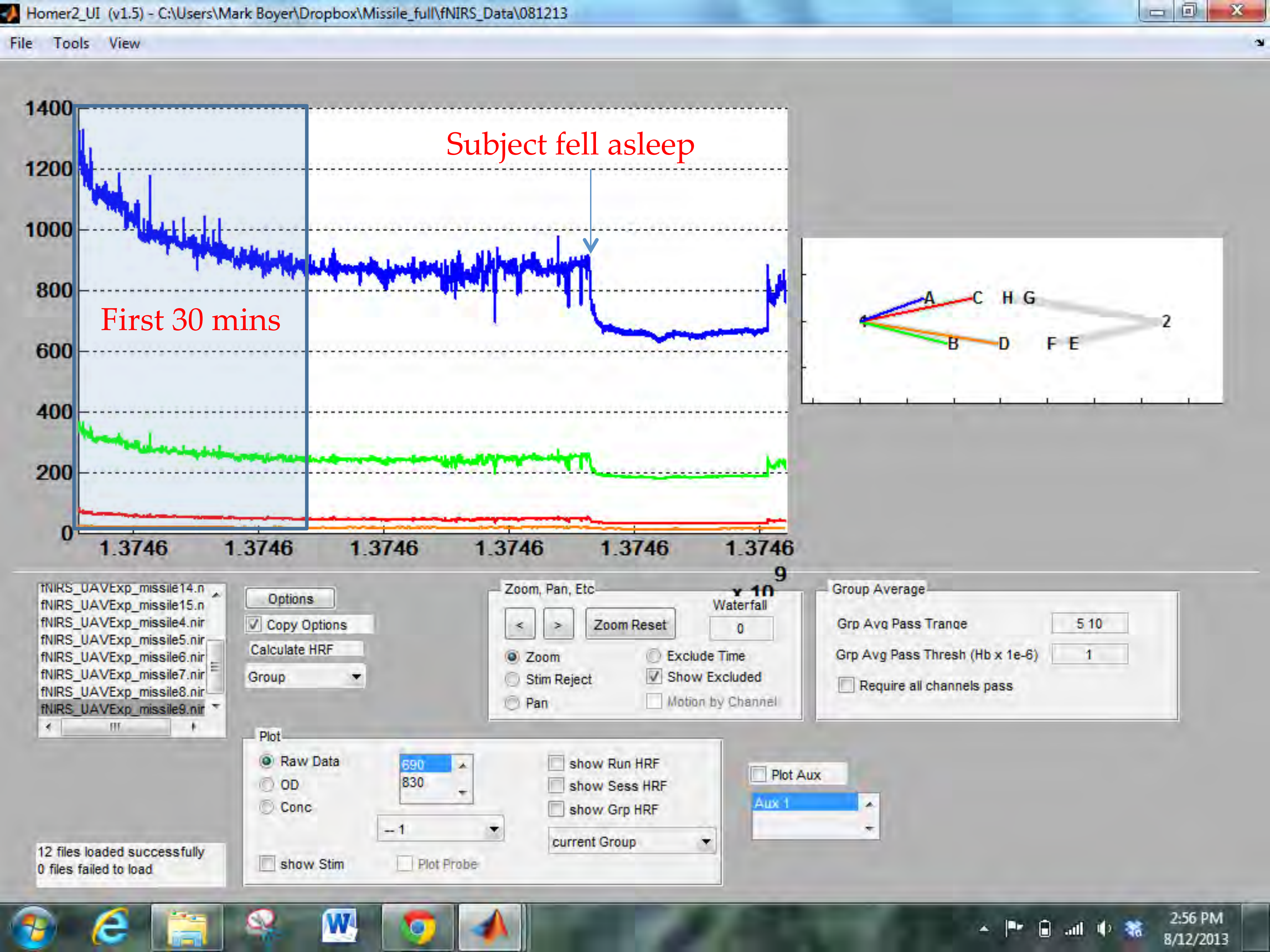


- Type of features had a clear effect on the classification results
  - HR had big improvement over driving only (64% -> 80%)
  - Adding SCL also improves

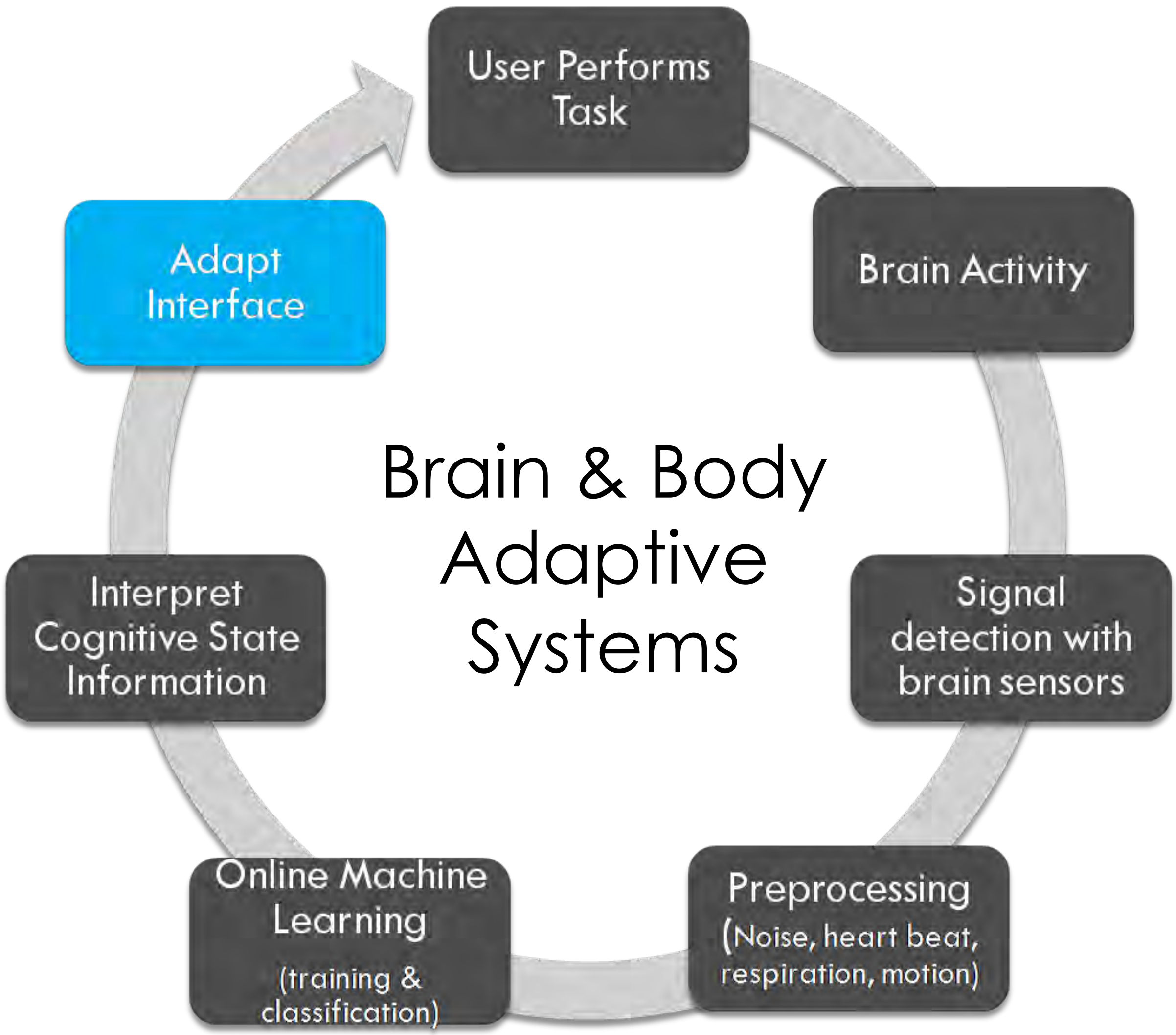
Long Duration, Low Workload



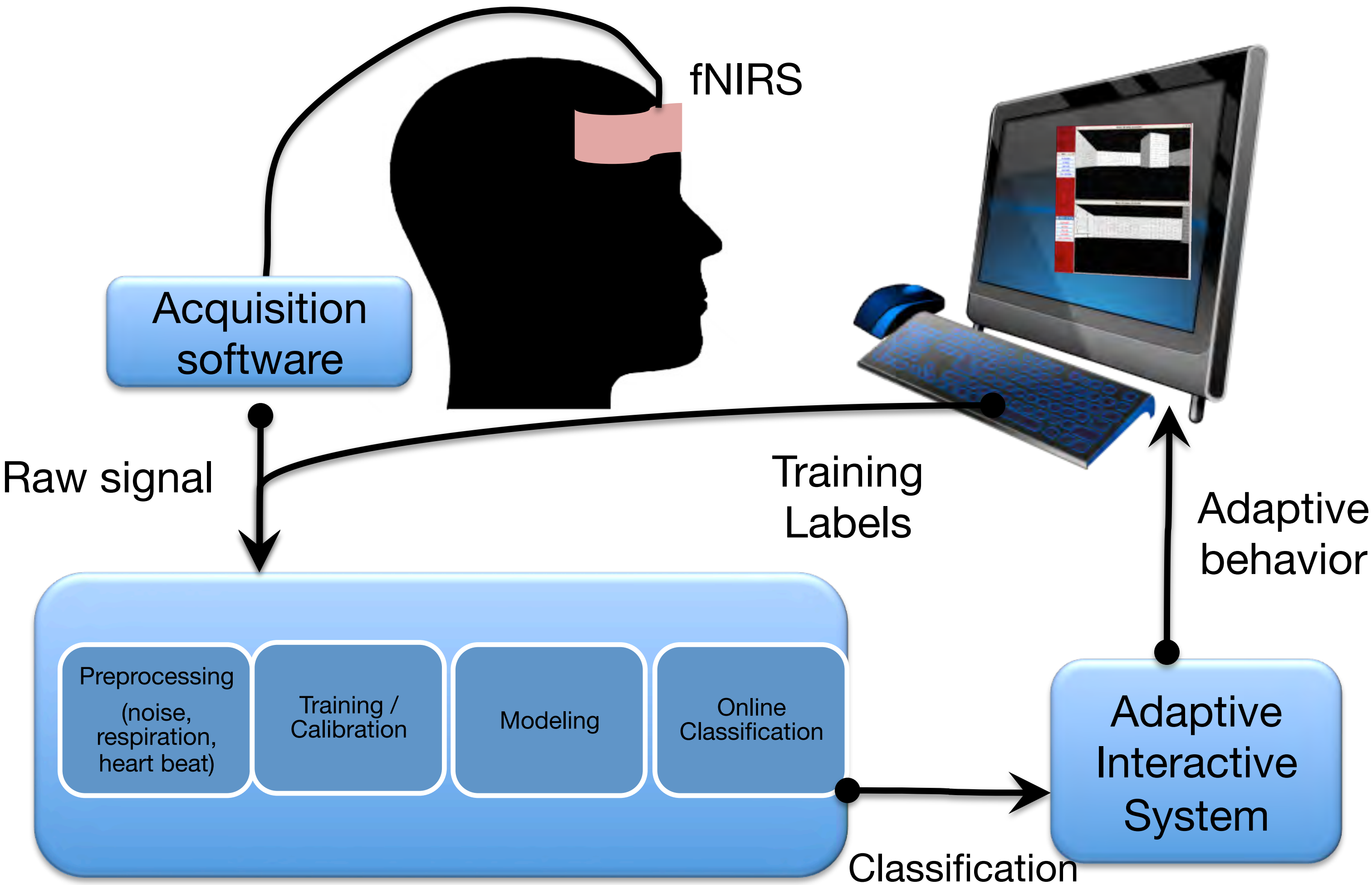
- 3.5 hour session
- controlling the sensors for 3 Unmanned Aerial Vehicles
- job is to direct which UAV will track which missile
- mission is to achieve sufficient track accuracy on every missile
- Targets begin to appear at 40, 100, or 160 minutes
- 3 or 6 targets at a time



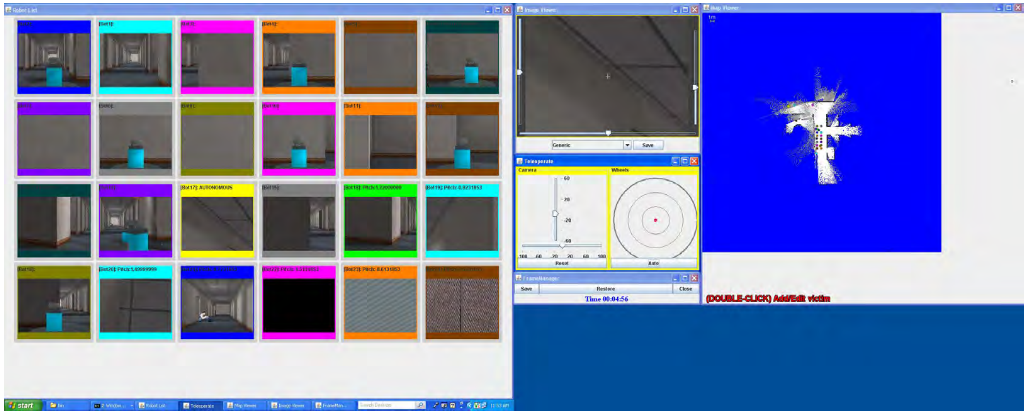
Homer2_UI (v1.5) - C:\Users\Mark Boyer\Dropbox\Missile_full\fNIRS_Data\081213
File Tools View
Subject fell asleep
First 30 mins
1400
1200
1000
800
600
400
200
0
1.3746 1.3746 1.3746 1.3746 1.3746 1.3746
x 10^9
A C H G
2
B D F E
fNIRS_UAVExp_missile14.n
fNIRS_UAVExp_missile15.n
fNIRS_UAVExp_missile4.nir
fNIRS_UAVExp_missile5.nir
fNIRS_UAVExp_missile6.nir
fNIRS_UAVExp_missile7.nir
fNIRS_UAVExp_missile8.nir
fNIRS_UAVExp_missile9.nir
Options
Copy Options
Calculate HRF
Group
Zoom, Pan, Etc
< > Zoom Reset
Waterfall
0
Zoom
Stim Reject
Pan
Exclude Time
Show Excluded
Motion by Channel
Group Average
Grp Avg Pass Trange 5 10
Grp Avg Pass Thresh (Hb x 1e-6) 1
Require all channels pass
Plot
Raw Data
OD
Conc
690
830
-- 1
show Run HRF
show Sess HRF
show Grp HRF
current Group
Plot Aux
Aux 1
show Stim
Plot Probe
12 files loaded successfully
0 files failed to load
2:56 PM
8/12/2013

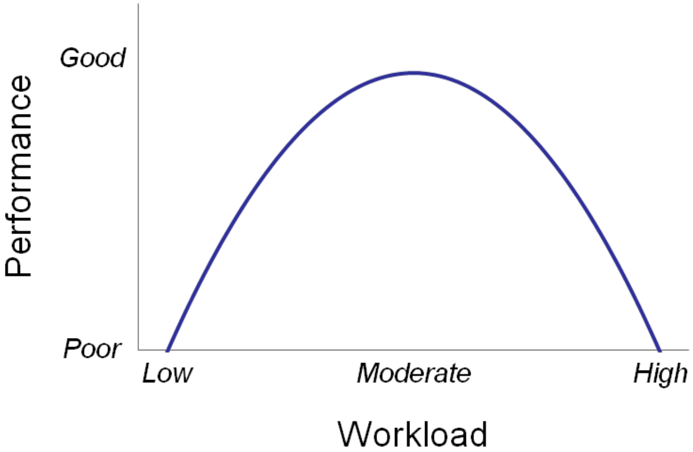

User Performs Task
Brain Activity
Signal detection with brain sensors
Preprocessing (Noise, heart beat, respiration, motion)
Online Machine Learning
(training & classification)
Interpret Cognitive State Information
Adapt Interface
Brain & Body Adaptive Systems

Brain as input channel

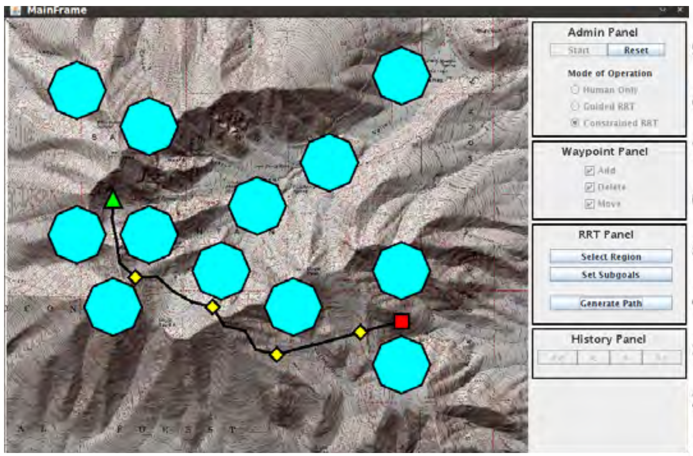


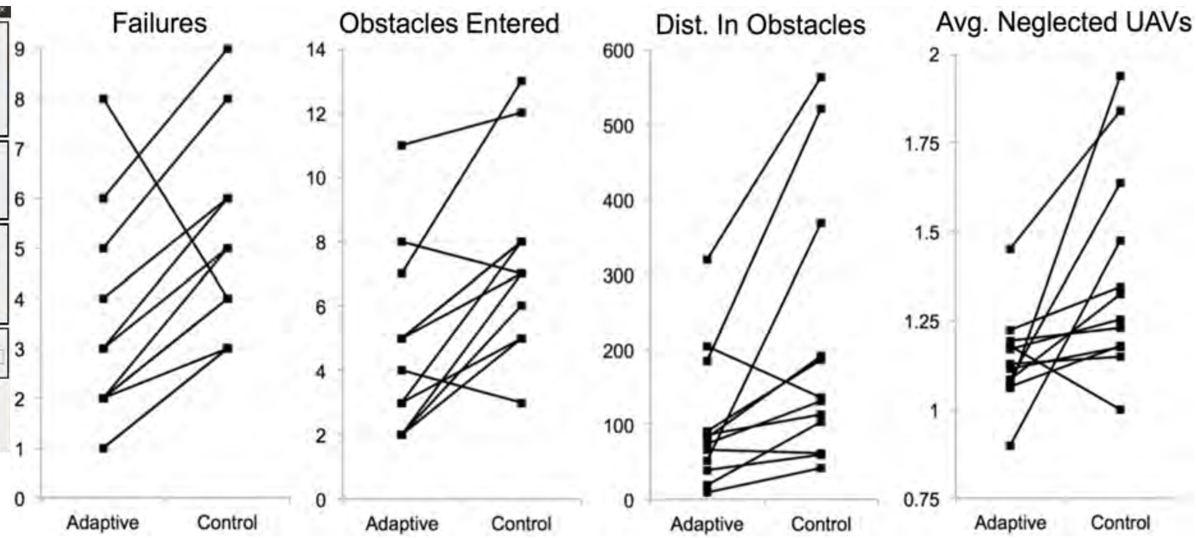
Case Study: Humans and Autonomy

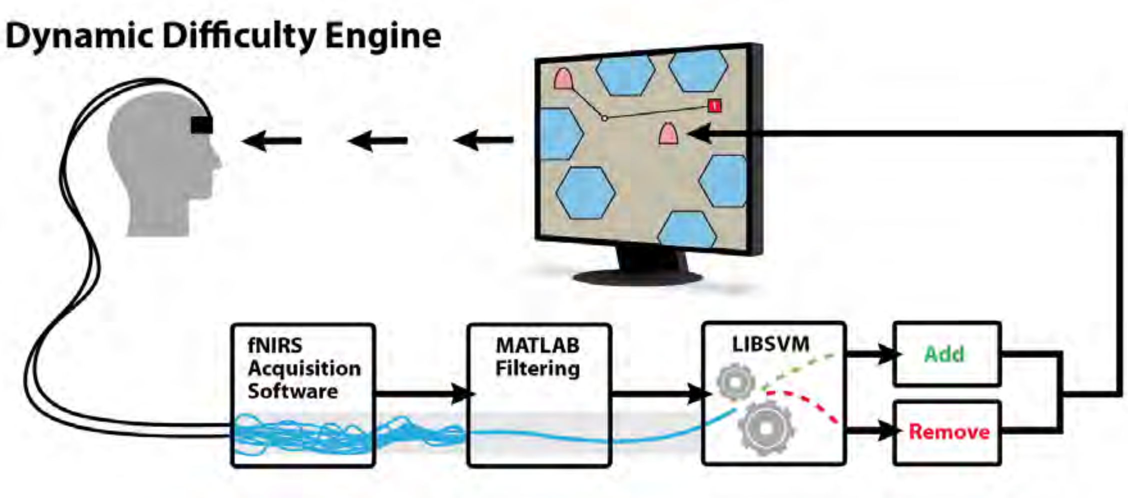




Case Study: Dynamic Difficulty & Task Allocation







User Interface Guidelines

- **Augment** other input devices
- **Subtle**, helpful changes to interface
- Not **disruptive** if signal is **misinterpreted**
  - **Imperfect** classification, **noisy** data
  - Avoid **irreversible**, mission-**critical** adaptations

Examples

- Adapting **autonomy** levels
- Modifying **quantity** of information
- Transform **modality** of information presentation
- Task **allocation,** manage **task load, difficulty**

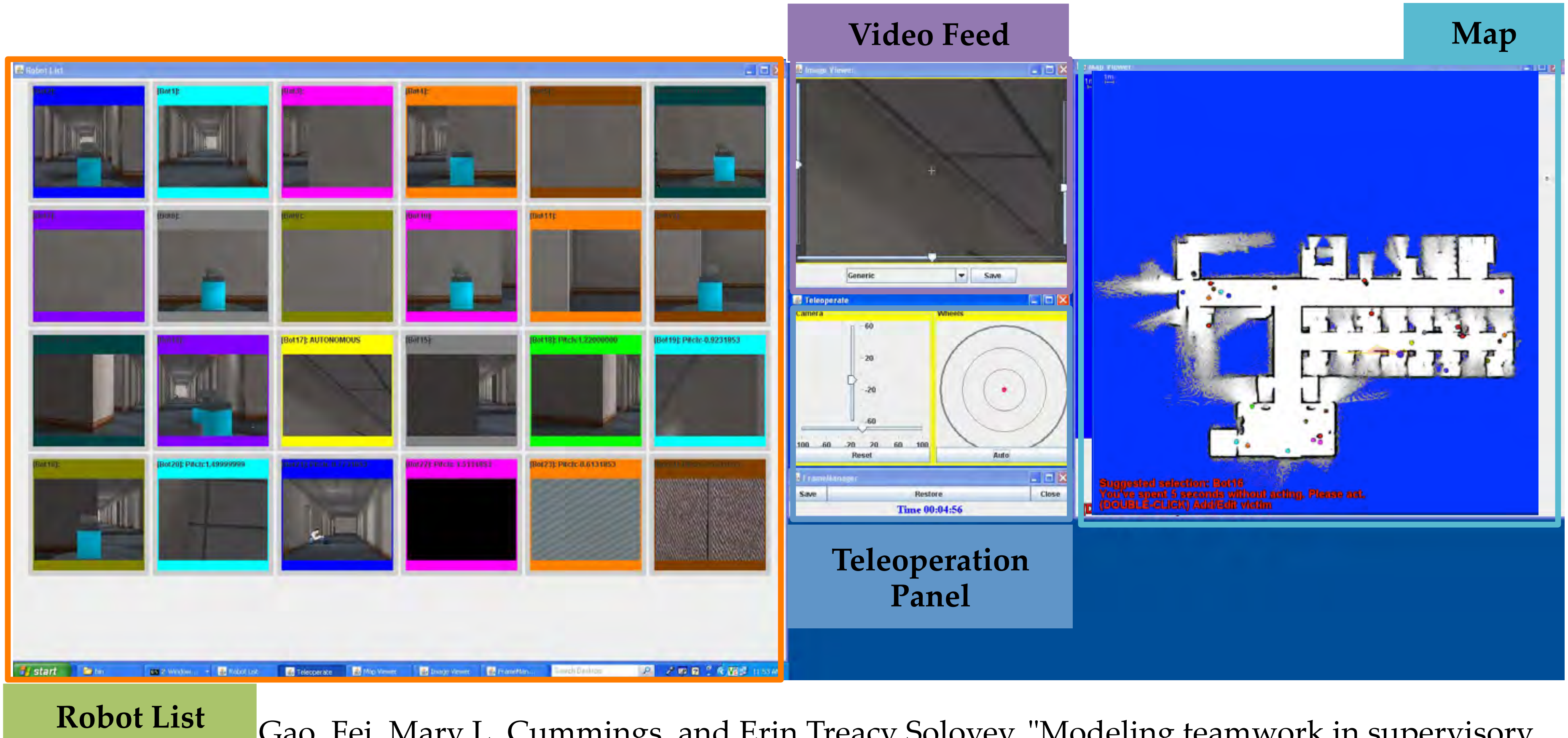
Tradeoffs in Teamwork

+	−
Process Gain	Process loss
Synergy	Breakdown in internal team processes
Adaptability & Flexibility	Collaboration overhead
Productivity	

Human-in-the-loop experiment: Effect of team structure and scheduling notification on operators' performance, subjective workload, work processes, and communication

Teamwork Experiments

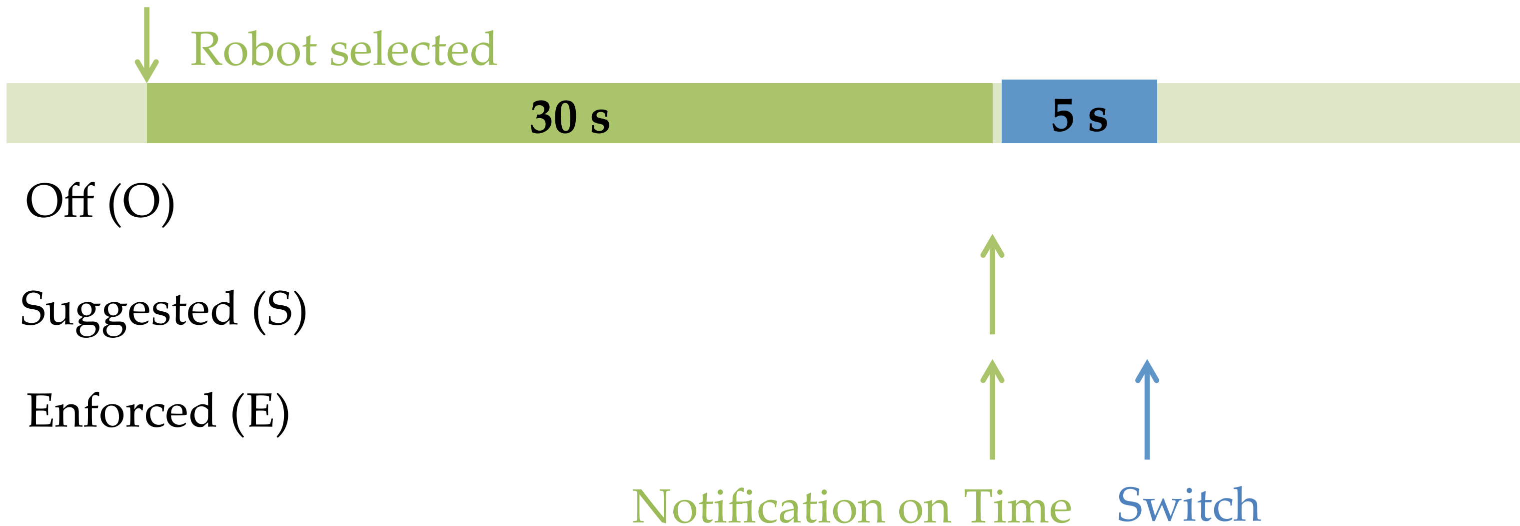
Urban Search & Rescue Task: find as many victims as possible and mark their position on the map.



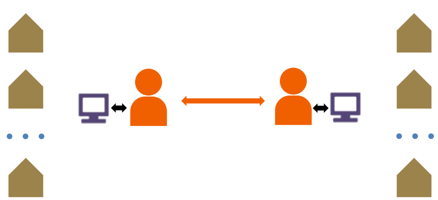
Gao, Fei, Mary L. Cummings, and Erin Treacy Solovey. "Modeling teamwork in supervisory control of multiple robots." IEEE Transactions on Human-Machine Systems 44.4 (2014): 441-453.

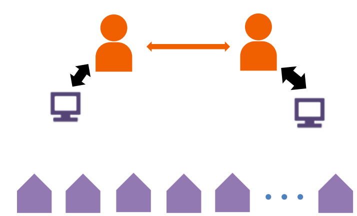
Independent Variables

- Robot Usage Notification



- Team Structure
  - Sector (S) teams
  - Pool (P) teams





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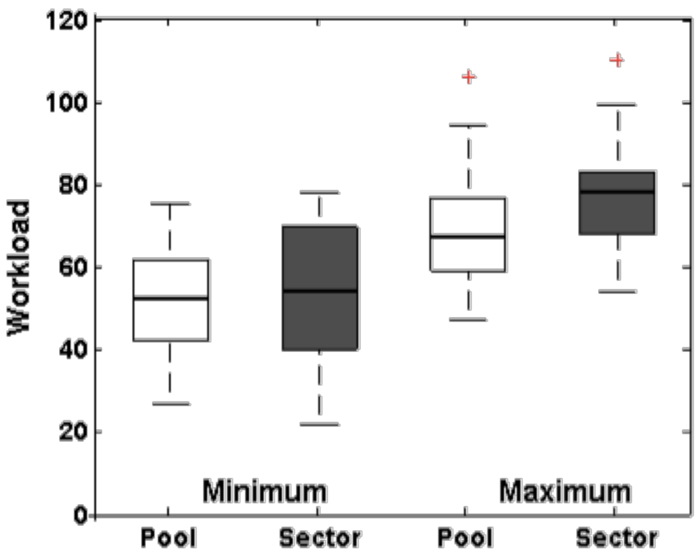
Results

Teamwork

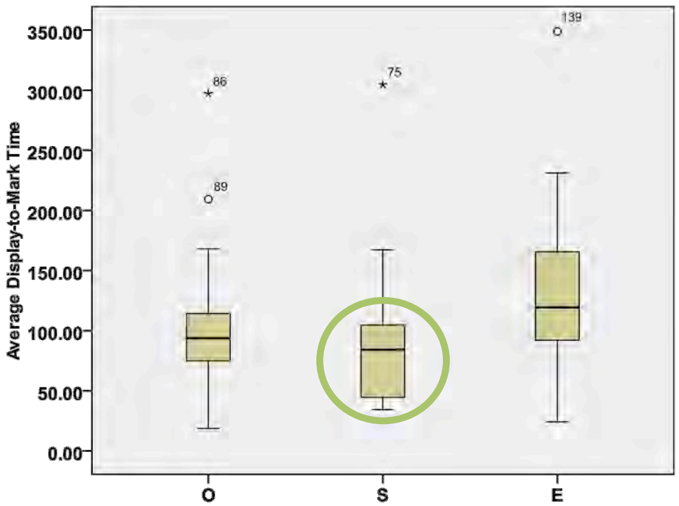
- *Pool* structure results in lower workload (NASA-TLX).



- Communication time was moderately negative correlated with errors in Pool teams (r = -0.309, p = 0.008).

Notification

- In Sector Teams, those with Suggested notification identify and mark victims faster as measured by display-to-mark time.



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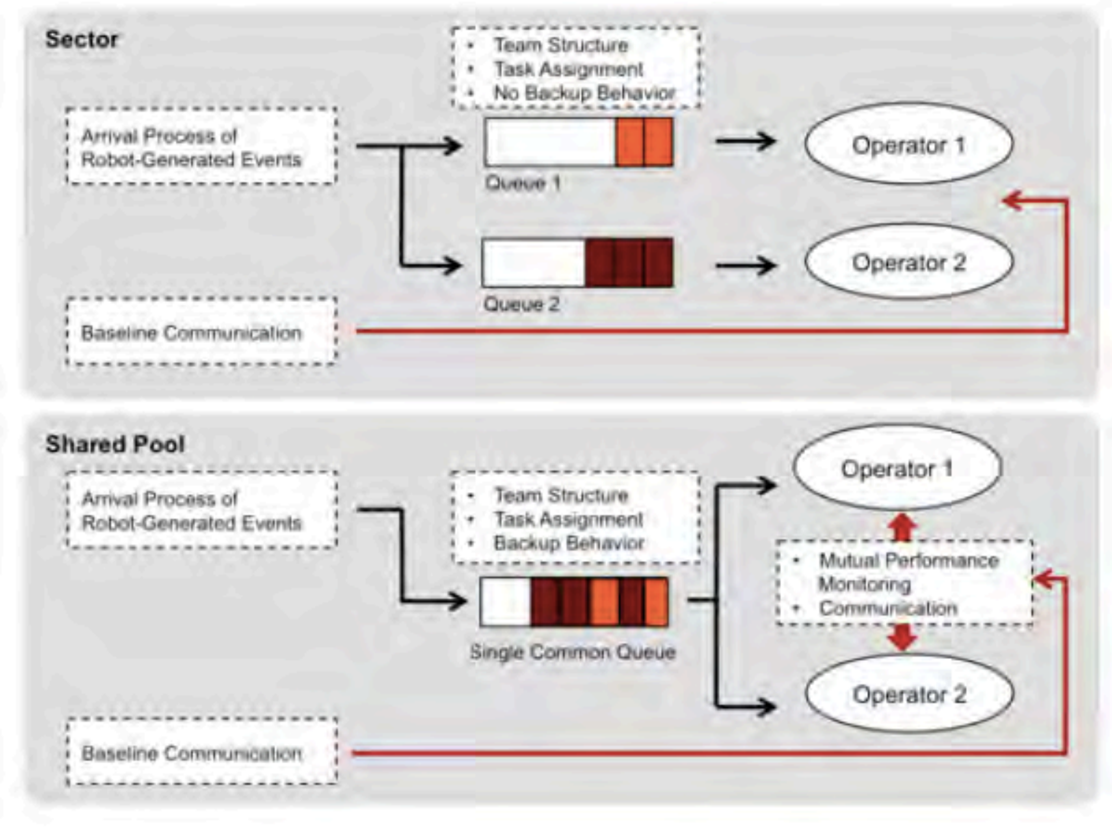
Team Performance Modeling

Discrete-Event Simulation (DES)



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Team Structure Conclusions

- Lower workload reported with *Pool*
- Similar performance with both structures
- *Pool*: more communication, balanced workload from backup behavior
- DES model:
  - replicate experiment
  - Explore uncertainty & backup
    - *Pool* balanced workload, but more coordination
    - Backup meaningful only when the task load is unevenly distributed

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