

# Examination of Several Candidate Physiological Metrics for Adaptive Training in a UAV Simulation



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# Overview

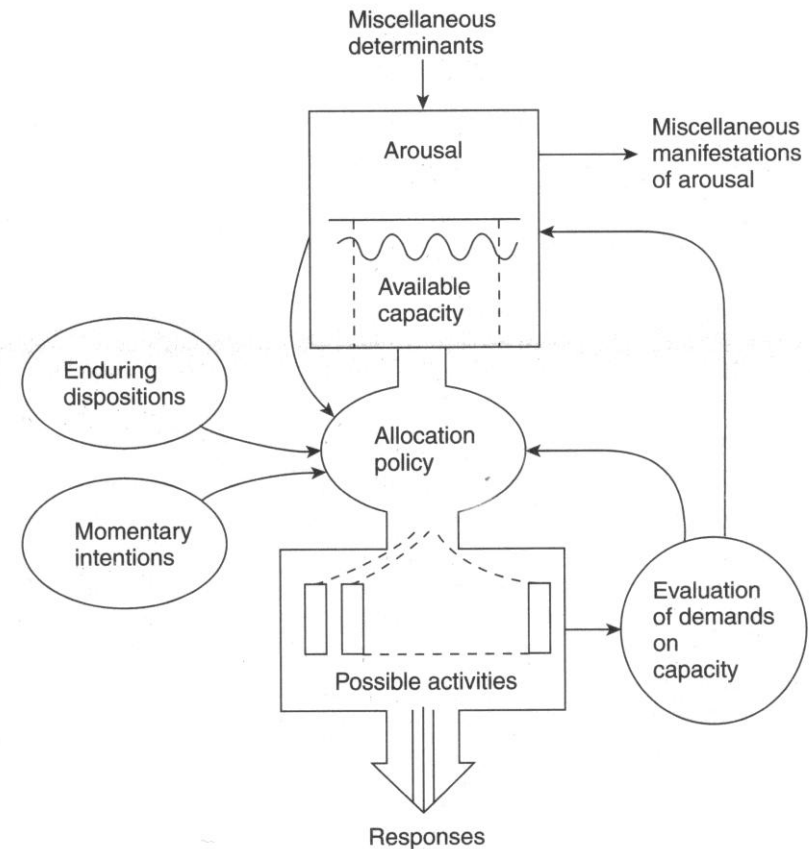
- **Goal:** Development of a real-time adaptive training for UAV operators driven by neurophysiological measures
  - Individually tailored training
- **Today:** Current state of our effort toward this goal

# Theoretical Approach



# Kahneman's (1973) Capacity Model

- Humans are limited capacity processors
  - i.e. can be overloaded
- The varying capacity of resources influenced by
  - a. arousal level
  - b. enduring disposition
  - c. momentary intentions



# Effective/Efficient Training

- Match between
  - Format and Rate at which material is presented
  - State of the Learner
    - Enduring disposition, arousal level, and momentary intension of learner
- Cognitive Load Theory (Sweller, 1998, 2006) - keep them in the “zone”
  - Alter intrinsic (rate) and extraneous (format) load
  - Multiple Working Memory Processes
    - Verbal, visual, & spatial (Baddely & Hitch, 1974, 1994, & Darling, et al., 2009)

# Experiment 1- UAV Target Detection Study

- EEG correlates of Visual Working Memory (WM)
- Spectral analysis
  - long term (**arousal level or tonic**) and
  - short-term (**momentary or phasic**) changes in alpha and theta activity.
- Pre-stimulus alpha



# Target Trial Level 1



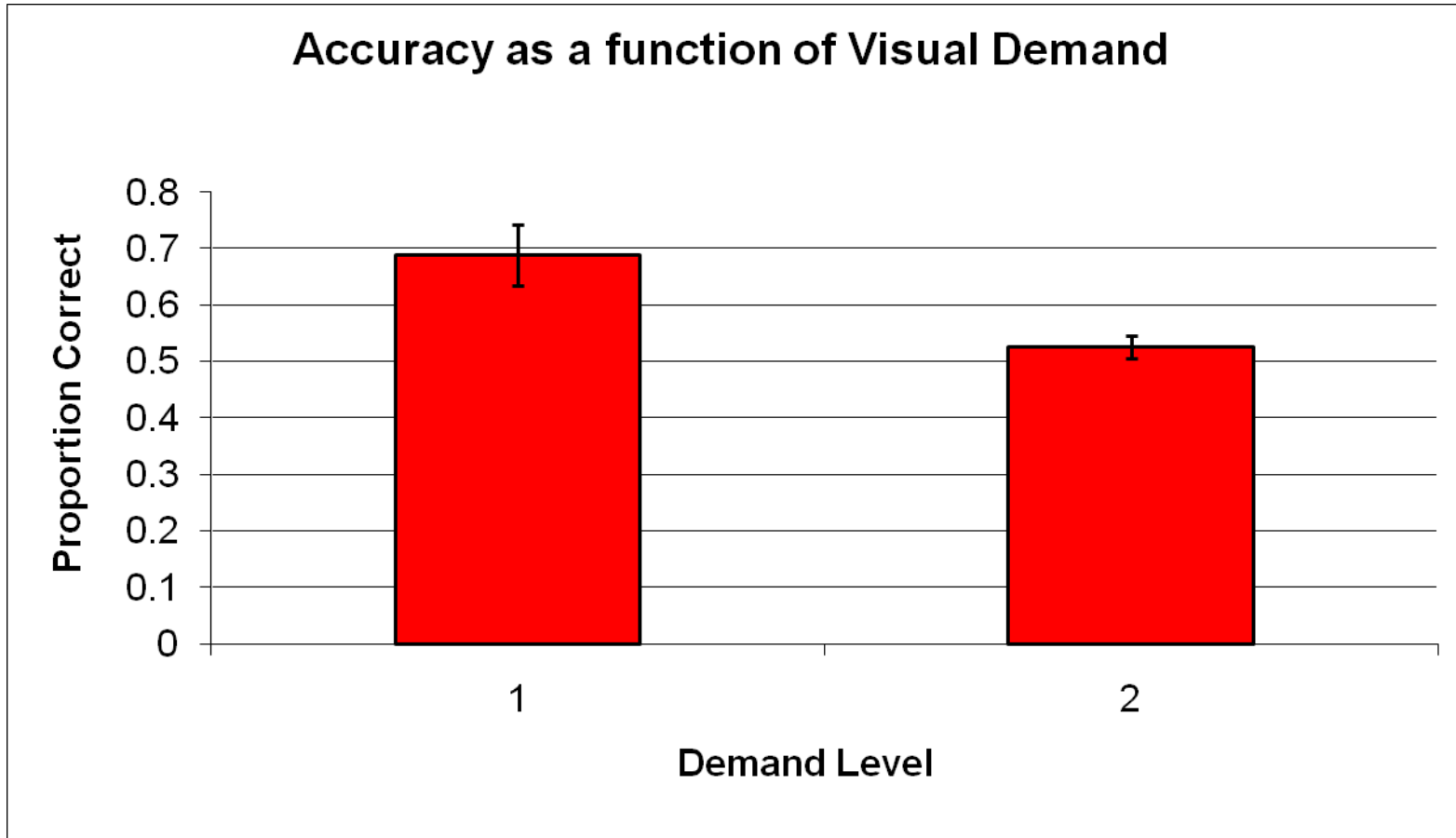
Target is a green tank moving in the opposite direction.

# Target Trial Level 2



Target the same, but distracter tanks move in all directions.

# Behavioral Results



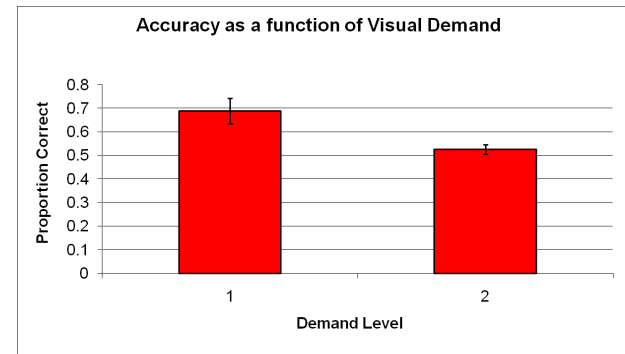
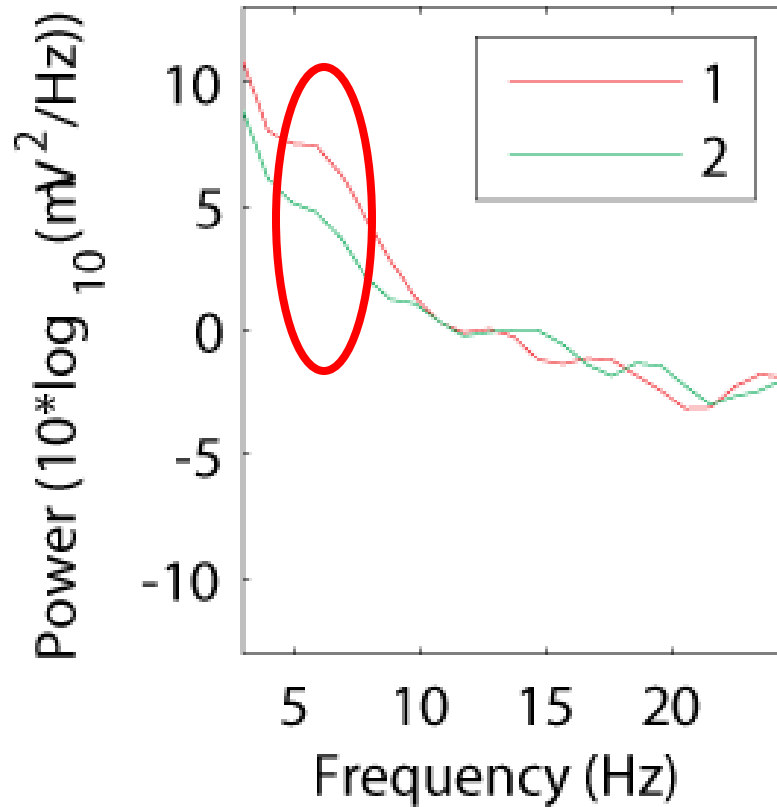
Level 2 – clearly more difficult. Performance at chance level for many.

# General Arousal – Tonic Changes

Long-term changes with time on task  
across several minutes (i.e., 10-20 m)

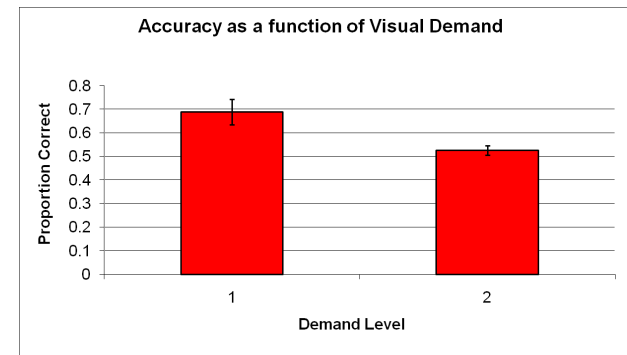
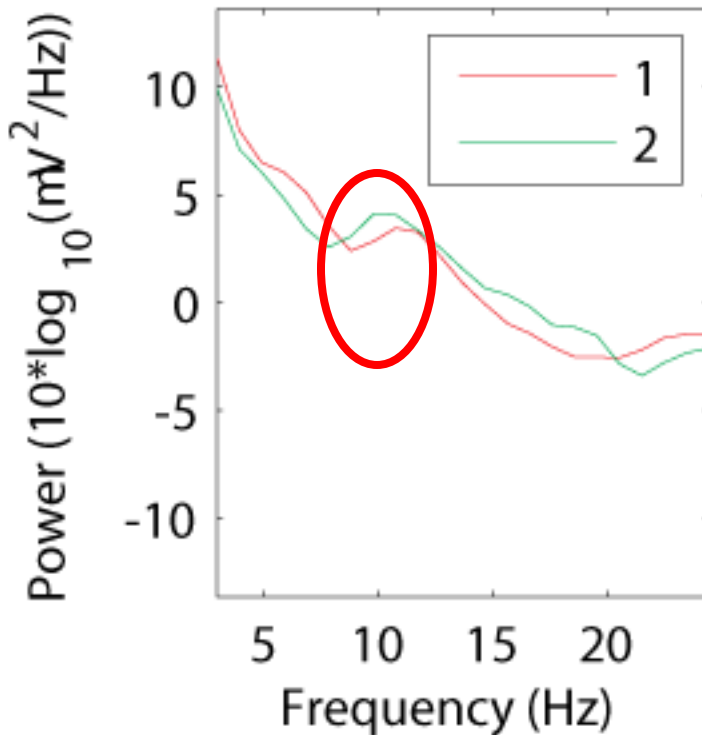
# Frontal Midline theta (Fz)

is higher when accuracy is higher (better visual working memory performance)



# Parietal Alpha (Pz)

is lower when visual working memory performance is better



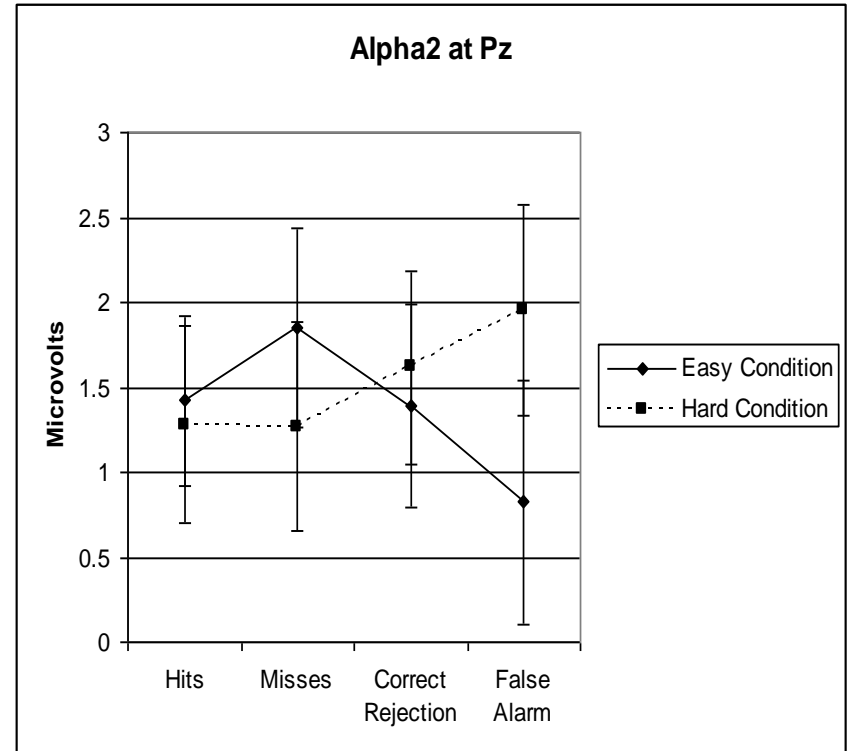
## Momentary Intentions:

Can we tell whether or not the person is engaged in a task at a specific point in time?

**Examine prestimulus alpha**

# Prestimulus Alpha

- Fast alpha (10-13 Hz) at parietal site for the 1 s time interval **before a stimulus** was presented differed as a function of task difficulty and **type of error which would be made**.
  - Hard condition,
    - fast alpha increased immediately prior to a miss, relative to correct detections and also relative to false alarms.
    - reverse pattern was observed in the Easy condition.

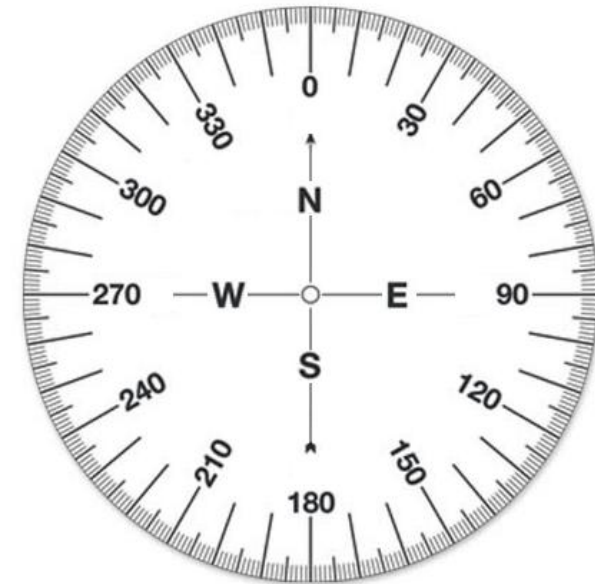


# Lessons Learned – Experiment 1

- Promising neurophysiological metrics:
  - Relative power in the theta & alpha bandwidths
  - Prestimulus alpha
- Next step - examine in conjunction with behavioral performance measures


# Experiment 2 - UAV target direction of Travel (DOT) study

- Participants received training & then watched simulated UAV videos
- Wearing ABM (Advanced Brain Monitoring) system and being monitored by Tobii X120 system
- Task: Detect targets & determine their direction of travel, then rate subjective effort



# Experiment 2- Interface

- Estimating direction from camera feed
  - Locate Target
  - Determine vehicle's direction of travel
  - Add target's relative direction to heading to calculate true direction
  - Rate mental effort



The screenshot shows a software interface for an experiment. It features a central camera feed of a landscape with a road and a target marked by a white crosshair. A red box highlights the heading '300' in the top left. Another red box highlights a text box on the right containing the instruction: 'Your response was 330. Please rate your mental effort for the previous target calculation on a scale of 1-10. (1= very little mental effort, 10= extreme mental effort)'. Below this is a red box containing the number '5' and a 'Submit Response' button. Labels with arrows point to these elements: 'UAV heading' points to the heading display, 'Target' points to the crosshair, 'Mental effort rating and directions' points to the rating instruction, and 'Where participant provides answers' points to the rating input area.

UAV heading

Heading 300

Your response was 330  
Please rate your mental effort for the previous target calculation on a scale of 1-10.  
(1= very little mental effort, 10= extreme mental effort)

5

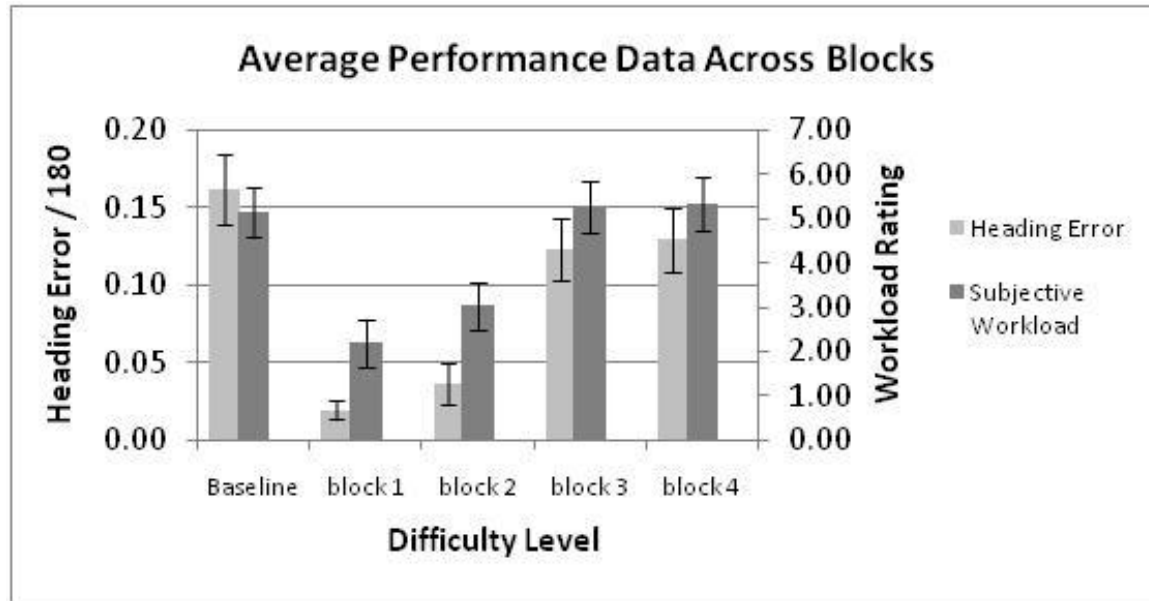
Submit Response

Target

Mental effort rating and directions

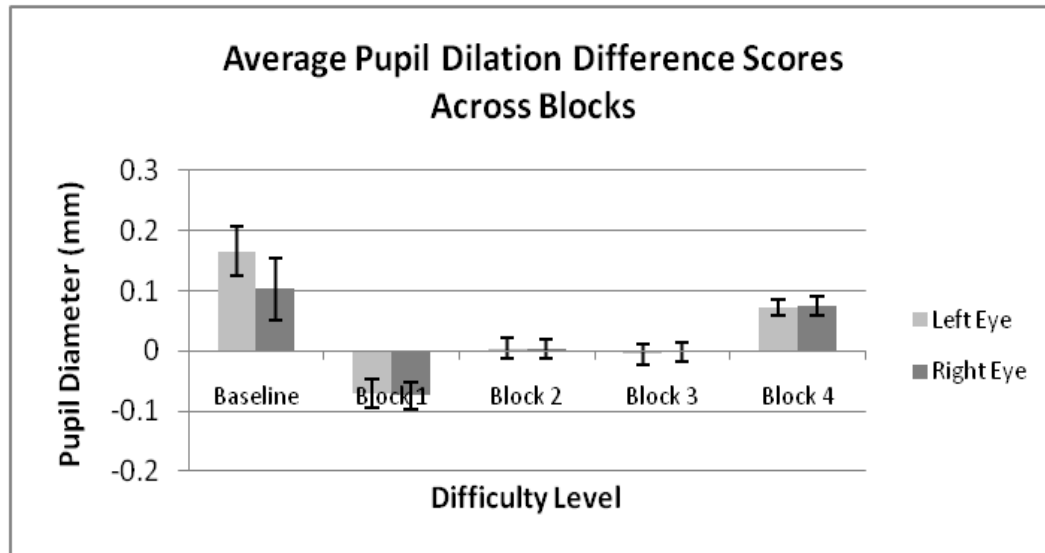
Where participant provides answers

# Performance Data for Pilot UAV Task



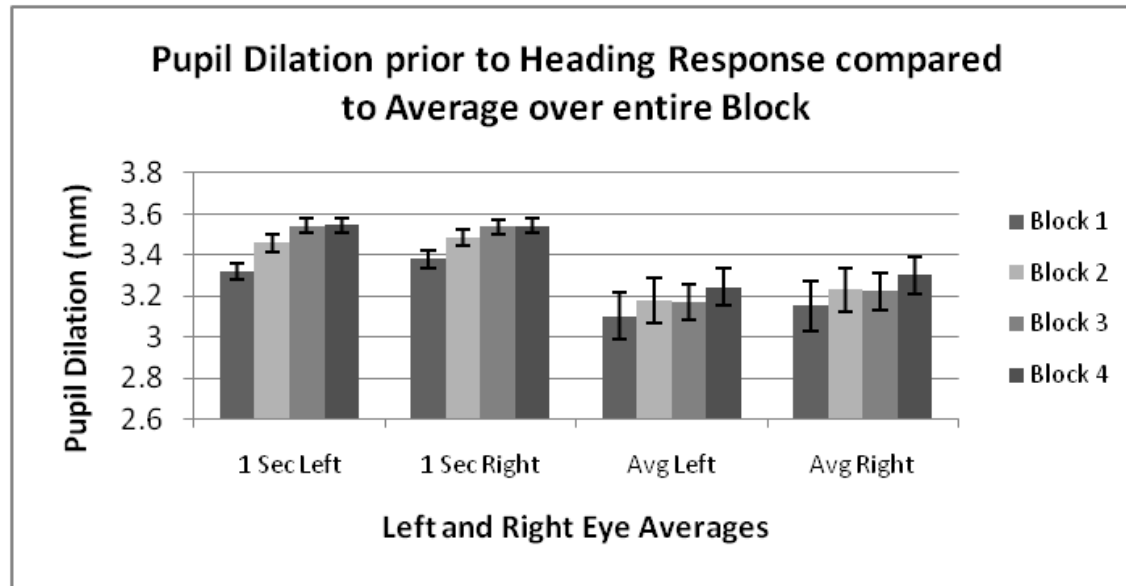
- Heading error increased over blocks
- Subjective workload ratings increased over blocks
- Shows effective manipulation of difficulty levels

# Pupil Size over and within Blocks



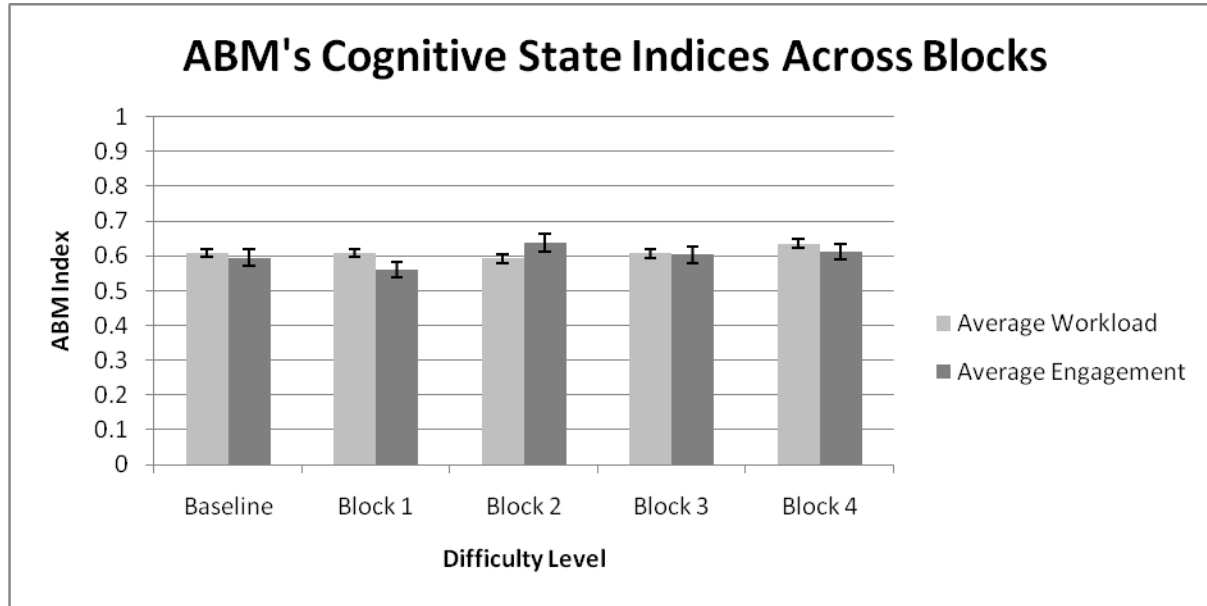
- Pupil size increases over blocks of increasing difficulty level
  - Used difference scores to decrease effects of individual differences in pupil size

# Pupil Dilation during Heading Response



- Pupil size is highest during the most mentally demanding part of the task (1 sec prior to heading response)
- Pupil size also increases across blocks when looking at both averages and during heading response

# ABM Engagement and Workload Indices



- ABM's engagement and workload indices averaged three seconds prior to participant giving heading response
- ABM EEG engagement and workload not significant across or within blocks (i.e., no significant difference between average across block and three seconds prior to heading response)

# Experiment 3 – Detect, Identify DOT & Determine Vehicle Identity

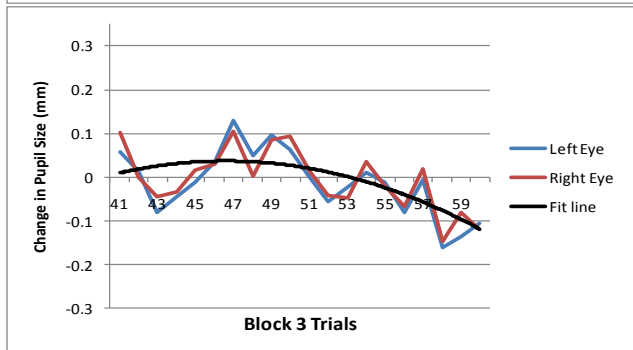
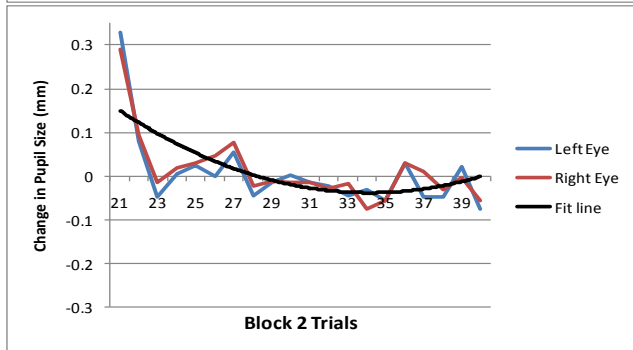
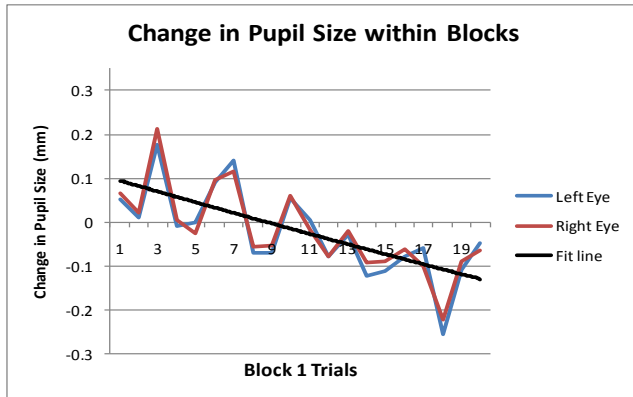
EEG, Pupilometry & comparative  
classification methods

# Addition of a target Identification task

- Learn to:
  - Recognize & name each vehicle
  - 6 different vehicles used
- Detect Target
- Determine DOT
- Identify Target
  
- Rate subjective workload for calculating heading and ID'ing vehicle
  
- EEG, Pupillometry, performance, & subjective workload examined

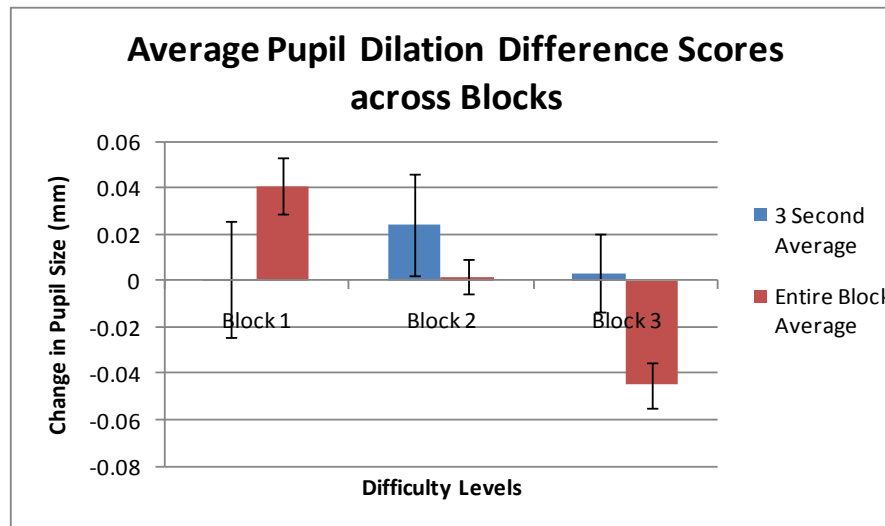


# Pupil Dilation prior to Heading Response



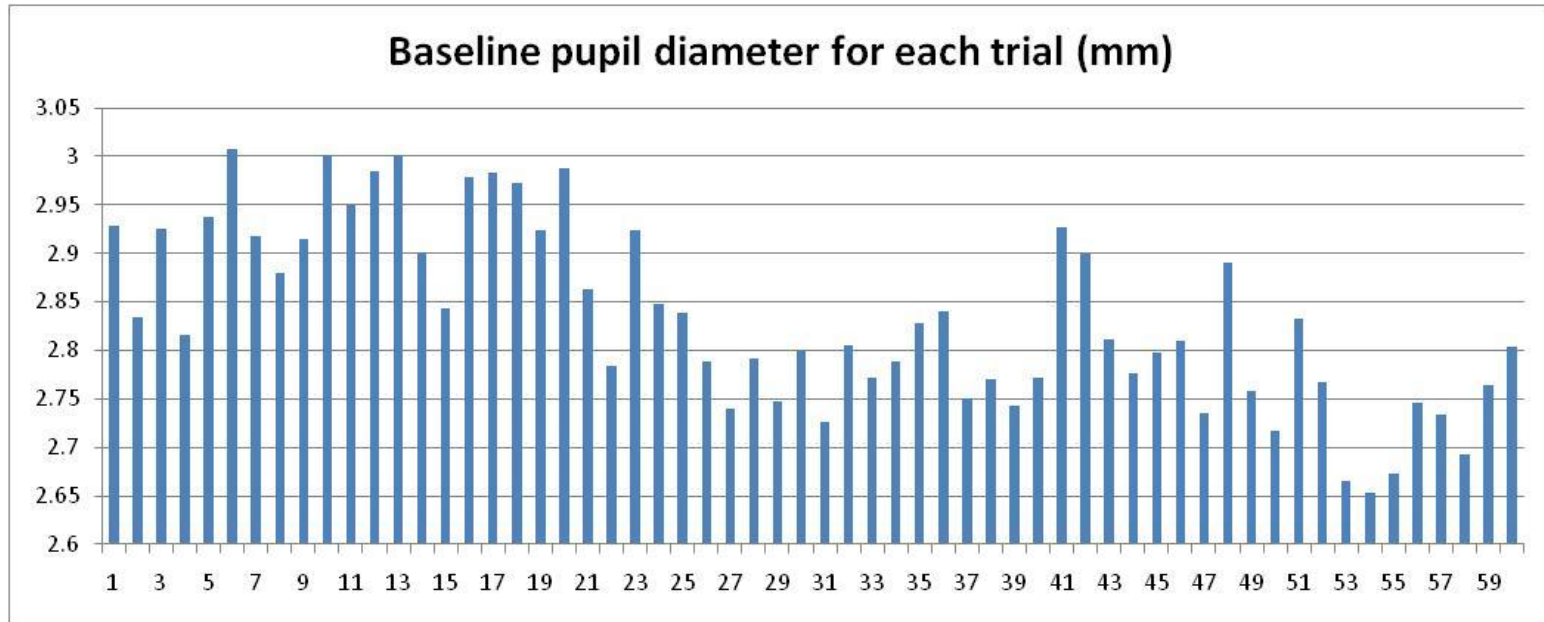
- Decreases within levels of difficulty
  - Could show learning
- What happens when overloaded
  - Block 3? Fatigue?
- All data (incorrect and correct heading response data included)
  - Performance analysis in process

# Pupil Dilation Between Blocks

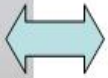


- Contrary to pilot study data, block averages decrease
  - Could show a fatigue effect
  - Different participants, more complex task
- Heading response averages show dilation between block 1 and 2, but then a decrease in block 3
  - Could show overloading or giving up
    - Performance data is currently being investigated to answer this

# Fatigue

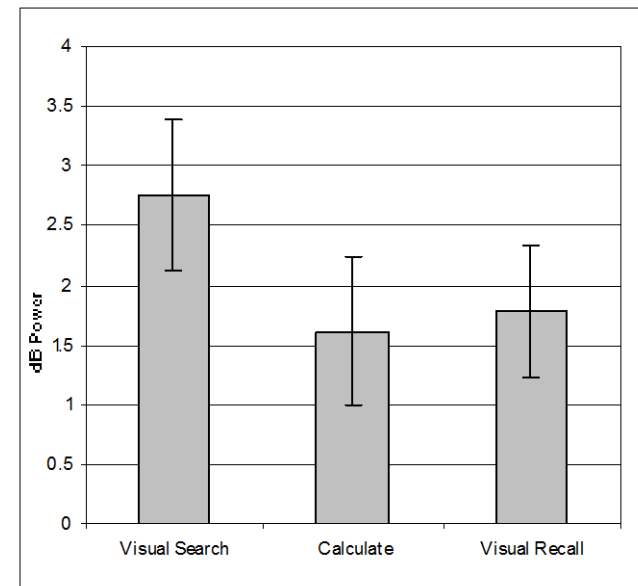


- “Baseline” period: before vehicle appears on screen
  - Should not vary in difficulty across all trials
- Different subject pool? Motivation?
- Future Studies: Randomize order of difficulty or account for effects of fatigue

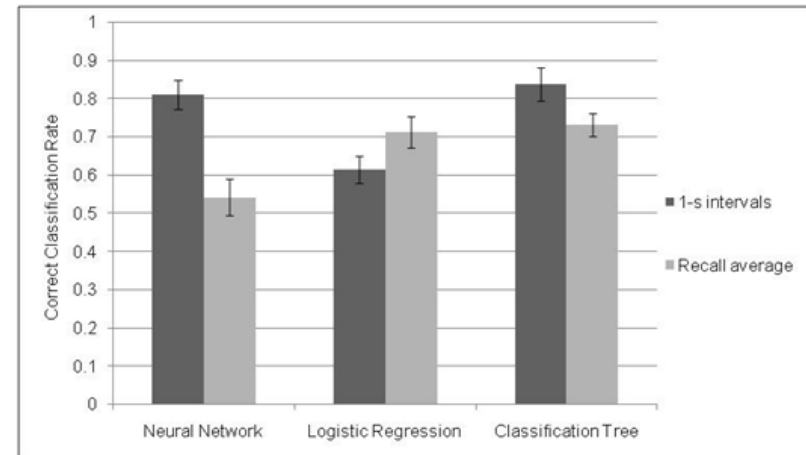
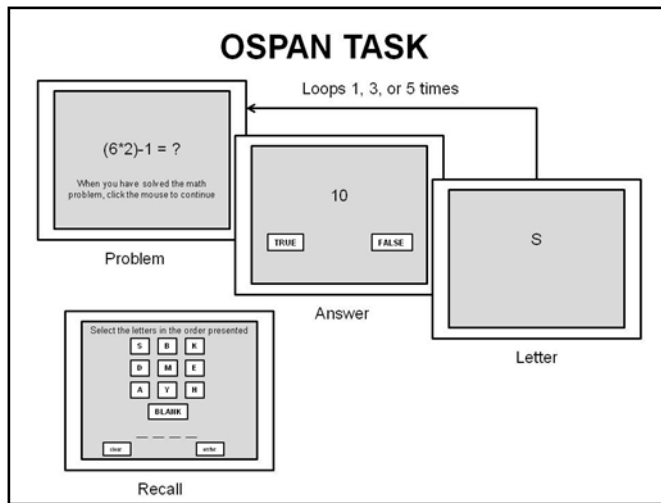


# EEG Spectral Analysis

- Fast alpha was reduced significantly during more demanding parts of the task (calculation and visual identification)



# Model comparisons: OSPAN task



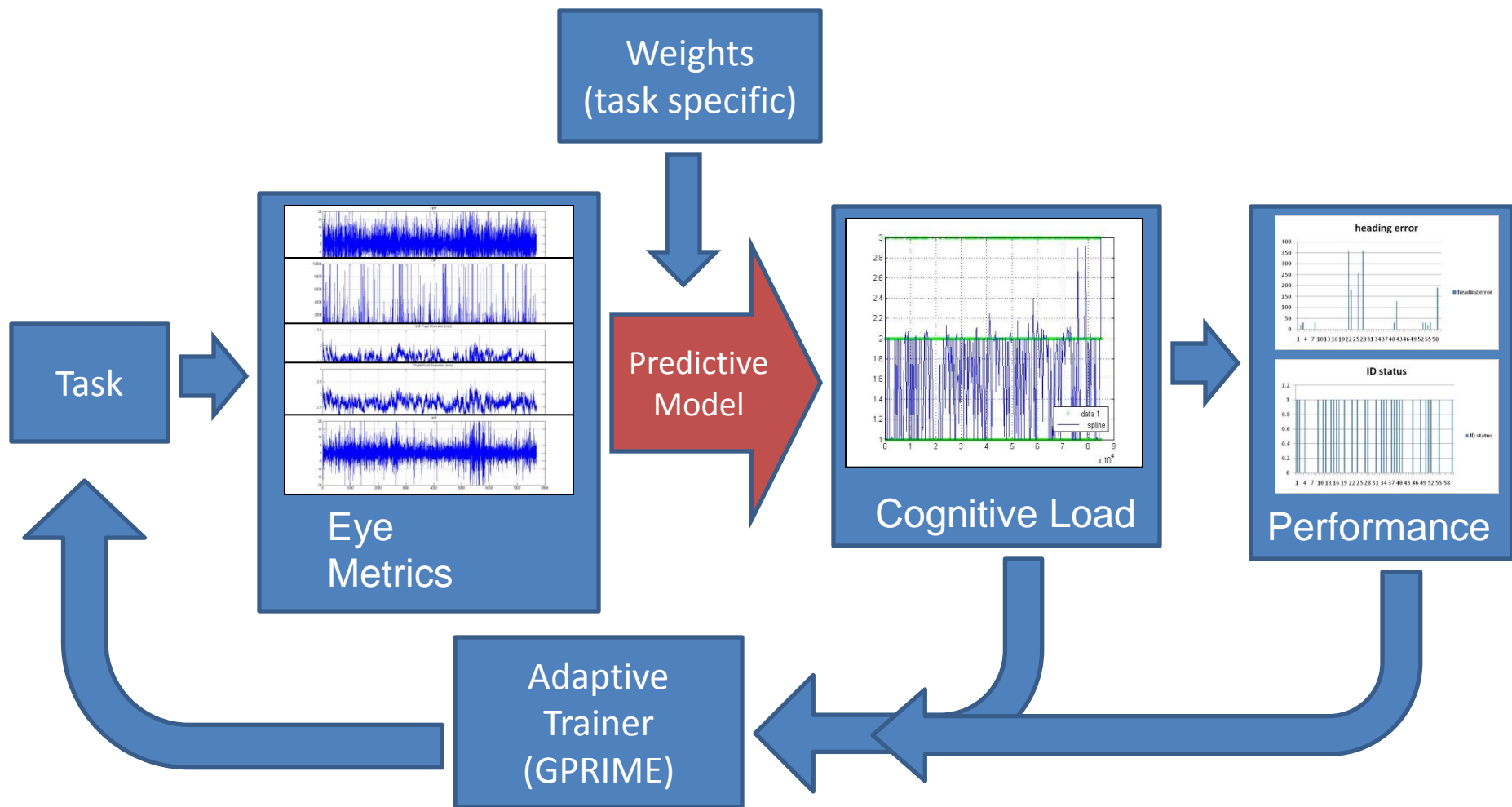
Significant model and interaction effects on correct classification rate

- ANN and Classification Tree modeling techniques were used to predict cognitive load from eye metrics
  - With inputs of pupil diameters, divergence, and fixation, ANN and Classification trees have comparable performance
  - Classification tree technique has additional benefits of being transparent
- Goal is to use OSPAN task to train a model to classify data from a new task
  - In progress

# Next Steps

- Analyze physiological data with performance data
  - Varying levels of motivation amongst participants
- Consider other physiological metrics
  - Blink, heart rate, posture, etc.
- Compare a performance driven training to a physiologically driven training
- Assess effectiveness of adaptive training in an operational environment

# Goal: Adaptive Training



# Questions & Discussion?



Gratitude goes to:

ONR – Roy Striping, Program Manager - funding

Research Team-

GMU: Dan Roberts, Brian Taylor & Jane Barrow

NRL: Ciara Sibley, Anna Cole, Allan Fong