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

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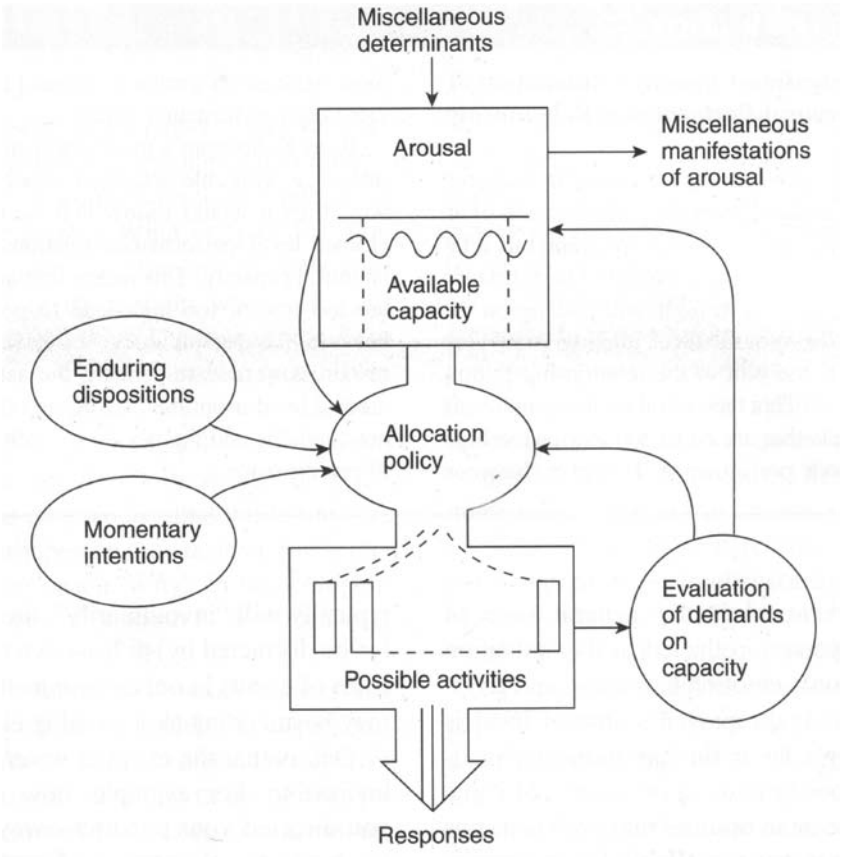
Overview

- **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

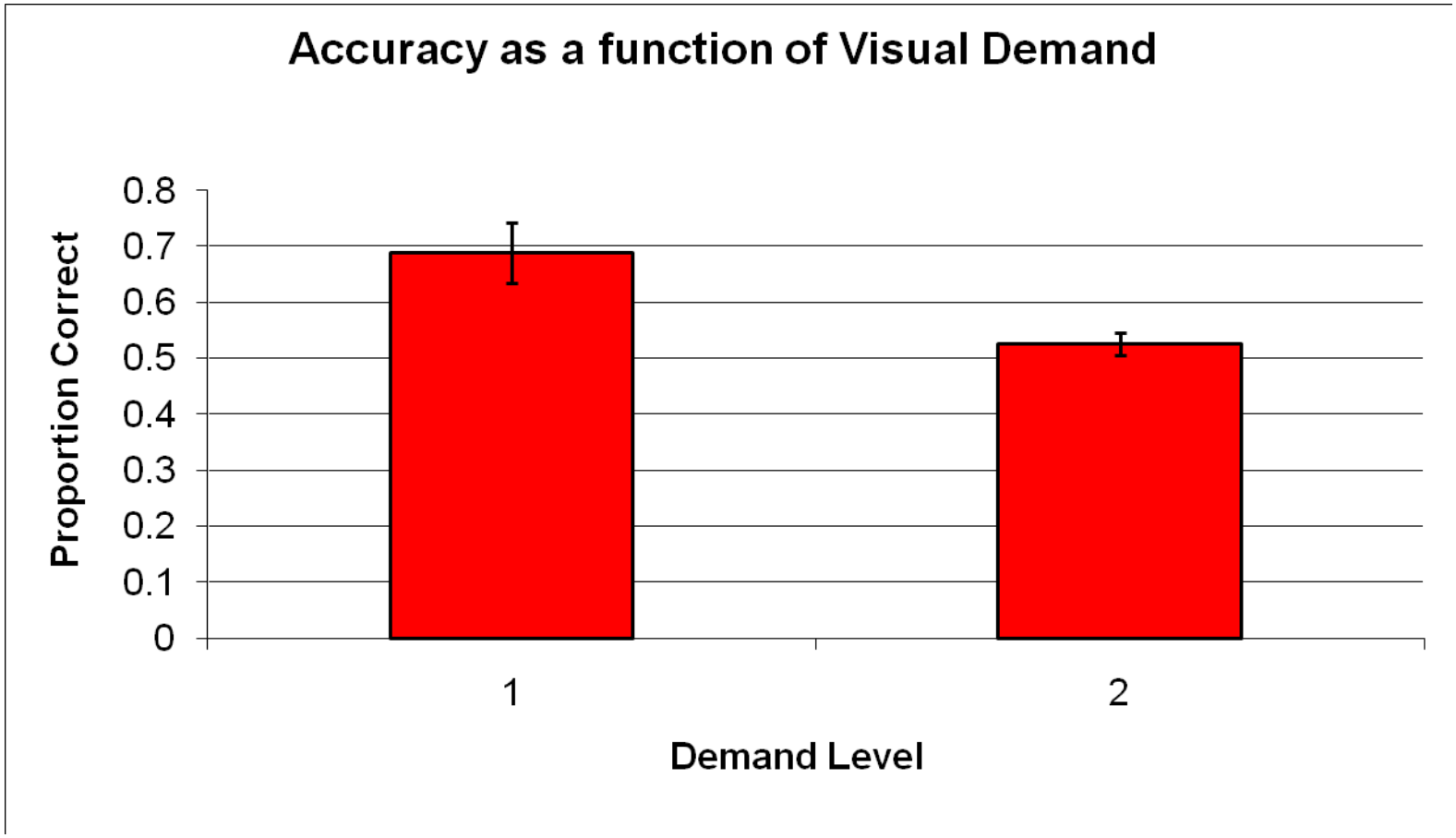
Target Trial Level 1

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



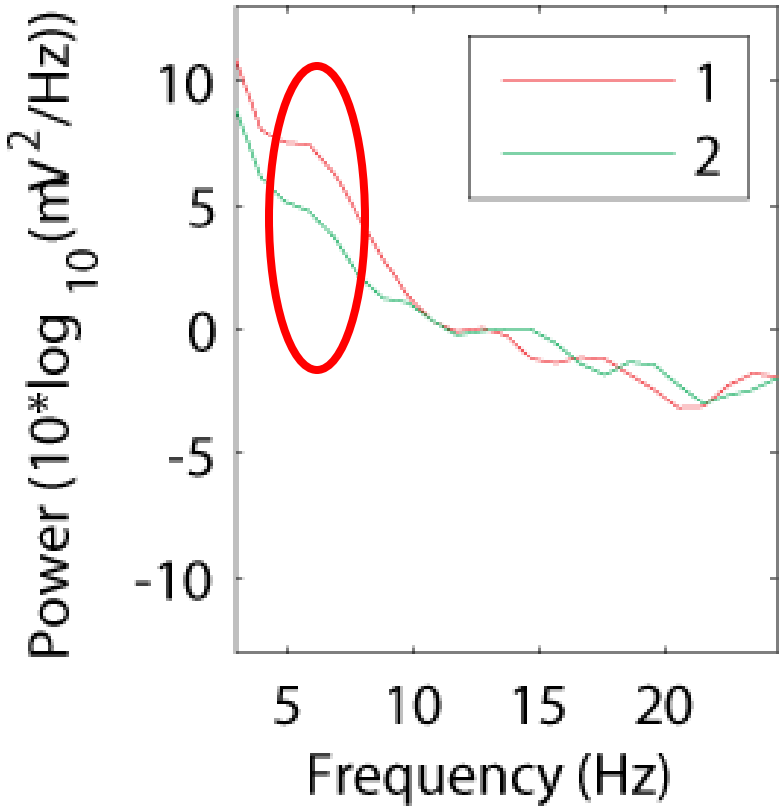
Level 2 – clearly more difficult. Performance at chance level for many.

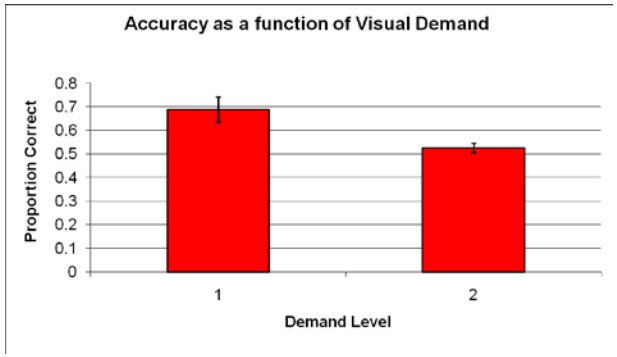
General Arousal – Tonic Changes

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

Frontal Midline theta (Fz)

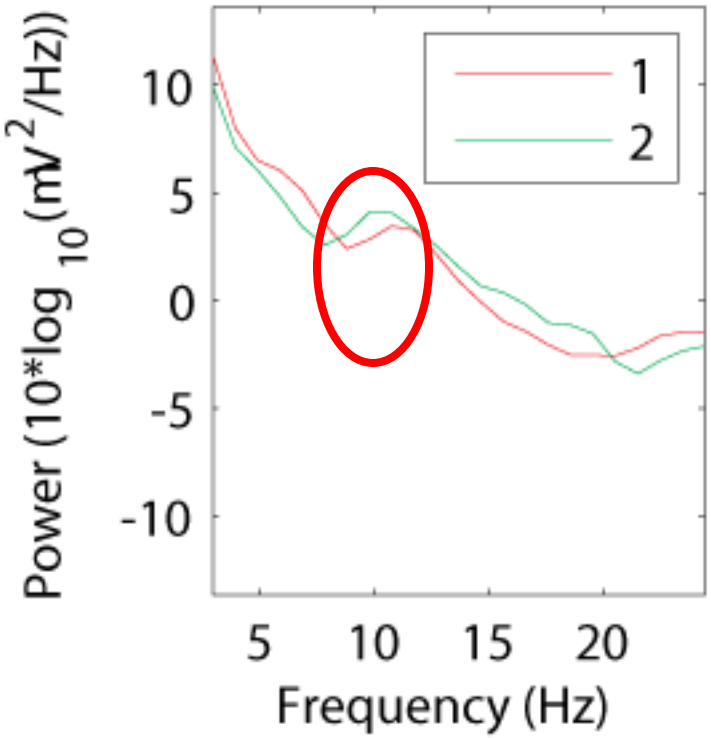
is higher when accuracy is higher (better visual working memory performance)

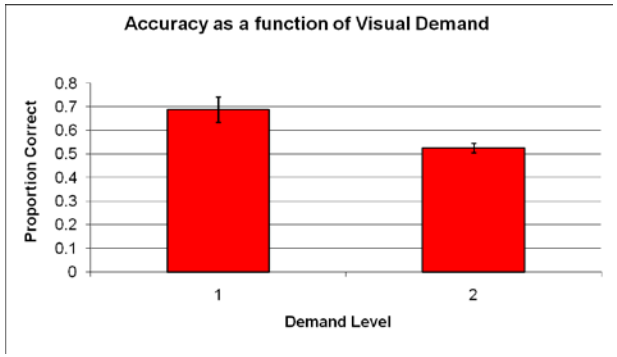




Parietal Alpha (Pz)

is lower when visual working memory performance is better



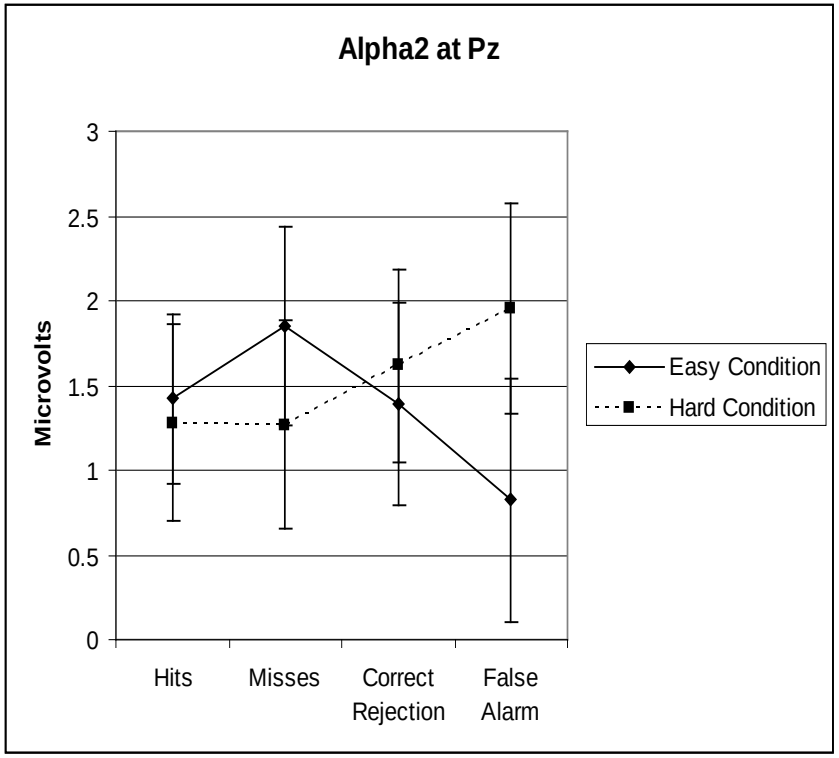


Momentary Intentions:
Can we tell whether or not the person is engaged in a task at a specific point in time?

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.

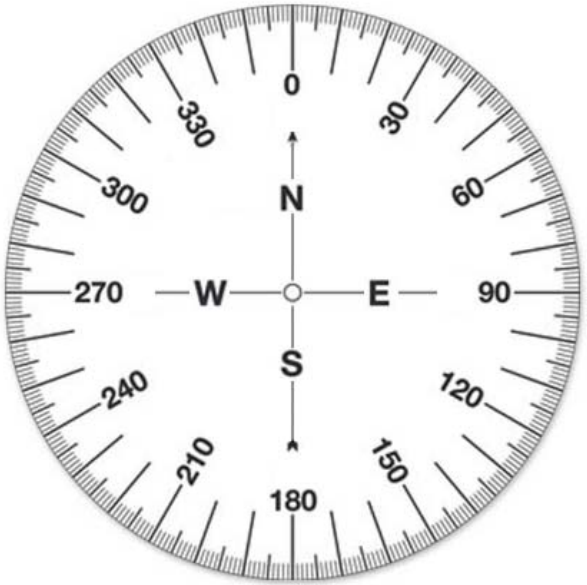


Lessons Learned – Experiment 1

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

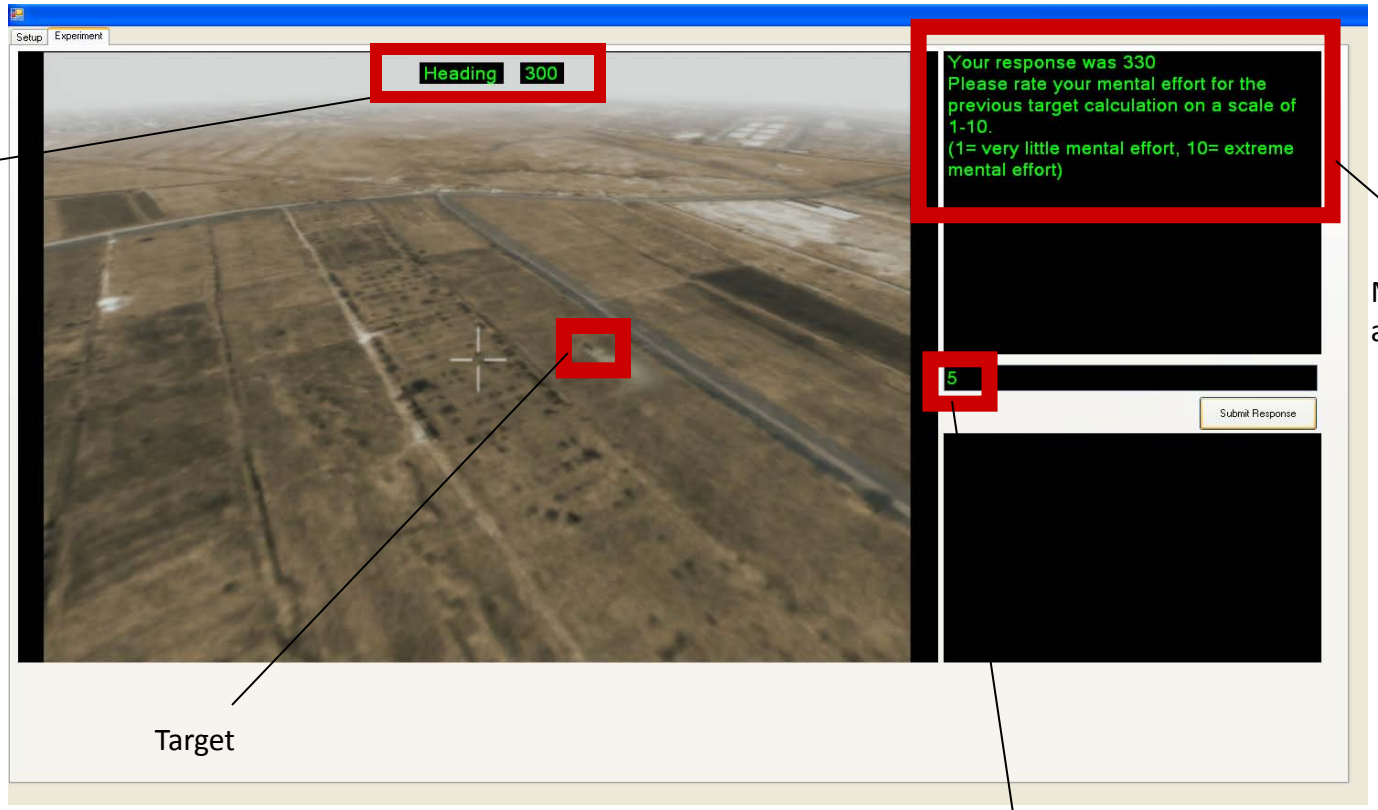
Experiment 2 - UAV target direction of Travel (DOT) study

- 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



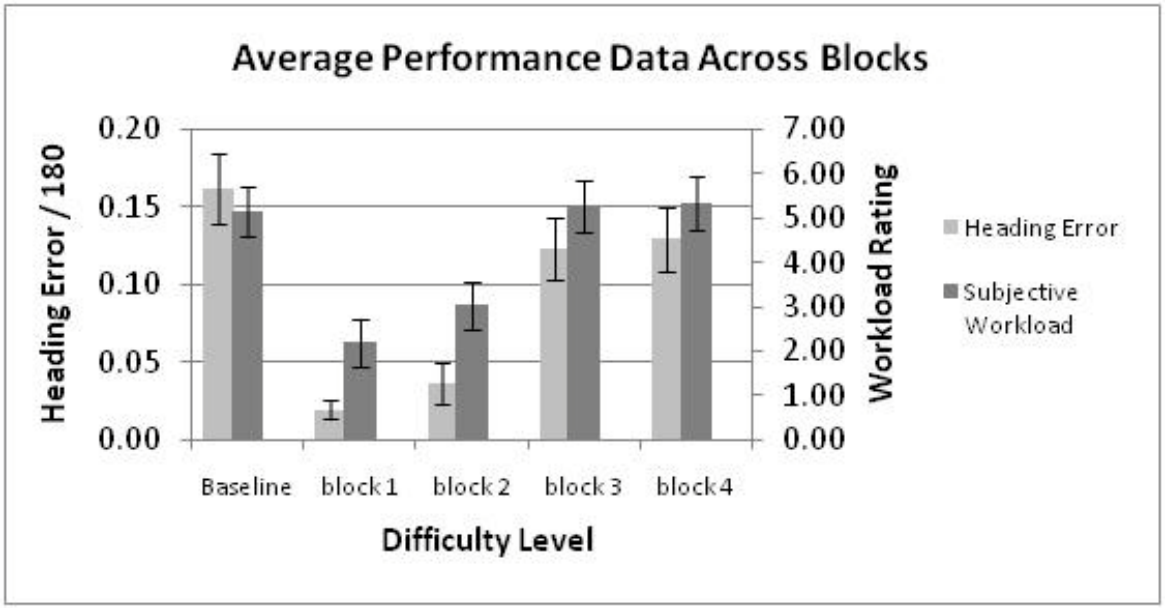
UAV heading

Mental effort rating and directions

Target

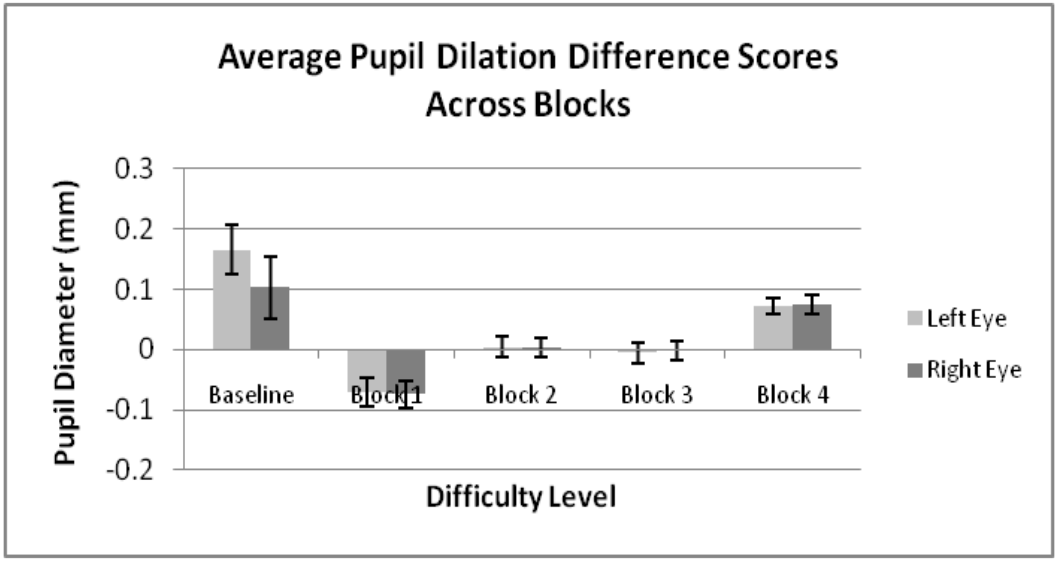
Where participant provides answers

Performance Data for Pilot UAV Task



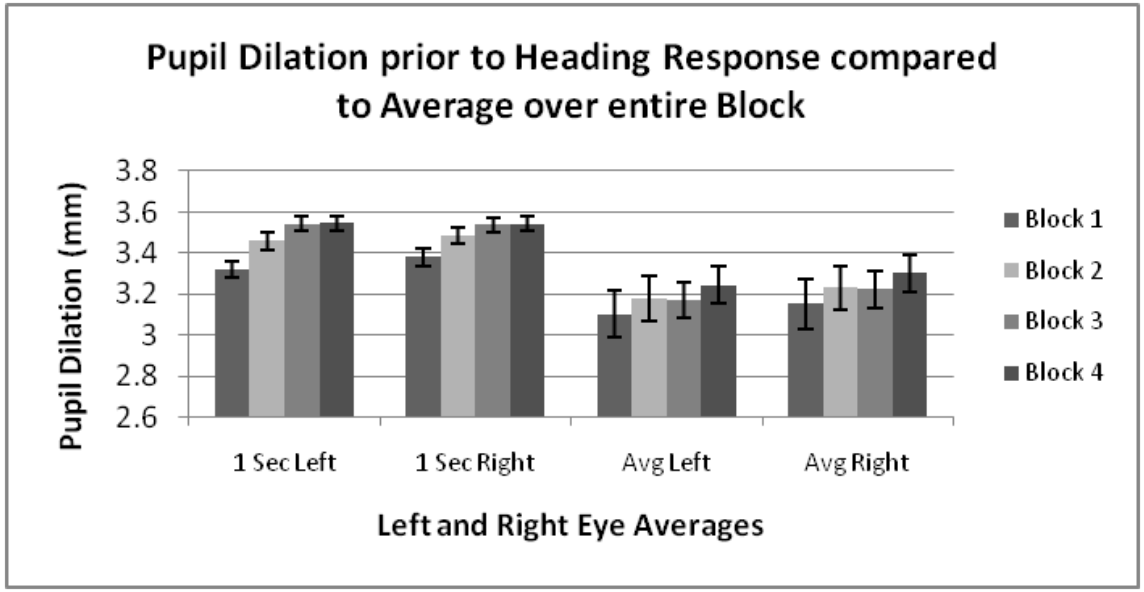
- Heading error increased over blocks
- Subjective workload ratings increased over blocks
- Shows effective manipulation of difficulty levels

Pupil Size over and within Blocks



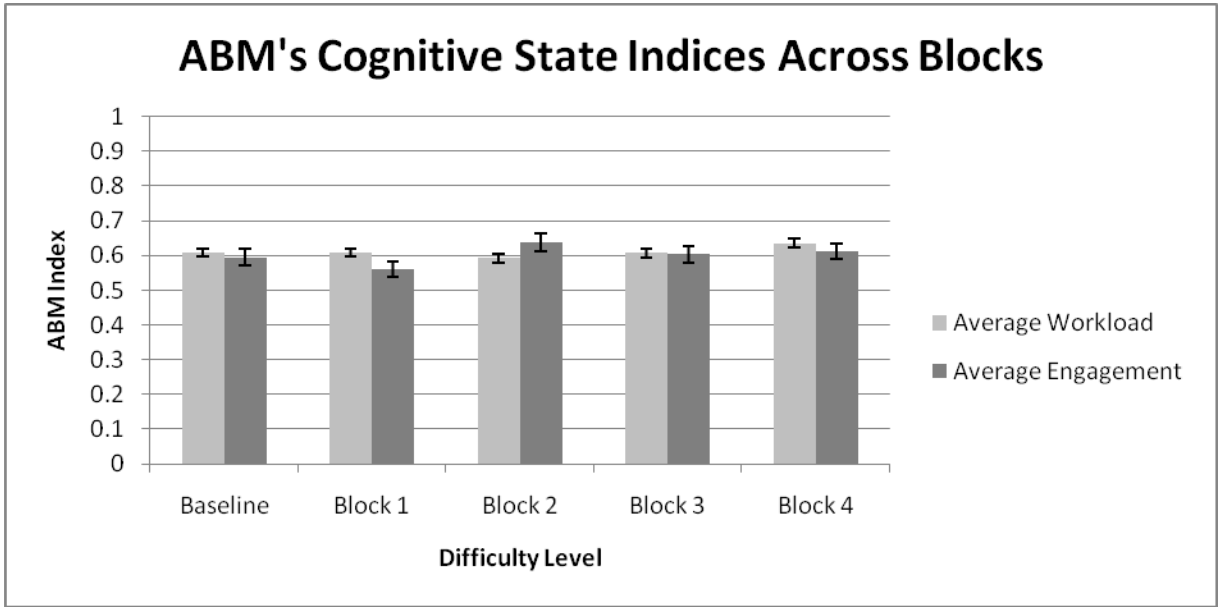
- Pupil size increases over blocks of increasing difficulty level
  - Used difference scores to decrease effects of individual differences in pupil size

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

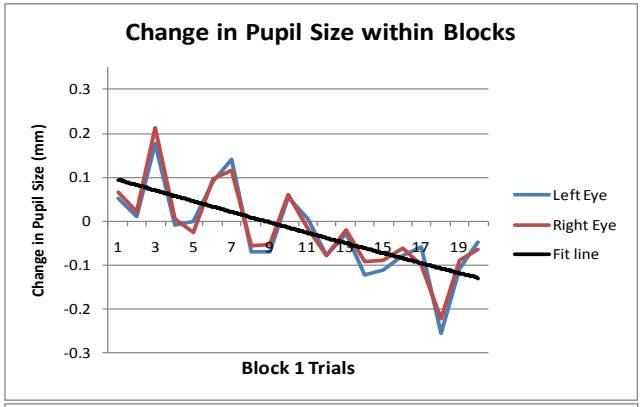
Addition of a target Identification task

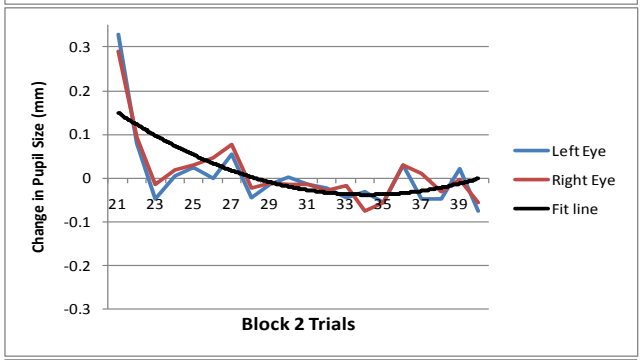
- Learn to:
  - Recognize & name <u>each vehicle</u>
  - 6 different vehicles used
- Detect Target
- Determine DOT
- Identify Target

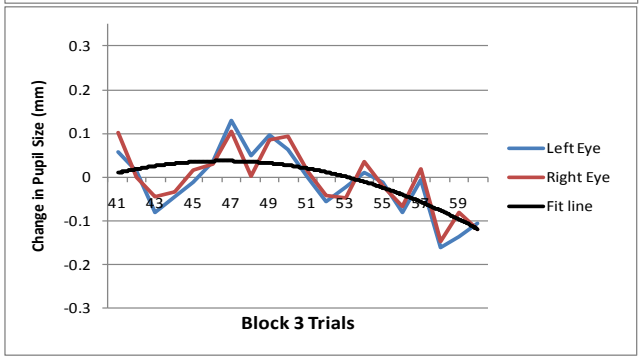
- Rate subjective workload for calculating heading and ID'ing vehicle

- EEG, Pupilometry, performance, & subjective workload examined

Pupil Dilation prior to Heading Response

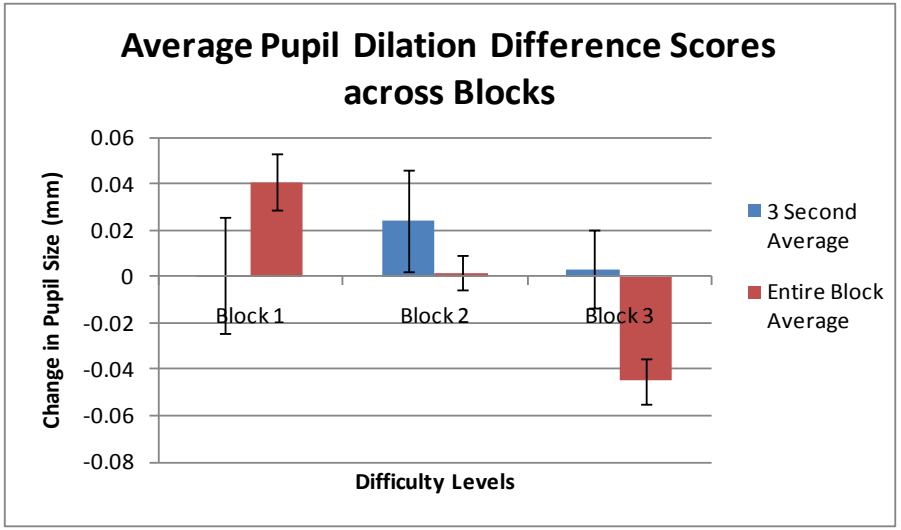






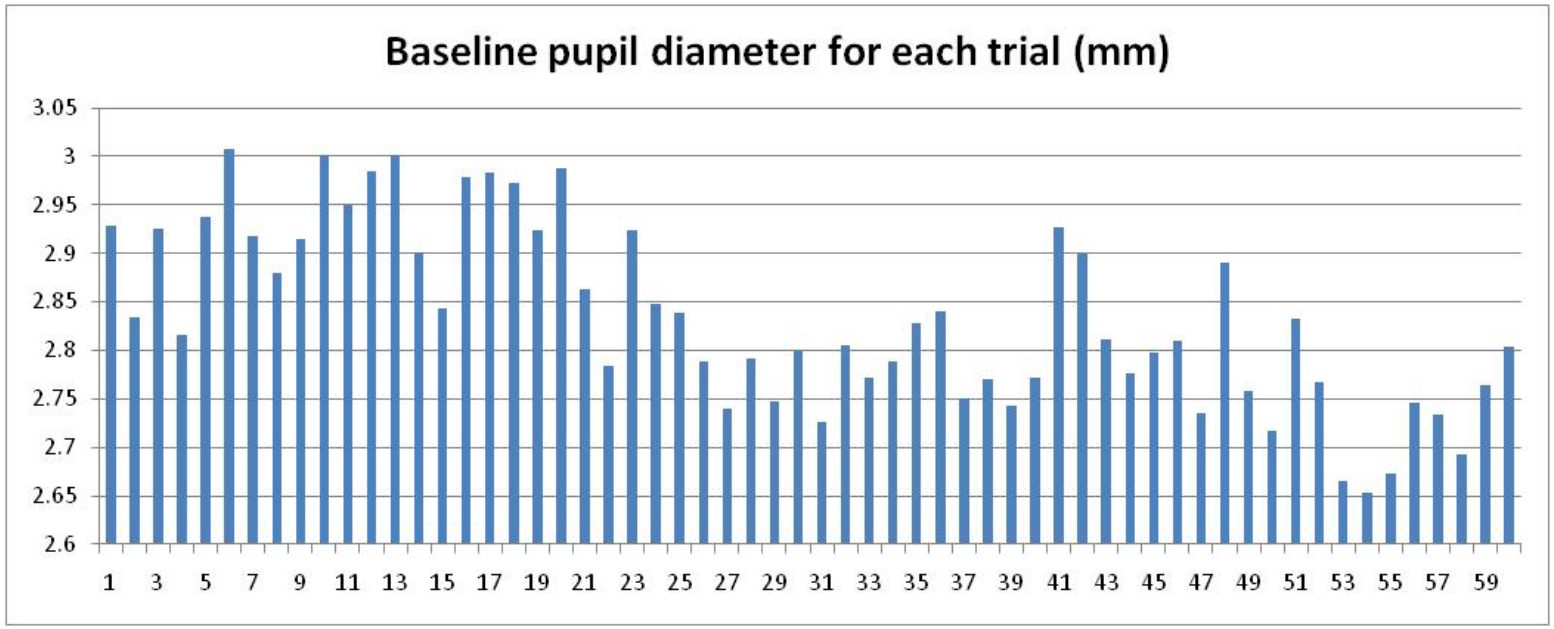
- Decreases within levels of difficulty
  - Could show learning
- What happens when overloaded
  - Block 3? Fatigue?
- All data (incorrect and correct heading response data included)
  - Performance analysis in process

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

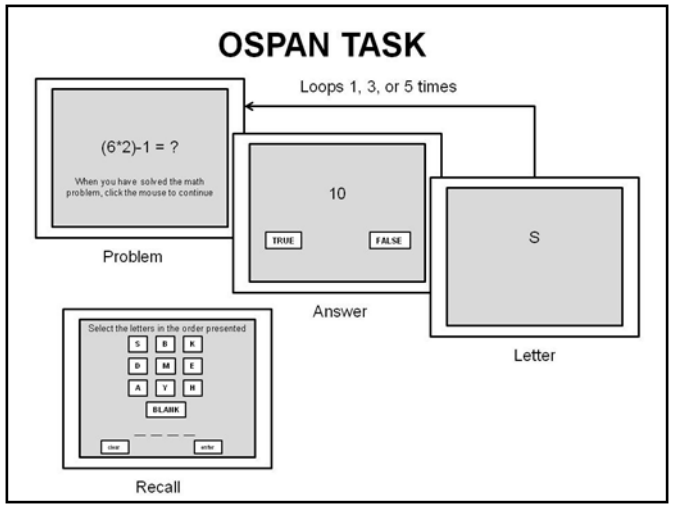


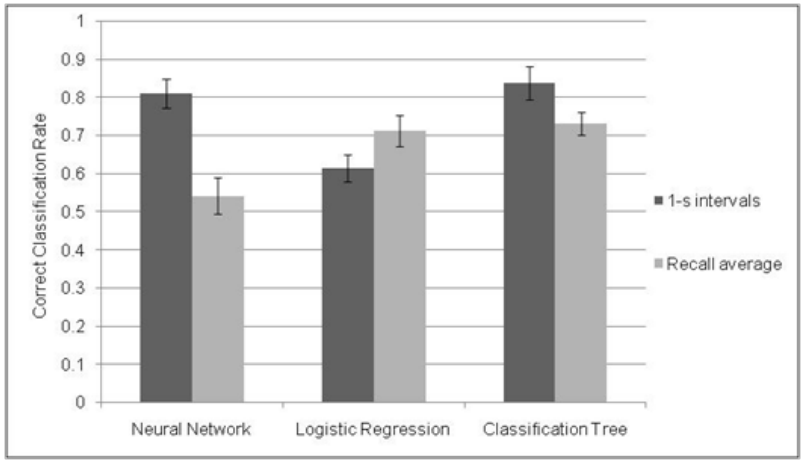
- "Baseline" period: before vehicle appears on screen
  - Should not vary in difficulty across all trials
- Different subject pool? Motivation?
- Future Studies: Randomize order of difficulty or account for effects of fatigue

EEG Spectral Analysis

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

Model comparisons: OSPAN task





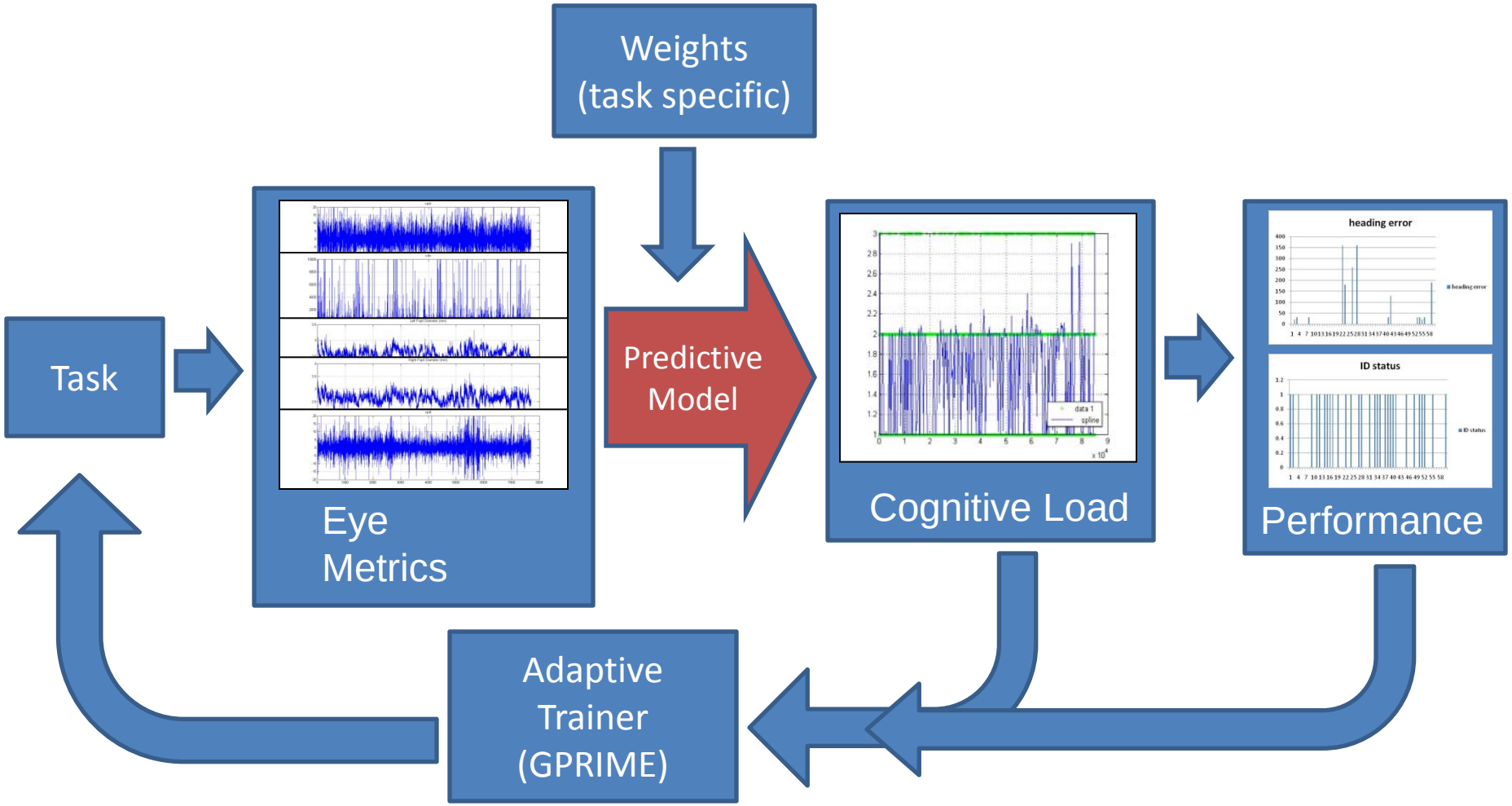
Significant model and interaction effects on correct classification rate

- 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?

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Research Team-
GMU: Dan Roberts, Brian Taylor & Jane Barrow
NRL: Ciara Sibley, Anna Cole, Allan Fong