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 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

Accuracy as a function of Visual Demand

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
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, 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
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

- 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

Task

Weights (task specific)

Eye Metrics

Predictive Model

Cognitive Load

Adaptive Trainer (GPRIME)

Performance
Questions & Discussion?

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