INSTITUTE for SIMULATION & TRAINING

# Physiological and Subjective Assessment for Training in Emergent Environments

Gerald Matthews[1] and Lauren Reinerman-Jones[2]
*(University of Central Florida)*

[1]gmatthews@ist.ucf.edu [2]lreinerm@ist.ucf.edu

INSTITUTE for SIMULATION & TRAINING

## Overview

- Relevance of workload measurement to training
- Subjective assessments of workload and stress
- Psychophysiological metrics for workload
- Workload response in three simulation studies (NPP, UAV, UGV)
- Individual differences: Performance prediction
- Applications
- Conclusion

## Training, Workload and Stress

- Training generally mitigates overload and stress
- Two forms of workload/stress reduction:
  1. *Direct effects*
     - Acquisition of more effective strategies for coping with workload and negative emotion
  2. *Indirect effects*
     - Automatization of processing likely to reduce workload and consequent stress (on high workload tasks)
- Benefits are not guaranteed
  - Suboptimal learning, strategic readjustment
  - Individual differences are likely
- Needs for monitoring workload and stress during training

## Training for Unexpected Events

- Typical unexpected event
  - Cognitive overload and failure of problem-solving/situation awareness (industrial disasters)
  - Accompanied by stress and fatigue
  - Reciprocal effect: stress feeds back into overload
- But also…
  - Complacency and failure to grasp gravity of event
  - May be exacerbated by automation (aviation incidents)
- Training needs
  - Metrics for gauging psychological impact of events
  - Metrics for evaluating simulated scenarios
  - Interventions matched to individual vulnerabilities

## Assessment Challenges for Training

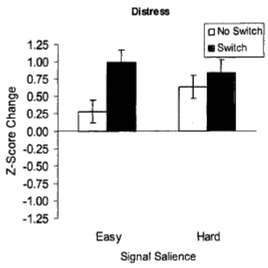
- Multifactorial nature of stress and workload
  - Explicit and implicit components
    - Limited convergence between subjective workload (NASA-TLX) and various physiological metrics (Matthews, Reinerman-Jones, Abich & Barber, 2014)
  - Both explicit and implicit measures are multidimensional
    - e.g., 6 components of NASA-TLX workload
- Multidimensional assessment important for training
  - Changing sources of workload (e.g., task demands vs. effort)
- Two training effects on stress
  - Anticipation of stress (baseline)
  - Acute stress management (task-induced response)

## Subjective Metrics: Dimensional Models

- Workload: NASA-TLX (Hart & Staveland, 1988)
  - External sources: Mental, physical, and temporal demands
  - Internal sources: Effort, performance, and frustration
- Subjective state: DSSQ (Matthews et al., 2002, 2013)
  - Task engagement, Distress, Worry
    - Plus subscales
  - Validated in studies using a range of task and environmental stressors
  - Supplement with appraisal and coping measures

# Stress States: Workload Transition

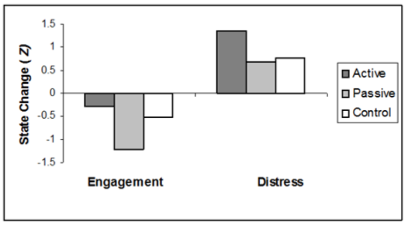
- Sudden workload transition
  - Vigilance studies
  - Changes in workload increase distress (Helton et al., 2004)
  - Pre-task warning of workload change does not help (Helton et al., 2008)
  - Low-high and high-low switches both detrimental

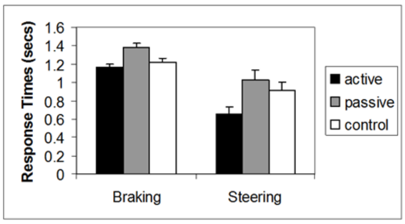



*Workload switch effects in vigilance* (Helton et al., 2004)

# Stress States: Unexpected Events

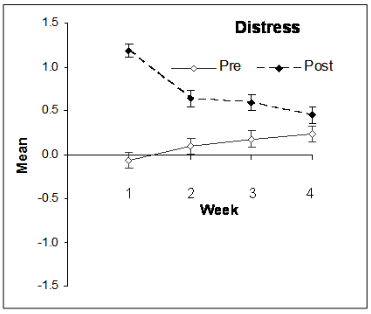
- Simulated vehicle driving (Saxby et al., 2013)
  - Automated-to-manual workload transition
  - Automated driving induces passive fatigue (loss of engagement)
  - Workload manipulation induces active fatigue and stress
  - Passive fatigue: slowed response to emergency (van pulling out)



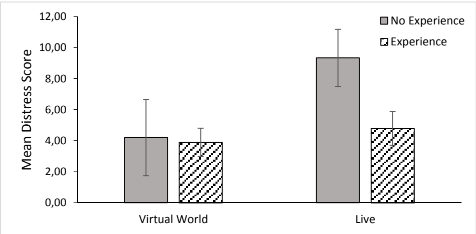
## Stress States: Change with Practice

- Four sessions of practice on a speeded working memory task (Matthews & Campbell, 2010: N=112)
  - Practice enhances performance
  - Effects on subjective distress
    - Increasing baseline distress
    - Decreasing post-task distress
  - Consistent distress – working memory correlation across sessions
  - Illustrates tracking of stress and its functional significance during training




## Assessment of Training

- Virtual world vs. live training for Army room clearing (Maxwell, Lackey, Salcedo & Matthews, 2014)
- Participants 64 reserve unit Soldiers; only some had prior experience
- Virtual world experience mitigated distress in the no-experience group



# Psychophysiology of Workload

- Multiple sensors: EEG, ECG, hemodynamic (CBFV, fNIR), and eye tracking
- Compared with subjective measures (e.g., NASA-TLX)

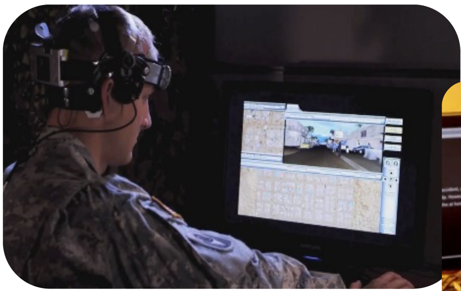
| *Pros* | *Cons* |
|---|---|
| Objective (no reporting bias) | Bias from physiological factors (e.g., metabolism, arousal) |
| Link to neuroscience | Limited evidence on validity |
| Continuous measurement | Plethora of data (need metrics) |
| | Practical issues (training, cost) |

# A Suite of Workload Sensors

| Sensor | Method | Metrics | Notes on Metrics | Ambulatory Assessment |
|---|---|---|---|---|
| Electrocardiogram (ECG) | • Typical electrode placement: single-lead electrodes on the center of right clavicle and lowest left rib | • Heart rate (HR) or Inter-beat interval (IBI)<br>• Heart rate variability (HRV) | • HR, IBI: Sensitive to arousal, activity<br>• HRV: Mental effort, emotion regulation | • Straightforward: Ambulatory measures compare well with those from laboratory ECG equipment |
| Electroencephalogram (EEG) | • Multiple scalp electrodes | • Spectral power densities (SPDs) for frequency bands (delta, theta, alpha, beta, gamma)<br>• Derived indices | • Task effort (frontal theta)<br>• Other bands sensitive to arousal, cognitive activity<br>• Task Load Index - Ratio of theta Fz: alpha Pz | • Challenging: low voltage signal, technical issues<br>• Recent advances: wireless systems, miniaturization, 'dry' electrodes (no gel) |
| Cerebral bloodflow velocity (CBFV) | • Transcranial Doppler (TCD) ultra-sonography using probes above zygomatic arch | • Bilateral CBFV in medial cerebral arteries<br>• Task-induced response | • Cognitive engagement vs. fatigue<br>• Sensitive to coping | • Not yet practical—but useful for lab-based validation |
| Functional near-infrared spectroscopy (fNIR) | • Forehead IR light sources and detectors to measure prefrontal blood oxygenation | • Bilateral cortical oxygenation in the prefrontal cortex | • Task-directed effort, executive processing | • Portable and usable in field settings |
| Eyetracking | • Camera recording of the eye | • Frequency and duration of fixations<br>• Pupillometry: Index of Cognitive Activity (ICA) | • Cognitive load<br>• Also for areas of interest | • Head mounted units are promising |

## Physiological Sensor Integration

- Evidence for physiological links with performance supports the integration of Electroencephalography (EEG), Eye Tracking, Electrocardiography (ECG), and Hemodynamics (fNIR, TCD)



## Physiology and Simulation Testbeds

- Include tasks that are independent and interact within complex dynamic environments while still supporting the controls demanded of a laboratory.
- Must have built in methods for inclusion of measures collected from multiple computers, third-party applications, and participants through external time synchronization techniques.
- Physiological sensors must be accounted for in any task battery as an alternative means of assessing observer performance and state and for predicting and augmenting within a given environment.

## Psychometric Issues

- Individual metrics are internally consistent (reliable)
- Metrics are sensitive to external workload manipulations
  - Simulation studies of nuclear power plants (NPPs), unmanned ground vehicles (UGV)
  - Sensitivity of metrics varies across tasks and manipulations
  - Assessment of workload response as a multivariate profile
- No clear unitary workload response
  - Metrics are only weakly intercorrelated
  - Metrics are weakly related to subjective workload (e.g., NASA-TLX)

## Evaluating Metrics for NPP

- Nuclear Regulatory Commission (NRC) has developed a tool to support the evaluation of workload (WL), situation awareness (SA), and teamwork (TW) metrics (Reinerman-Jones et al., 2015)
- Generic Metrics Catalog (GMC)
  - Database of metrics listing psychometric properties and study characteristics
- Decision-Making Wizard (DMC)
  - Decision tree to assist NRC reviewers in evaluating the choice and implementation of a metric.
- Available at http://www.nrc.gov/reading-rm/doc-collections/nuregs/contract/cr7190/

## Diagnosticity for Sources of Demand

- Multiple sources of excessive demand
  - Multi-tasking
  - Difficult perceptual discriminations
  - Time pressure
  - ...and numerous others
- Can we use physiology to identify sources of demand?
  - e.g., distinctive workload 'signature' for multi-tasking
  - Support targeted group-based or personalized training
- Are diagnostic patterns general across applications?
  - e.g., does the multi-tasking 'signature' generalize across different task combinations and settings?
  - Or does the signature depend on task context?

## Summary of Studies

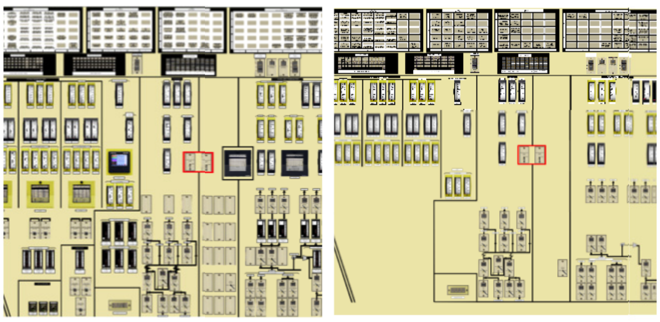
- Three studies
  1. Simulated NPP operation (N=81: Reinerman-Jones et al., submitted)
     - Task type: Checking, detection, response implementation
  2. Simulated UGV task (N=150: Abich et al., in press; Matthews et al., 2014; Reinerman-Jones et al., 2014)
     - Task type : Change detection, human threat detection
     - Multi-tasking: Single vs. dual
  3. Simulated UAV operation (N=68: Wohleber et al., submitted)
     - Multi-tasking: 2 vs. 6 UAVS (+time pressure)
     - Negative feedback: none vs. present)
- Comparison of physiological workload profiles
- A note on stress (UAVs)

## Nuclear Power Plant Simulation

- Generic Pressurized Water Reactor (GPWR) simulator (Reinerman-Jones, Guznov, Mercado, & D'Agostino, 2013)
  - Based on GSE plant control room, modified with input from SMEs
  - Modified operating procedure (initiating event: EOP-EPP-001)
  - Sequence of tasks performed by three-person crew using three-way communication
    - Senior Reactor Operator (SRO: experimenter)
    - Reactor Operator (RO 1: participant)
    - Reactor Operator (RO2: confederate/experienced participants)
  - Checking, Detection, Response Implementation tasks
  - Two-hour training session: participants required to reach 80% accuracy criterion
  - 81 participants (45 M, 36F)

## Panel Modification

Original (experts) → Modified (trained novices)



# NPP Tasks

- Checking
  - Inspection of an instrument or control to verify that it was in the correct state (e.g., "“verify valve PCV-444B is shut")
- Detection
  - Locate and monitor a gauge for five minutes ("e.g., verify gauge TI-430 SB and report when less than 400 PSIG")
  - Expected to impose attentional demands
- Response Implementation
  - Identify a control, and then open or shut a switch on that control (e.g., "shut valve 1CS-235B")
- All tasks made up of steps executed using three-way communication between SRO and RO

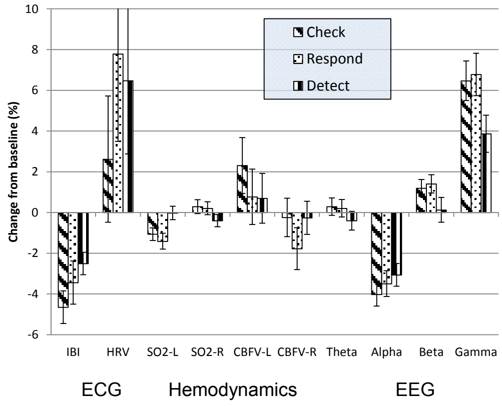
# Task Effects: Subjective

- Detection induces higher workload, higher distress, lower task engagement


[Performance difficult to compare across tasks: ROs require more clarifications for detection]

# Physiological Workload Response

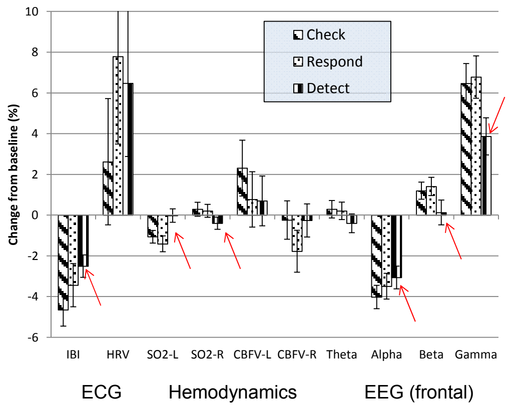
- Change from baseline (%) for each workload metric
- Of most interest: differential task effects




Also, overall effects of performance
- Cardiac activity
- Shift to higher frequency EEG

# Physiological Workload Response

- Differences between Detection and other two tasks
- Multiple metrics are sensitive




- Patterned workload response
  - Lower arousal (IBI, alpha)
  - Higher effort ($rSO_2$)
  - Less high-level cognition (beta, gamma)
- Some classic workload metrics insensitive (HRV, frontal theta)

INSTITUTE for SIMULATION & TRAINING

## NPP Study: Implications

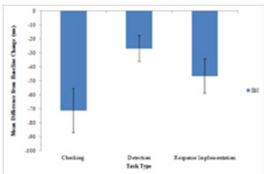
- Different task components of the OP vary in workload and stress (subjective data)
- High workload components (e.g., detection)
  - A focus for training
  - A vulnerability during unexpected events
- Physiological data
  - No general workload response
  - Patterned, nuanced response
  - May reflect multiple neural systems
- Do these findings generalize to UGV?

INSTITUTE for SIMULATION & TRAINING

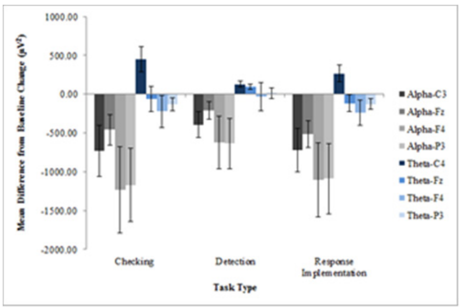
## NPP Workload Response: Stability over Time

- Leis et al. (2014): Similar OP to previous study
- Three experienced participants. Seven training sessions, plus five experimental sessions (over three months)

*ECG: Smaller IBI response*




*EEG: Less alpha blocking*




- No session effects: stable response

## UGV Simulation (MIX)

- Mixed Initiative eXperimental (MIX) testbed (Abich et al., 2013; Taylor et al., 2013)
  - Simulation of Operator Control Unit (OCU) of Unmanned Ground Vehicle (UGV)
  - Theory driven tasks integrated into a moderately high fidelity simulation system based on DoD employed icons and terrains
  - Detailed logging capabilities that permit the use of multiple sensors simultaneously synchronizing with performance events.
- Configured to incorporate multiple task demand manipulations
- Does workload response generalize to this different domain?

## MIX Screen Display

- Study used multiple scenarios based on display below
- Averaged data presented here

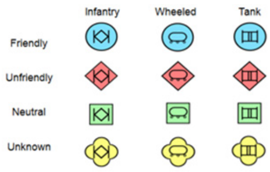

UGV autonomously navigates throughout a generic Middle Eastern town occupied by enemy threats

- Threat: Discriminate human figures
- Change: Monitor icons representing entities

# MIX: Stimuli for Detection Tasks

- *For Threat Detection*


- *For Change Detection*

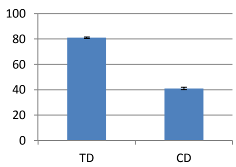



Change detection. Icons on map display may:
- appear
- disappear
- move

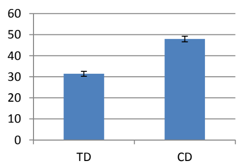
# Threat Detection vs. Change Detection

- Threat detection is easier, lower in workload and less stressful

Accuracy (%)

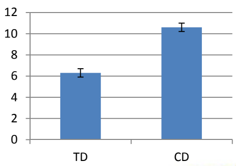



Workload (TLX)

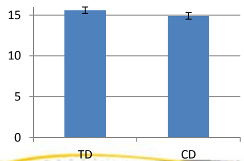



TD = Threat Detection
CD = Change Detection

Distress (DSSQ)




Task Engagement (DSSQ)

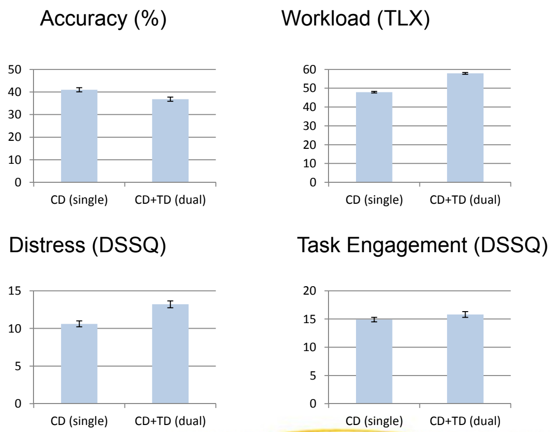


# Physiological Workload Response

- Change detection vs. threat detection (single task)
  - *For change detection (higher workload)*
  - ECG: Lower HRV
  - Hemodynamics: Higher $SO_2$ (bilateral)
  - EEG: higher theta, lower beta
  - Eyetracking: higher pupillary Index of Cognitive Activity (ICA)
- Different pattern of workload response to NPP tasks
  - Reflecting differing attentional demands (multi-stimulus monitoring vs. vigilance)

# Single Task vs. Dual Task

- Single task is easier, lower in workload and less stressful




TD = Threat Detection
CD = Change Detection

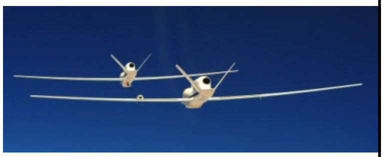
*Physiology*:

Only sensitive metric is eye fixation duration (shorter for dual task)

INSTITUTE for SIMULATION & TRAINING

# Multi UAV Simulation (RESCHU)

- Control of multiple UAVs on map display
  - Direct each UAV to a target location
  - Find target at location in camera view
  - Monitor messages in text box
  - Avoid hazards

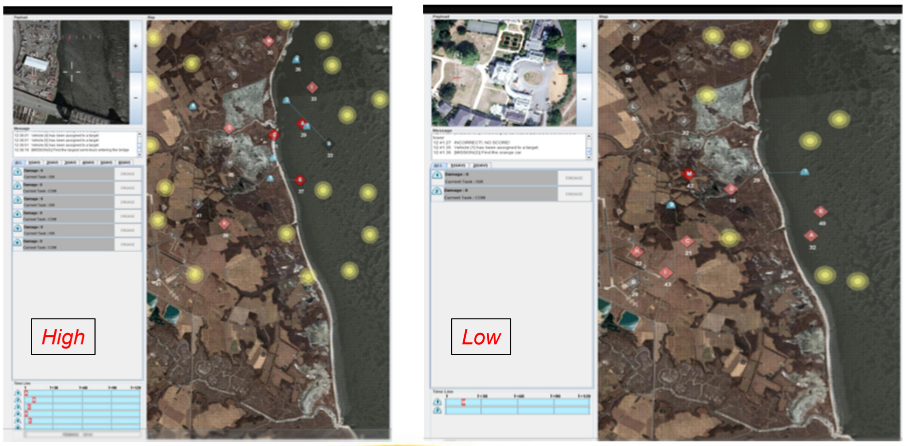


- 68 undergraduate participants (31 men, 37 women)
- Within-subjects manipulations (Panganiban & Matthews, 2014)
  - (focus on stress as well as workload)
  - Task load (#UAVs, time pressure)
  - Negative feedback (non-contingent)
- 30 min training followed by series of 10-min tasks

INSTITUTE for SIMULATION & TRAINING

# Workload Manipulation

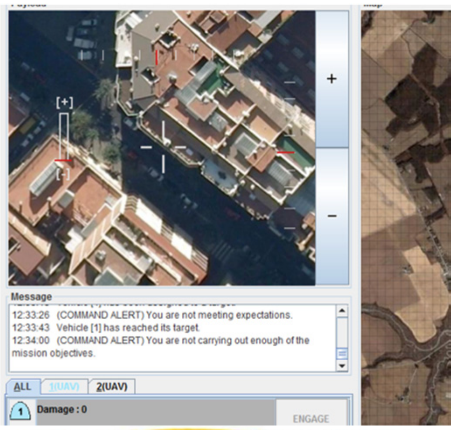
- 2 vs. 6 UAVs (+time pressure variation, #hazards)



INSTITUTE for SIMULATION & TRAINING

# Negative Feedback Manipulation

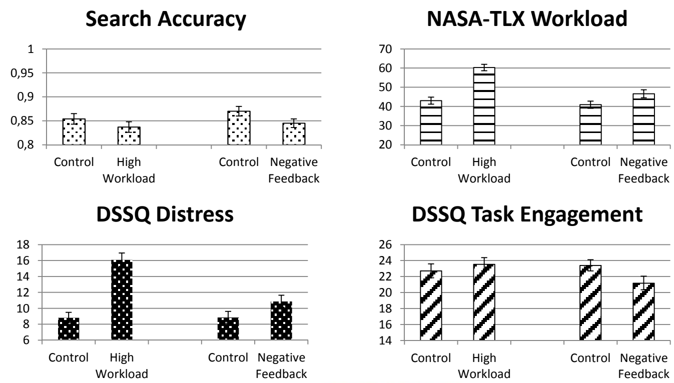
- Periodic negative messages (versus neutral messages)




INSTITUTE for SIMULATION & TRAINING

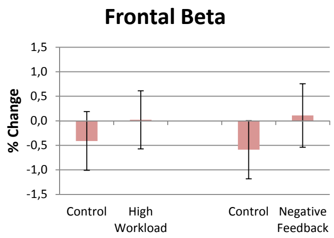
# Cognitive Load/Stress Manipulations

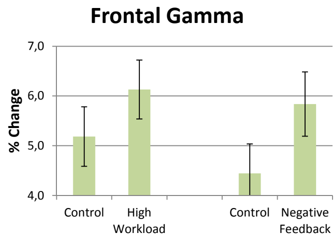
- Both factors: Poorer performance, higher workload, higher distress
- Negative feedback: Also reduces subjective engagement



# Physiological Workload Response

- Different response pattern to both NPP and UGV studies
- Strongest effects of manipulations on EEG
  - Increased high frequency response




- Increased HRV (both)
- Decreased CBFV (feedback only)

# Summary of Workload Effects

- Patterns of response specific to task/manipulation
- Subjective workload may signal a variety of neuro responses
- Metrics must be validated for a specific training context

| Study | Task or Manipulation | NASA-TLX effect (points) | Metrics for elevated workload (expected) | Metrics for reduced workload (unexpected) |
|---|---|---|---|---|
| NPP simulation | Detection (vs. other tasks) | 4.9 | Higher $rSO_2$ (fNIR) | Lower beta, gamma<br>Lower heart rate<br>Higher alpha |
| UGV simulation | Change detection (vs. threat detection) | 16.1 | Lower HRV, higher $rSO_2$ (fNIR), higher frontal theta, higher ICA | |
| UGV simulation | Dual-task (vs. single task) | 10.0 | Shorter fixation duration | |
| UAV simulation | Cognitive load (vs. low cog. load) | 16.7 | Higher beta<br>Higher gamma | Higher HRV |

- N.B. Comparisons also affected by power of statistical analyses and strength of manipulations

## Implications for Stress Metrics

- Increased distress common response to task demands
- DSSQ distress correlates at ~.5 with NASA-TLX workload
  - Distress depends also on appraisal and coping strategy
- Changes in distress may be accompanied by greater or lower task engagement
  - e.g., negative feedback: distress + disengagement
  - Game-like tasks provoke both distress and engagement
- Physiology can identify different forms of distress
  - e.g., distress on RESCHU linked to high-level cognitive activity (increased high frequency EEG)

## Performance Prediction

- Pronounced individual differences in both workload/ stress response and performance
- Abich, Matthews, & Reinerman-Jones (submitted): data from UGV study
  - All measures are internally consistent across task conditions (αs range from .857 - .997)
  - Measures averaged across scenarios
- Two perspectives on prediction
  1. Use of pre-task measures to predict performance
     - Personnel selection, fitness-for-duty applications
  2. Use of concurrent measures to predict performance
     - Diagnostic monitoring, including training

# Prediction from Subjective and Physio Metrics

- Prediction from baseline/pre-task metrics
  - Criteria are accuracy on change (CD) and threat detection (TD)

| | | EEG | | | DSSQ-Pre | |
|---|---|---|---|---|---|---|
| | HRV | Theta | Beta | | Distress | Eng. |
| CD | -.225** | -.210** | -.261** | | -.261** | .209* |
| TD | -.079 | -.087 | -.057 | | -.277** | .154 |
| Note: *p < .05, **p < .01 | | | | | | |

- Regression statistics

| Criterion | Predictor Set | | | |
|---|---|---|---|---|
| | Physio ($R^2$) | Subjective ($\Delta R^2$) | Final R | Adj $R^2$ |
| CD | .17** | .05* | .48** | .18 |
| TD | .02 | .08* | .32* | .05 |
| Note: *p < .05, **p < .01 | | | | |

- Both types of metric necessary to optimize prediction

# Prediction from Subjective and Physiological Metrics

- Concurrent/post-task metrics
  - Criteria are accuracy on change (CD) and threat detection (TD)

| | | EEG | | | DSSQ-Post | | |
|---|---|---|---|---|---|---|---|
| | HRV | Alpha | Beta | Fix. Dur. | Dist. | Eng. | Worry |
| CD | -.258** | -.149 | -.259** | .262** | -.392** | .451** | -.302** |
| TD | -.074 | -.172* | -.154 | .161 | -.214** | .280** | -.247** |
| Note: *p < .05, **p < .01 | | | | | | | |

- Regression statistics

| Criterion | Predictor Set | | | |
|---|---|---|---|---|
| | Physio ($R^2$) | Subjective ($\Delta R^2$) | Final R | Adj $R^2$ |
| CD | .238** | .148** | .621** | .314 |
| TD | .095 | .065* | .400 | .063 |
| Note: *p < .05, **p < .01 | | | | |

- Both types of metric necessary to optimize prediction

## Applications

- Multidimensional tracking of workload during training
- Augmented cognition: ‘closing the loop’
- Identifying individual vulnerabilities
- Personnel selection

## Multidimensional Tracking of Workload during Training

- Workload metrics may be diagnostic of overload
  - Diagnosticity may depend on context
  - Different metrics may identify different sources of overload
- Use in scenario-based training
  - What are the events during training that provoke overload?
  - Physiological metrics better suited to tracking specific events than subjective ones
  - Design of scenarios to regulate workload
- Use for training handling of unexpected events
  - Design of scenarios to provoke overload

# Augmented Cognition

- Human-Robot Teaming
  - How to make the robot sensitive to human workload?
  - Robot could be more supportive or proactive when human is overloaded
  - Use of physiology to monitor human functioning
- Closing the loop
  - Algorithm for continuous monitoring of human workload
  - Criterion value triggers adaptive response from robot
  - Work in progress using UGV simulation

# Identifying Individual Vulnerabilities

- UAV (RESCHU) study
  - Resilience factors such as grit, hardiness, and meta-worry predict stress response
  - Systematic individual differences in vulnerability to overload and to negative evaluation
- Resilience training
  - Train for the vulnerabilities of the individual
  - Focus on performance and/or affective response
    - Cognitive strategies for overload
    - Detached mindfulness for negative evaluation stress

## Personnel Selection

- Challenges for selection – how to identify…
  - Aptitude for working with complex tech (e.g., NPP, UAV interfaces)
    - Including automated and autonomous systems
  - Aptitude for maintaining performance during unexpected events
  - Aptitude for maintaining performance under multiple stressors
- Maximize prediction of performance and stress, in-context
  - Use of simulated environments
  - Use of multiple physiological and subjective indices
  - Multivariate statistical modeling

## Conclusions

- Unexpected events often (not always) provoke cognitive overload and stress
- Scenario based-training can accommodate unexpected events
  - Assessment of training raises psychometric challenges
- Context-bound multivariate assessment of workload and stress meets these challenges
  - Both subjective and physiological assessment is of value
  - Assessment of both scenarios and individual response
- Further applications
  - Resilience training, fitness-for-duty assessment, selection

# References


Abich, J., IV, Matthews, G. , & Reinerman-Jones, L.E. (submitted) *Individual differences in UGV operation: A comparison of subjective and psychophysiological predictors.*

Abich, J., IV, Reinerman-Jones, L.E., & Matthews, G. (in press). Impact of workload factors on unmanned system Intelligence, Surveillance, and Reconnaissance operations. *Ergonomics*.

Abich, J., IV, Taylor, G., & Reinerman-Jones, L. (2013, July). Establishing workload manipulations utilizing a simulated environment. Paper presented at the 8th International Conference of HCI International 2013, Las Vegas, NV.

Helton, W. S., Shaw, T., Warm, J. S., Matthews, G., & Hancock, P. (2008). Effects of warned and unwarned demand transitions on vigilance performance and stress. *Anxiety, Stress, & Coping*, *21*, 173-184.

Helton, W.S., Shaw, T.H., Warm, J.S., Matthews, G., Dember, W.N. , & Hancock, P.A. (2004.) Workload transitions: Effects on vigilance performance, and stress. In *Human performance, situation awareness and automation: Current research and trends*, Edited by: Vincenzi, D.A., Mouloua, M. and Hancock, P.A. (pp. 258–262). Mahwah, NJ: Erlbaum.

Leis, R., Reinerman-Jones, L., Mercado, J., Barber, D., & Sollins, B. (2014). Workload from nuclear power plant task types across repeated sessions. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* , *58*, 210-214).

Matthews, G., & Campbell, S. E. (2010). Dynamic relationships between stress states and working memory. *Cognition and Emotion*, *24* 357-373.

Matthews, G., Campbell, S., Falconer, S., Joyner, L., Huggins, J., Gilliland, K., Grier, R., et al. (2002). Fundamental dimensions of subjective state in performance settings: Task engagement, distress, and worry. *Emotion, 2,* 315-340.

Matthews, G., Reinerman-Jones, L. E., Barber, D. J., & Abich, J. (2014). The psychometrics of mental workload multiple measures are sensitive but divergent. *Human Factors, 57,* 125-143.

Matthews, G., Szalma, J., Panganiban, A. R., Neubauer, C., & Warm, J. S. (2013). Profiling task stress with the Dundee Stress State Questionnaire. In L. Cavalcanti & S. Azevedo (Eds.), *Psychology of stress: New research* (pp. 49-91). Hauppage, NY: Nova Science.

Maxwell, D., Matthews, G., Salcedo, J. , & Lackey, S.. (2014). Virtual world room clearing: A study in training effectiveness. *Proceedings of the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), Orlando, FL, 1-4 December 2014.*



# References



Panganiban, A. R., & Matthews, G. (2014). Executive functioning protects against stress in UAV simulation. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* , *58,* 994-998.

Reinerman-Jones, L. E., Matthews, G., Barber, D. J., & Abich, J. (2014). Psychophysiological metrics for workload are demand-sensitive but multifactorial. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 58,* 974-978.

Reinerman-Jones, L., Guznov, S., Mercado, J., & D'Agostino, A. (2013). Developing methodology for experimentation using a nuclear power plant simulator. In D .D. Schmorrow, & C. M. Fidopiastis (Eds.), *Foundations of augmented cognition* (pp. 181-188). New York: Springer.

Reinerman-Jones, L., Guznov, S., Tyson, J., D'Agostino, A., & Hughes, N. (2015). *Workload, situation awareness, and teamwork* (NUREG/CR-7190). Washington, DC: NRC.

Reinerman-Jones, L., Mercado, J., Sollins, B., D'Agostino, A., & Hughes, N. (submitted). Workload Associated with Nuclear Power Plant Main Control Room Tasks. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*.

Saxby, D. J., Matthews, G., Warm, J. S., Hitchcock, E. M., & Neubauer, C. (2013). Active and passive fatigue in simulated driving: Discriminating styles of workload regulation and their safety impacts. *Journal of Experimental Psychology: Applied, 19,* 287-300.

Taylor, G. S., Reinerman-Jones, L. E., Szalma, J. L., Mouloua, M., & Hancock, P. A. (2013). What to automate addressing the multidimensionality of cognitive resources through system design. *Journal of Cognitive Engineering and Decision Making*, *7*, 311-329.

Wohleber, R.W., Matthews, G., Reinerman-Jones, L. E., Sollins, B., Panganiban, A. R., & Scribner, D.R. (submitted). *Individual differences in resilience and affective response during simulated UAV operations.*