Situation Awareness and Fatigue Sensing

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Presentation to CCRTS

APL
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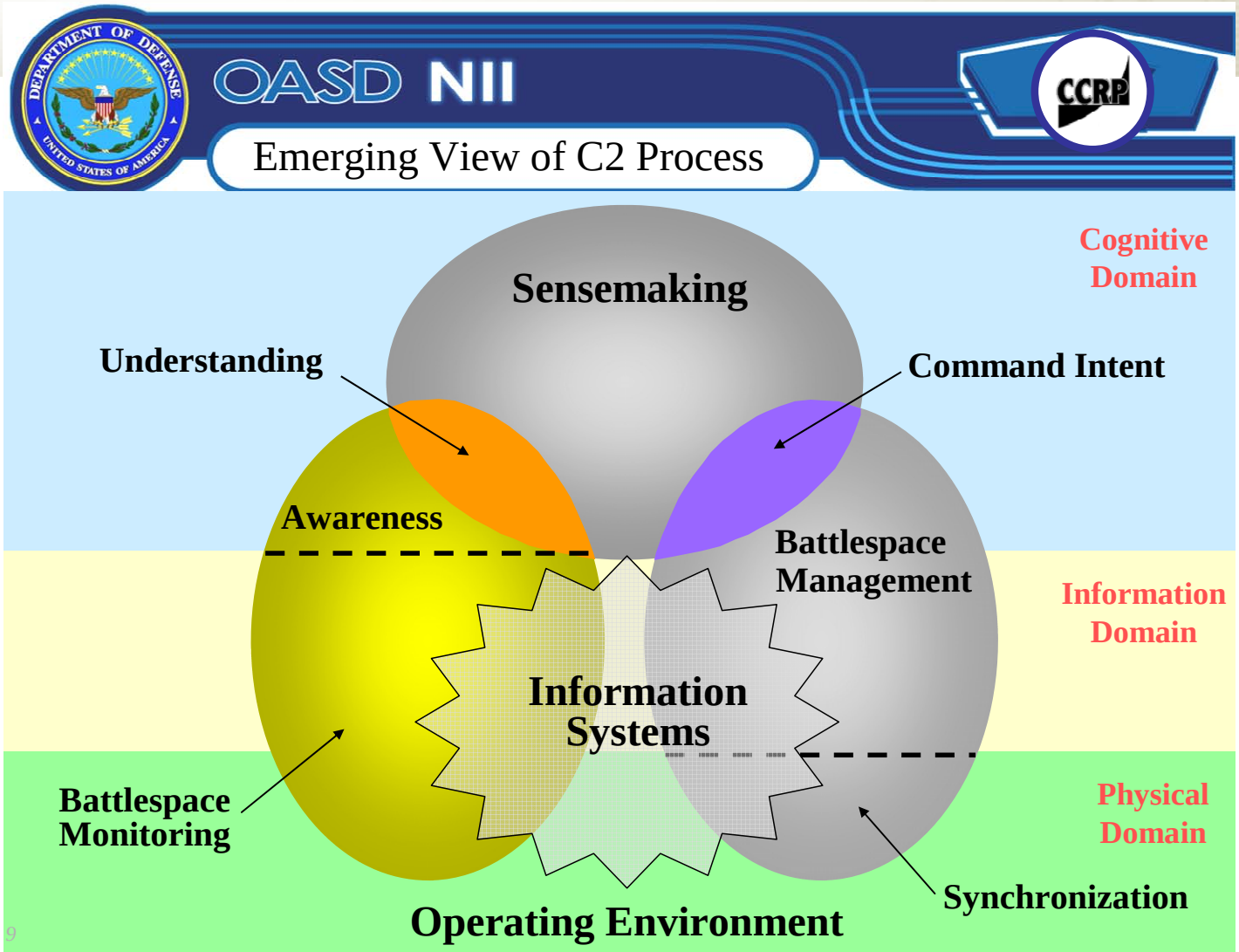
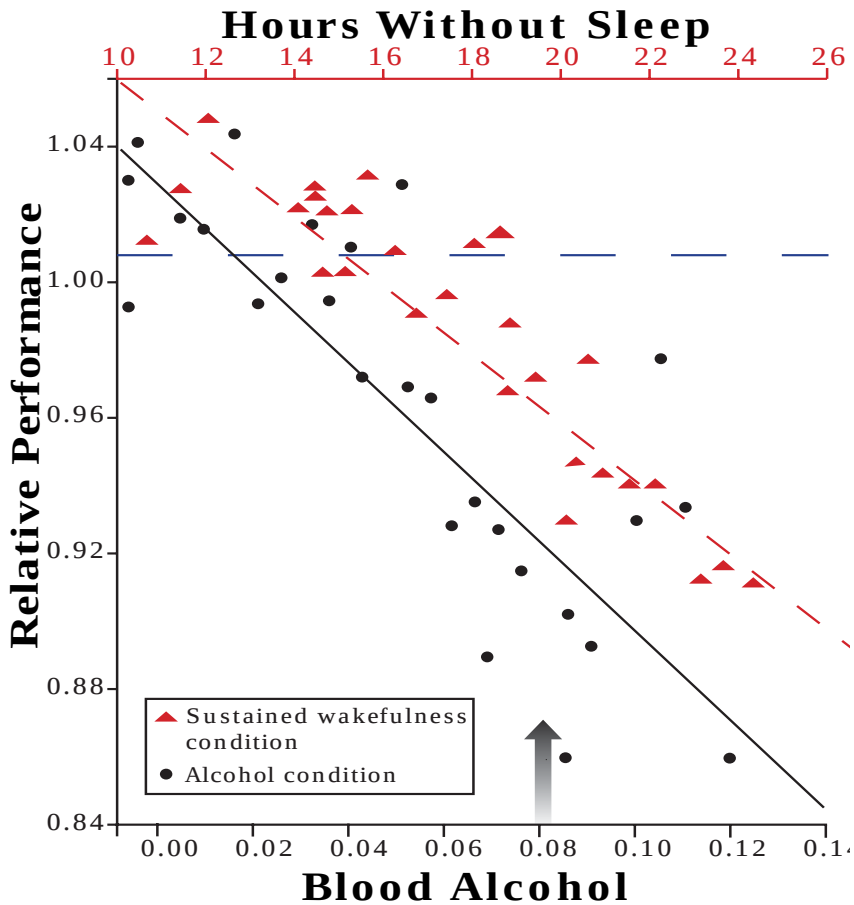
Operational Need



Situation Awareness is Critical to C2 performance, Fatigue Effects Performance – How does it Affect SA

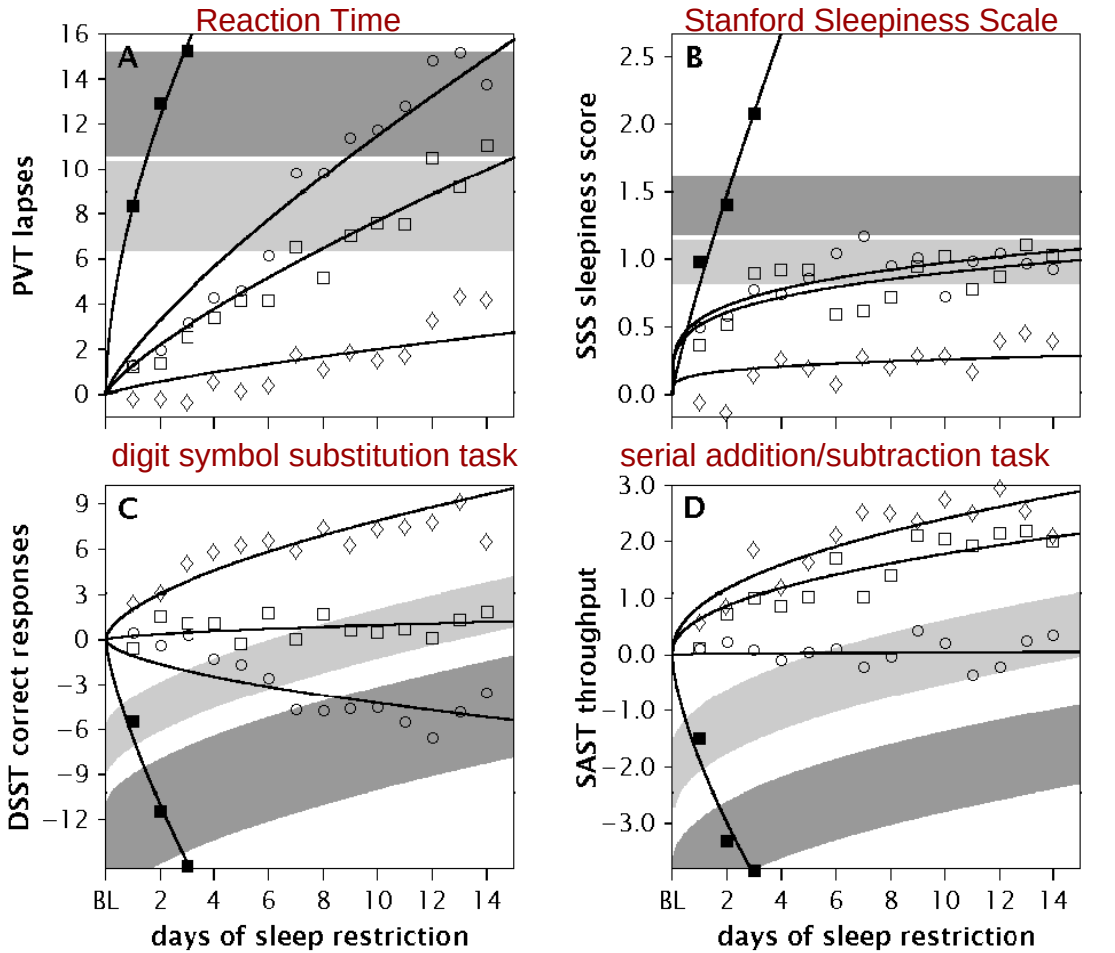
Fatigue Effects Performance

- Effects of fatigue on performance well recognized
- Most studies have been conducted with pilots and drivers
- Understood that fatigue effects cognitive performance, not well understood how that is manifested in C2 tasks
- Some initial studies show likely impact, situation awareness has not been specifically addressed



Fatigue Effects Performance, cont'd

- Effects of chronic fatigue similar to sleep deprivation
- Participants not aware of deprivation
- Understood that fatigue effects cognitive performance, not well understood how that is manifested in C2 tasks
- Some initial studies show likely impact, situation awareness has not been specifically addressed



Hans P.A. Van Dongen, Greg Maislin, Janet M. Mullington, David F. Dinges, 2004

Fatigue Management in C2

- Fatigue models
- Cognitive assessment and models
- Physiological sensors and model
- Countermeasures (system adaptation, breaks, scheduling, etc…)

Fatigue detection system and countermeasures that prevent degradation of operational performance

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Mapping Stressors to Cognition – Impact of Fatigue

Task Related Stress		Executive Function	Attention	Working Memory	Sensory Input	Integrated Evaluation
	Cognitive load	HIGH	MED	MED	MED	HIGH
	Physical load	LOW	HIGH	LOW	MED	LOW
	Situational Awareness	MED	HIGH	HIGH	HIGH	HIGH
Physiological Stress						
	Circadian	LOW	MED	LOW	LOW	MED
	Hydration	LOW	HIGH	LOW	MED	LOW
	Illness	LOW	MED	LOW	MED	LOW
	Mental fatigue	HIGH	MED	MED	MED	MED
	Sleep loss	LOW	HIGH	LOW	HIGH	MED
Environmental Stress						
	Hyperbaric	LOW	LOW	LOW	LOW	HIGH
	Hypoxia	LOW	MED	LOW	LOW	HIGH
	Noise	LOW	MED	LOW	HIGH	HIGH
	Vibration	LOW	LOW	LOW	HIGH	MED
	Sustained Accleration	LOW	LOW	LOW	LOW	HIGH
	Thermal	LOW	HIGH	HIGH	HIGH	MED

All Cognitive Functions Critical for Effective C2 Warfighter Decision Making

Table from Boeing presentation at 1st Annual Augmented Cognition Conference

New Discipline – Augmented Cognition

- **Goal -** enhance operational effectiveness by developing technologies capable of extending the information management capacity of the warfighter via closed loop system that adapts to the state of the warfighter to significantly improve performance.

- **Technologies**
  - ***Physiological Sensors***
  - ***Cognitive State Assessors***
  - ***Cognitive Models***
  - ***System Automation/Scheduling tools***

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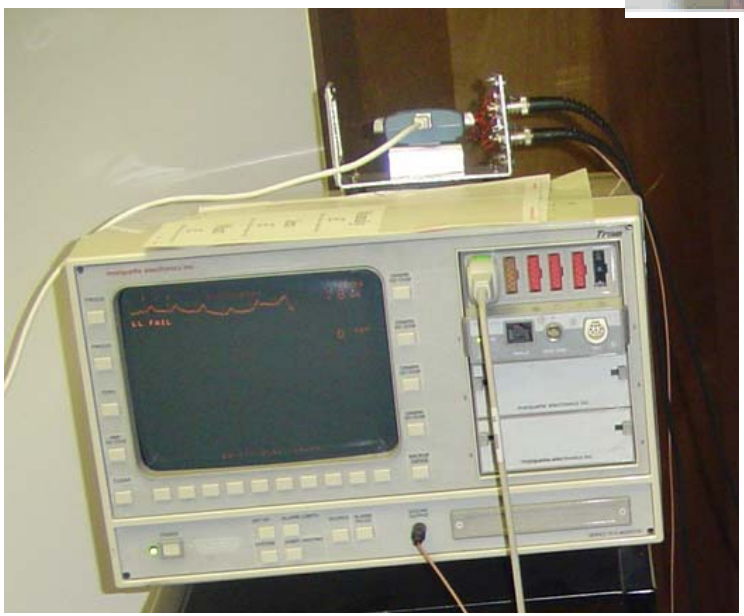
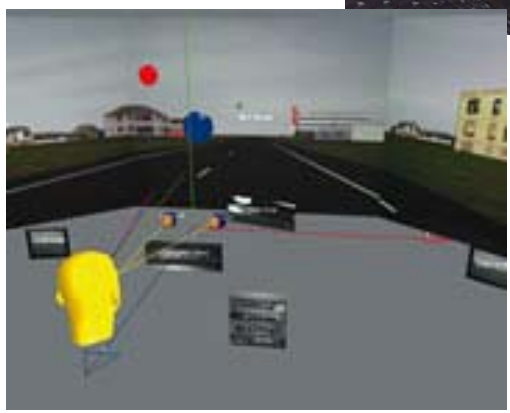
Physiological Measures to Assess Cognitive State

- Heart Rate
- Heart Rate Variability
- Activity
- Eye Scanning
- PERCLOS
- EEG





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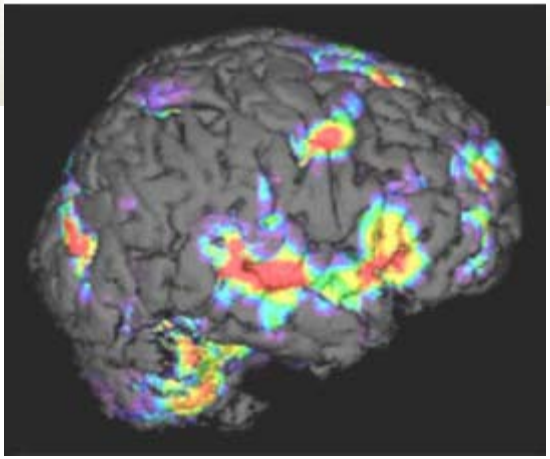
Research Need

- Significant research in the academic lab
- Need to extend to the warfighter
  - Assess with operational (or simulations of actual systems)
  - Employ operationally realistic scenarios
  - Test with representative samples – actual warfighters

Near Term Research Objectives

- Demonstrate measurement of SA over extended durations
- Demonstrate the relationship of fatigue and situation awareness
- Determine if SA (high, medium, low) degrades differentially over time
- Validate Physiological Measurement of C2 task performance

Situation Awareness



Perception & Cognition

1. **Perceive** the current situation

2. **Comprehend** what is changing

3. **Assess** how the changes impact the present situation

4. **Anticipate** what will happen as the situation develops

Statics

Dynamics

Trend Analysis

Projection

Technology

HSI

Maintain

Monitor

Evaluate

Command & Control

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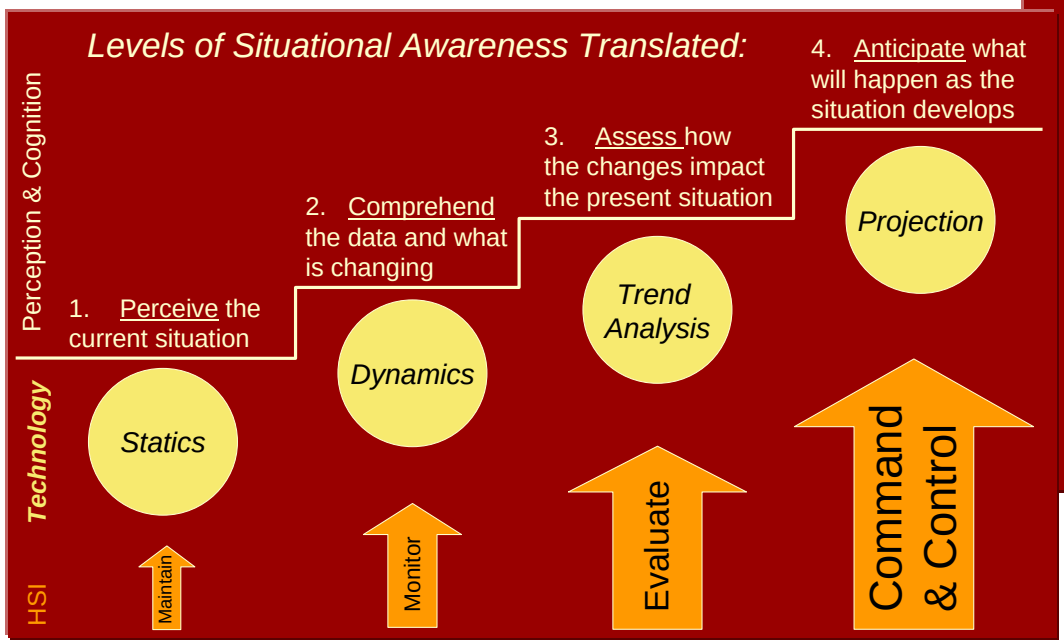
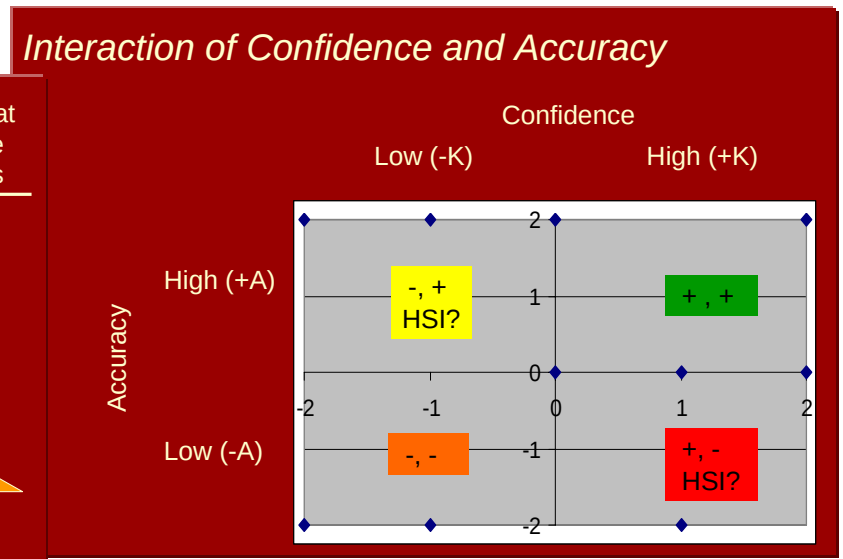
FY 05 Experiment

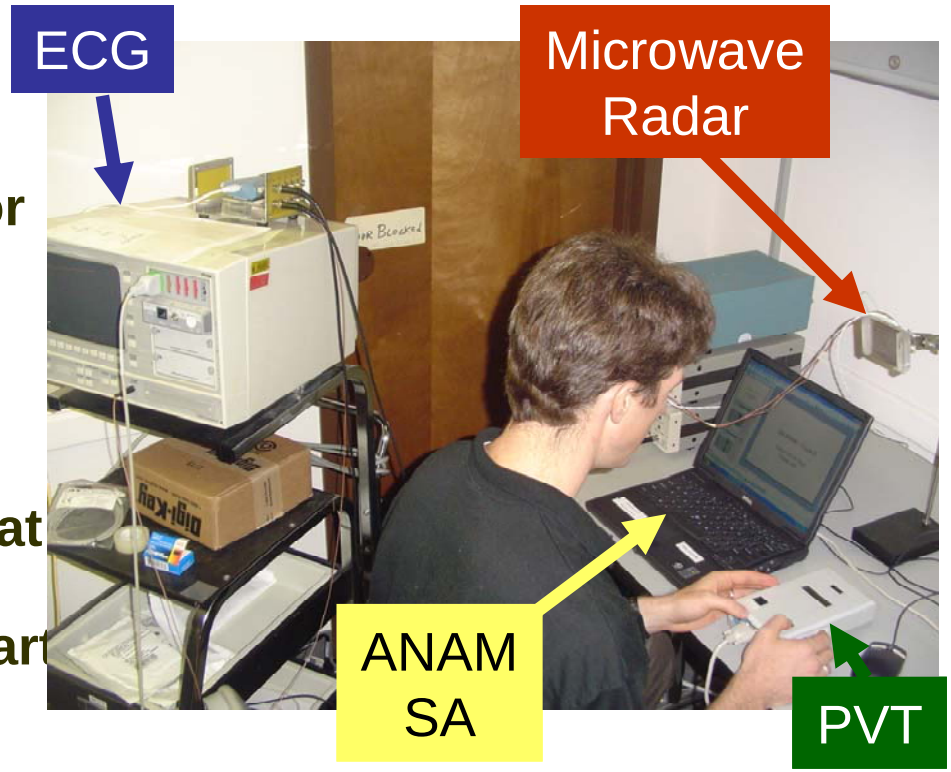
- **Pilot: proof of process and principle**
- **Investigating effects of fatigue on Situation Awareness**
- **Matured theory of SA, SA assessment, and SA analysis** (patent pending)
- **Investigate application of physiological measures for cognitive task performance assessment**





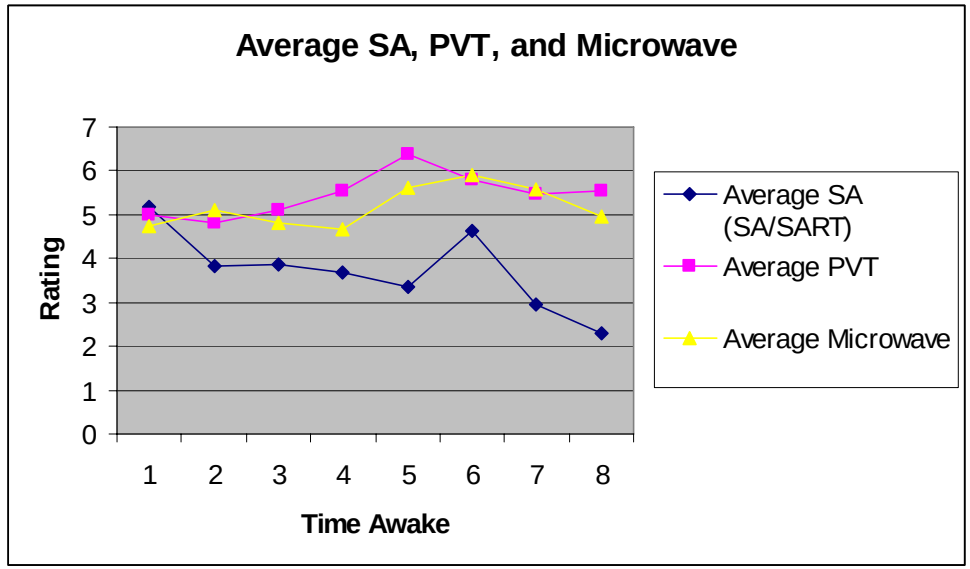
Method

- Six JHU/APL interns were participants
- Ran 2 experimental sessions
  - Training session ~16 hours prior to experiment
  - 36-hour duration
    - Wake-up call 0600 Fri,
    - baseline 0800 Fri,
    - testing 1800 Fri thru 1800 Sat
- Collected PVT, ANAM, SA performance while monitoring heart rate, heart rate variability, and activity
  - Tested every three hours starting at 12 hours of wakefulness
- Monitored participant activity between test sessions



Initial Findings

- **Increase in RT during cycle 5, (24 hours of wakefulness). Corresponding to the highest sleepiness indication reported by participants.**
- **SA did not decline significantly, but did not spike as could be expected due to learning curve.**
- **Microwave activity sensor well suited to detect sleep onset, not shown to be effective in this type of *physical configuration*.**



Results: Summary

- **Overall SA might be a sufficient single summary metric of SA**
  - SA Level 1 and Level 2 showed correlation with Overall SA and with each other
  - SA Level 3 did not correlate with any of the others
    - This is not surprising, as the participants were novice users. The ANAM and PVT Sleepy correlations with SA indicate that as a participant's self-reported sleepiness increases, SA levels decreased

- **Showed Potential Relationship Between Fatigue and Physiological Measures**
  - Consistent with literature, PVT Delay and PVT Sleepy correlated strongly; indicates fatigue
  - PVT measures had strong positive correlation with Heart Rate Variability;
  - PVT had negative correlations with HR, ANAM Logic, and ANAM Code expected; more tired, slower response, & less capable of solving logic & math problems
  - The decreased HR correlated to an increase in ANAM Sleepy, but also to an increase in ANAM Math. As noted on the previous slide, this increase in math abilities as participants become more tired is interesting
  - The self-reported ANAM Sleepy provided an indication of participant's performance on ANAM Logic and ANAM Code, as sleepiness increased scores decreased

Correlation Coefficients between SA Levels

	Overall SA	SA Level 1	SA Level 2	SA Level 3
O SA		0.814	0.921	0.359
SA1			0.579	0.369
SA2				0.278
SA3				

Correlation stronger than 0.5

- SA Level 1 and Level 2 showed correlation with Overall SA and with each other
- SA Level 3 did not correlate with any of the others
  - This is not surprising, as the participants were novice users. They likely did not possess the knowledge of the subject area or system to make projections about future trends

Overall SA might be a sufficient single summary metric of SA

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Correlation Coefficients between SA and other Tests

	PVT Average Delay	PVT Sleepy	HR	HRV	ANAM Sleepy	ANAM Math	ANAM Logic	ANAM Code
O SA	-0.165	-0.514	0.193	0.006	-0.560	0.325	0.124	0.338
SA1	0.181	-0.275	0.020	0.204	-0.320	-0.037	-0.280	0.021
SA2	-0.255	-0.492	0.199	-0.102	-0.620	0.567	0.228	0.499
SA3	-0.254	-0.446	0.512	-0.143	-0.201	0.333	0.610	-0.279

- The ANAM and PVT Sleepy correlations with SA indicate that as a participant's self-reported sleepiness increases, SA levels decreased
- The SA 3 and ANAM Logic correlation indicate that participants who were better at logic were also better able to make the predictions (necessary for Level 3)

Preliminary Evidence to Support Fatigue Management Concept

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Correlation Coefficients between PVT and other Tests

	PVT Average Delay	PVT Sleepy	HR	HRV	ANAM Sleepy	ANAM Math	ANAM Logic	ANAM Code
PVT Average Delay		0.773	-0.700	0.693	0.750	0.168	-0.818	-0.614
PVT Sleepy			-0.888	0.720	0.953	0.580	-0.729	-0.661

- Consistent with literature, PVT Delay and PVT Sleepy correlated strongly; indicates fatigue
- The PVT Sleepy correlated significantly with ANAM Sleepy as expected
- Both PVT measures had strong positive correlation with Heart Rate Variability; PVT Sleepy also correlated with ANAM Math, an oddity that warrants further investigation
- Negative correlations with HR, ANAM Logic, and ANAM Code expected; more tired, slower response, & less capable of solving logic & math problems

Shows Potential Relationship Between Fatigue and Physiological Measures

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Correlation Coefficients between HR and other Tests

	HR	HRV	ANAM Sleepy	ANAM Math	ANAM Logic	ANAM Code
HR		-0.744	-0.785	-0.554	0.640	0.369
HRV			0.752	0.311	-0.717	-0.535

- Heart Rate and Heart Rate Variability had a strong negative correlation
- The decreased HR correlated to an increase in ANAM Sleepy, but also to an increase in ANAM Math. As noted on the previous slide, this increase in math abilities as participants become more tired is interesting
- As HR increased, so did ANAM Logic scores; however, they were measured several minutes apart, not simultaneously, so it is difficult to draw conclusions

Shows Potential Relationship Between Fatigue and Physiological Measures

Correlation Coefficients within ANAM Tests

	ANAM Sleepy	ANAM Math	ANAM Logic	ANAM Code
ANAM Sleepy		0.487	-0.641	-0.817
ANAM Math			-0.147	-0.319
ANAM Logic				0.460
ANAM Code				

- The self-reported ANAM Sleepy provided an indication of participant's performance on ANAM Logic and ANAM Code, as scores decreased as sleepiness increased

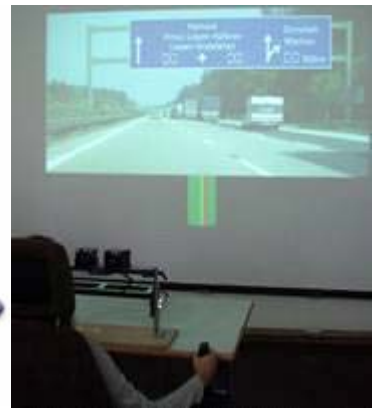
Preliminary Evidence that Cognitive Capabilities Degrade with Fatigue

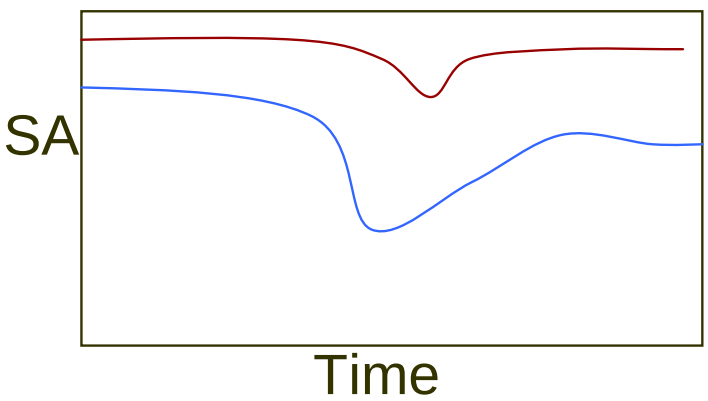
FY05 Research Issues

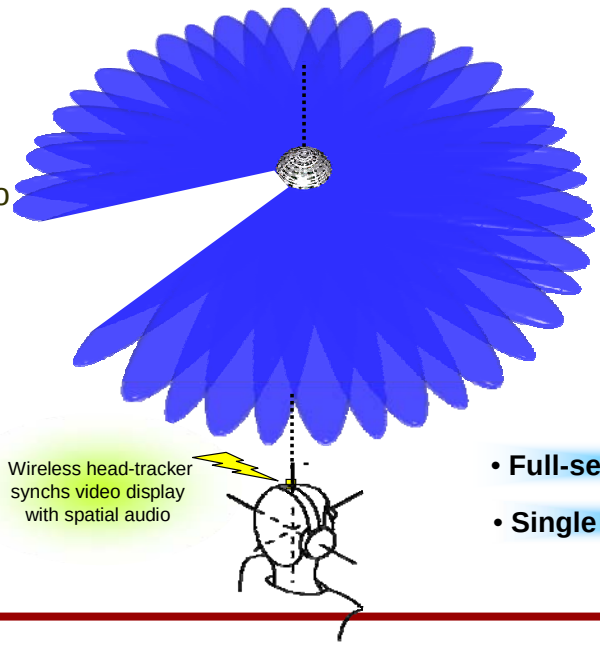
- Did we really evaluate SA?
- What other physiological measures can we use?
  - Likely a composite is more powerful than single metric.
- Does SA degrade differently if different quality is achieved?
  - Does poor SA degrade more/less than good SA?

FY06 Experiment

- **Add eye-tracker (gaze patterns, saccades, PERCLOSE) measures**
- **Test experts to fully gauge SA**
- **Test two instantiations of a system, compare SA, evaluate if/how SA degrades differentially over time**
- **Run study late spring/early summer**







- **Full-sensor monitoring**
- **Single or multiple D/E's**

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Summary:

FY05 experiment provides indication that approach and measures are useful for assessing fatigue effects

SA appears to be affected by fatigue

FY06 help to solidify findings and provide foundation for C2 fatigue management

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