Parallel Session

Operational Evidence of Fatigue: Shiftwork Operations

Sleep/Wake Cycles and Performance of ATC Operators

David Schroeder, Ph.D.
Retired FAA

14:20 - 14:45

June 17, 2008

Presented at the FAA Fatigue Management Symposium: Partnerships for Solutions; Vienna, VA: June 17-19, 2008

David Schroeder, Ph.D.
Biography

Dave received his Ph.D. in experimental psychology from the University of Oklahoma in 1971. He was a psychology technician for several years at the FAA Civil Aeromedical Institute (CAMI) while completing his dissertation. Following a clinical internship at the Norfolk Regional Center in Norfolk, NB he served as a clinical psychologist at the VA Medical Center in Murfreesboro, TN and in Topeka, KS. He returned to the FAA as a clinical research psychologist at what was then called the Aviation Psychology Laboratory in 1980. In 1980 he was called on to assume responsibility for the conduct of the first FAA employee wide attitude survey (1984), which was initiated in response to the air traffic controller strike of 1981. Division personnel maintained responsibility for the revision and administration of the biennial survey until 2006. In addition to his clinical research, his research interests have focused on air traffic control human factors: including assessments of the cognitive and personality factors associated with controller training success; evaluations of shiftwork and fatigue; controller stress; and human factors associated with operational errors. He was selected as manager of what is now called the Aerospace Human Factors Research Division in 1991. Scientists in the division conduct a program of high priority research on general aviation and air traffic control human factors. Development and acquisition of a $1.5 million advanced general aviation research simulator in 1995 allowed division personnel to address human factors issues associated with traditional GA aircraft as well as assessing human factors associated with the introduction of "glass cockpit" displays (highway in the sky). Human factors involving air traffic control have spanned a wide gamut from controller selection to laboratory and field studies of shift scheduling and fatigue, color vision requirements for controllers, psychological screening of controllers, errors in air traffic control, and assessments of the impact of automation, including ongoing efforts in support of NextGen.

Dave has made or co-authored over 120 presentations at scientific meetings and authored/co-authored over 75 technical reports/scientific publications. He has received recognition (commendations for outstanding performance) within the FAA for his individual/group accomplishments on numerous occasions. He received the Raymond F. Longacre Award for Outstanding Accomplishments in the Psychological and Psychiatric Aspects of Aerospace Medicine from the Aerospace Medical Association in 1997 and the Henry L. Taylor Founders Award from the Aerospace Human Factors Association in 2001.

Dave has participated in a number of high priority work groups throughout his career; NTSB/FAA teams to investigate operational errors and aviation accidents, a US-Russia Aviation Medicine Human Factors Working Group, the Scientific Task Planning group responsible for development of the National Plan for Aviation Human Factors (1995), DOT steering committee on Improving Transportation in a Maturing Society, and the Aviation Rulemaking Advisory Committee for Air Carrier Pilot Pre-Employment Screening Standards and Criteria, to mention a few. His excellence as a psychologist and human factors scientist is also evident in his election to several positions; President of the Oklahoma Psychological Association (1992), President of the APA Division of Applied Experimental and Engineering Psychology (2002/2003), Division representative to the APA Council (2008-2011), and President of the Aerospace Medical Association (2003/2004). He was elected as a member of the International Academy of Aviation

and Space Medicine in 2004 and in 2007 was elected to serve as a member of the scientific program committee. He is a fellow in both the American Psychological and Aerospace Medical Associations. He has been recognized in Who's Who in America and Who's Who in Medicine and Healthcare.

Sleep/Wake Cycles and Performance of ATC Operators

David J. Schroeder, Ph.D.
Thomas E. Nesthus, Ph.D.
Pam Della Rocco, Ph.D.

Aerospace Human Factors Research Division

Federal Aviation Administration

Presented at the FAA Fatigue Management Symposium: Partnerships for Solutions; Vienna, VA; June 17-19, 2008

General Concerns Associated with Shiftwork

- **Acute/Chronic Fatigue**
- **Sleep Disturbance (Quantity/Quality)**
- **Disruption in the Circadian Rhythm**
- **Impaired Performance**
- **Cardiovascular/Gastrointestinal Problems**
- **Family/Social Disruption**

Research Interest in Controller Schedules – Fatigue and Performance is International

- United Kingdom (Spencer, Rogers & Stone, 1997; Robertson & Spencer (2007)
- Italy (Costa, Schallenberg, Ferracin, & Guffurt, 1995)
- Canada (Heslegrave, et al. 1996)
- International Survey (Folkard & Condon, 1987)
- US Air Force (Luna, French, & Mitcha. 1997)
- New Zealand (Gander, 2001)
- NTSB Safety Recommendations (2007)
- U.S. (CAMI research 1970 to present)

CAMI ATCS Research Objectives

- Identify problems regarding shiftwork & fatigue through laboratory and field research
- Provide information to management & technical workforces regarding shiftwork and fatigue issues
- Identify and evaluate pertinent, primarily non-pharmacological fatigue countermeasures and make recommendations for implementation

Selected Research History

- Melton, et al. Study (1973)
- Lab Study of 2-2-1 Schedule (1992)
- Field Study; Miami ARTCC (1993)
- 10-Hr ARTCC Study (1993)
- Bright-Light Study; Brooks AFB (1996)
- Congressional ATCS Shiftwork & Fatigue (1999)
  - **Survey**
  - **Field Study**
  - **Lab Study**

Common U.S. ATC Shift Schedules

- Shift Scheduling practices are highly varied
- 4 primary schedules
  - 43.1% Counterclockwise Rapidly Rotation, with mids 2-2-1
  - 48.2% Counterclockwise Rapidly Rotation, No mids 2-1-2
  - 7.1% Straight 5s (Rotate after 5 straight shifts)
  - 1.6% Straight Shifts (Early Mornings, Days, Afternoons)

Counter-Clockwise Rapidly Rotating 2-2-1 Schedule

- **Rotates rapidly from afternoons, to days, to a midnight shift.**
- **Allows 8-10 hours off at shift rotations.**
- **Allows up to 80 hours off between workweeks.**
- **Allows time off after midnight shift for recovery.**

M	1400-2200
T	1400-2200
W	0600-1400
TH	0600-1400
TH/F	2200-0600
S	RDO
S	RDO
M	1400-2200
T	1400-2200
W	0600-1400
TH	0600-1400
TH/F	2200-0600

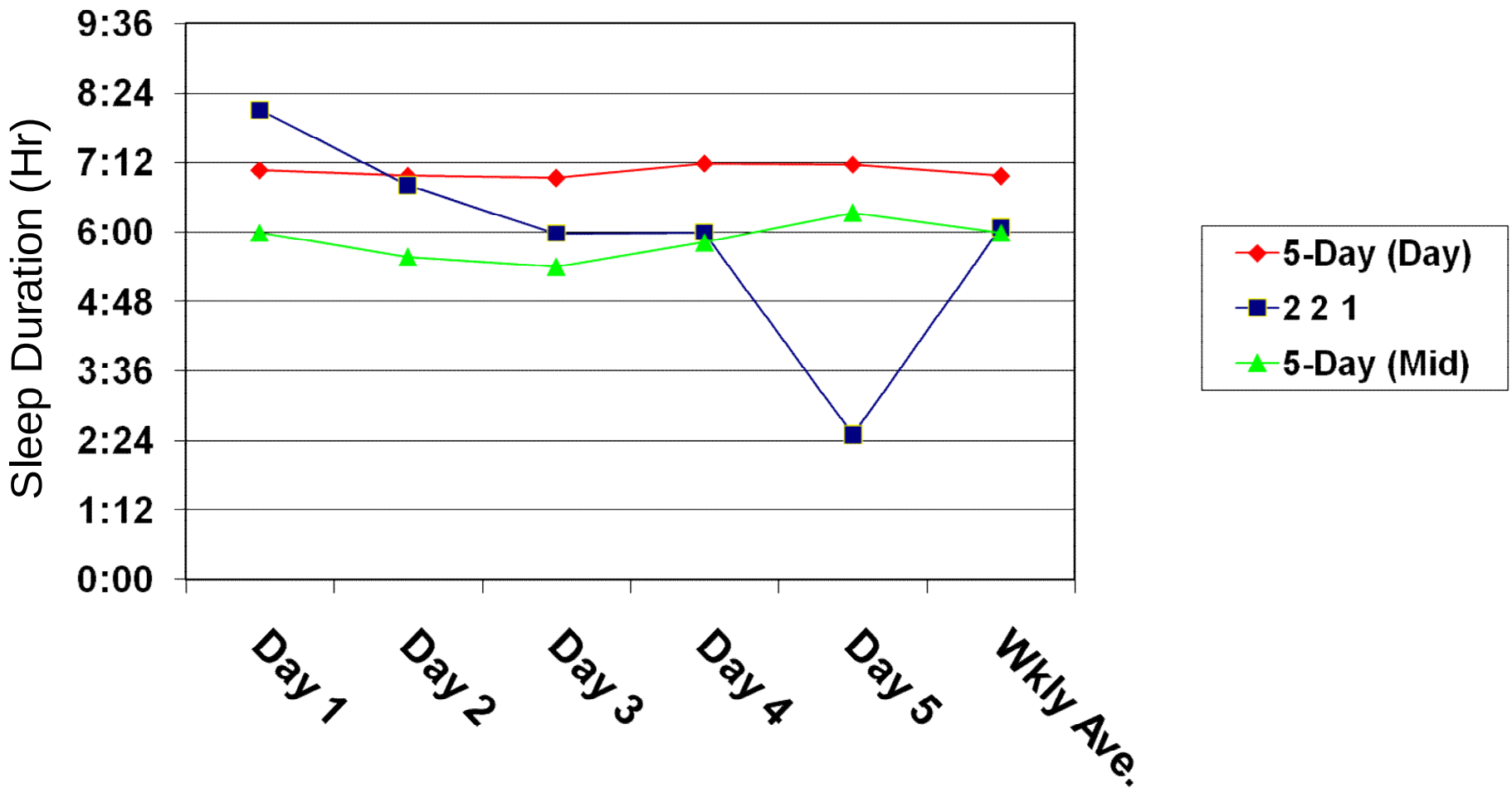
Presented at the FAA Fatigue Management Symposium: Partnerships for Solutions; Vienna, VA; June 17-19, 2008

Comparison Study: 5 Day Shifts vs. the 2-2-1 Schedule

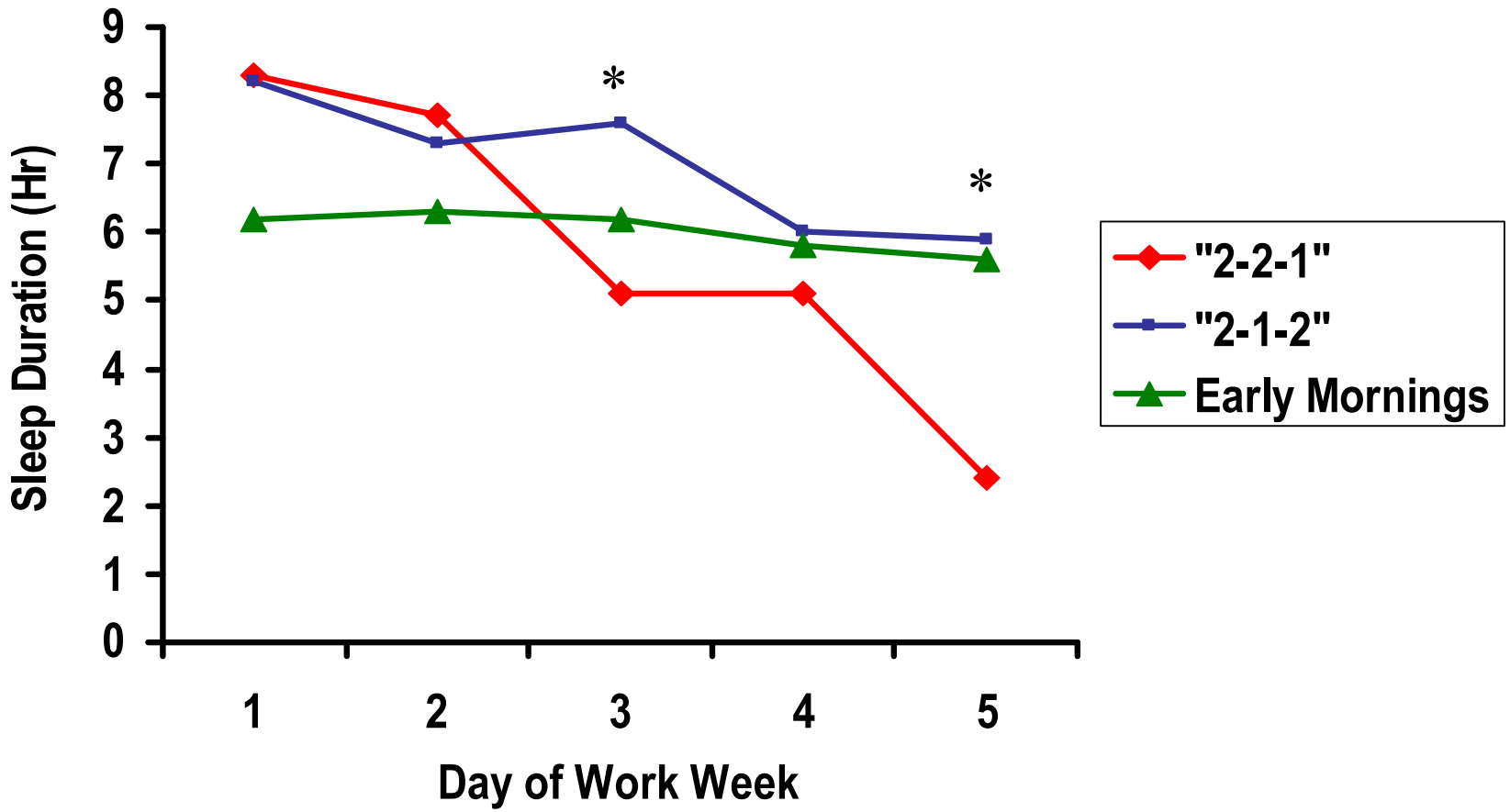
- 19 Controllers from Houston Intercontinental Tower
  - 5-day shift data from 1970
  - 2-2-1 shift data from 1971
- Assessments included physiological and psychological data
- Conclusion - no significant stress differences between the two schedules

Melton, et al., 1973

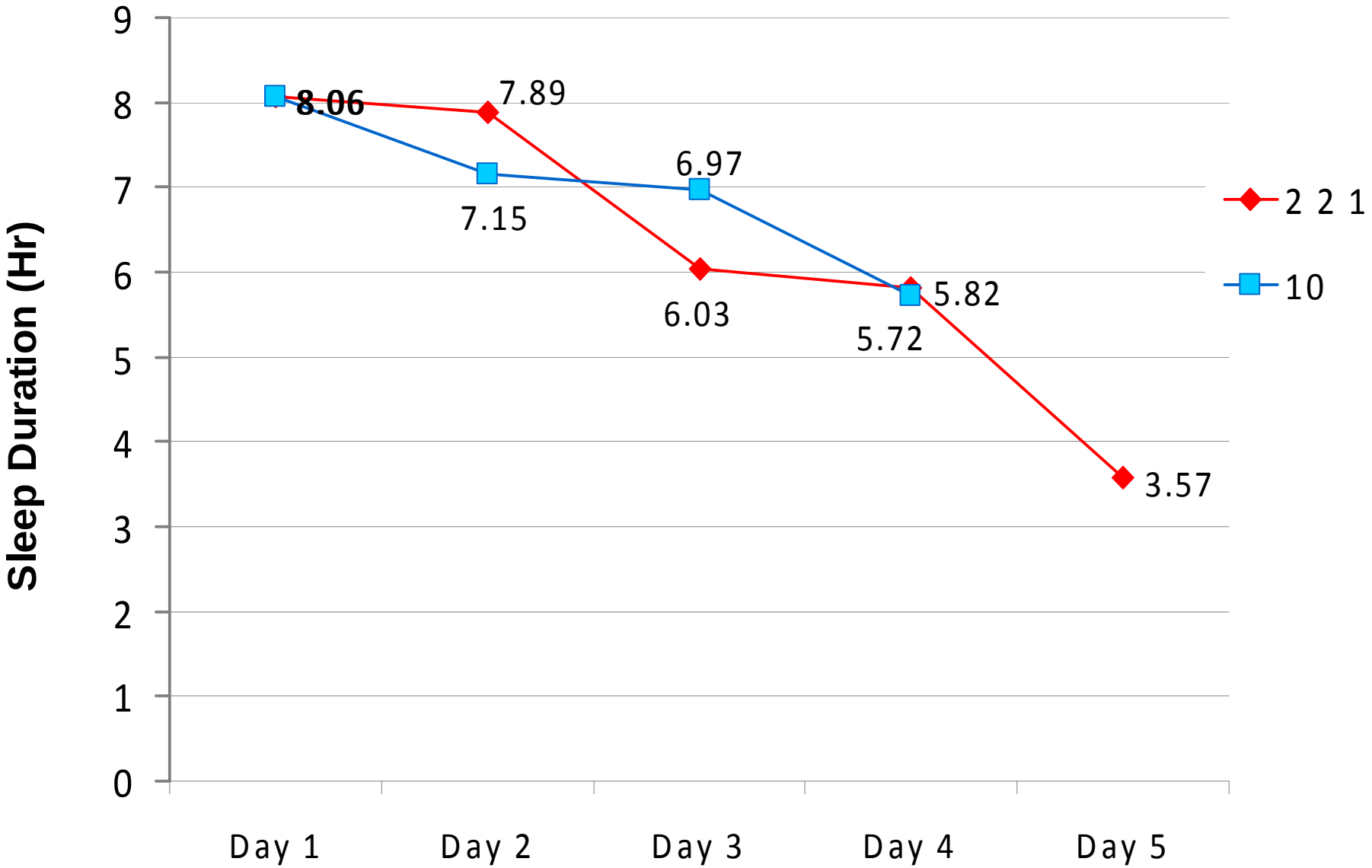
Comparison of 5-Day and 2-2-1 Schedule (Melton, et al., 1973)



Miami Field Study: Sleep Duration by Day of Week



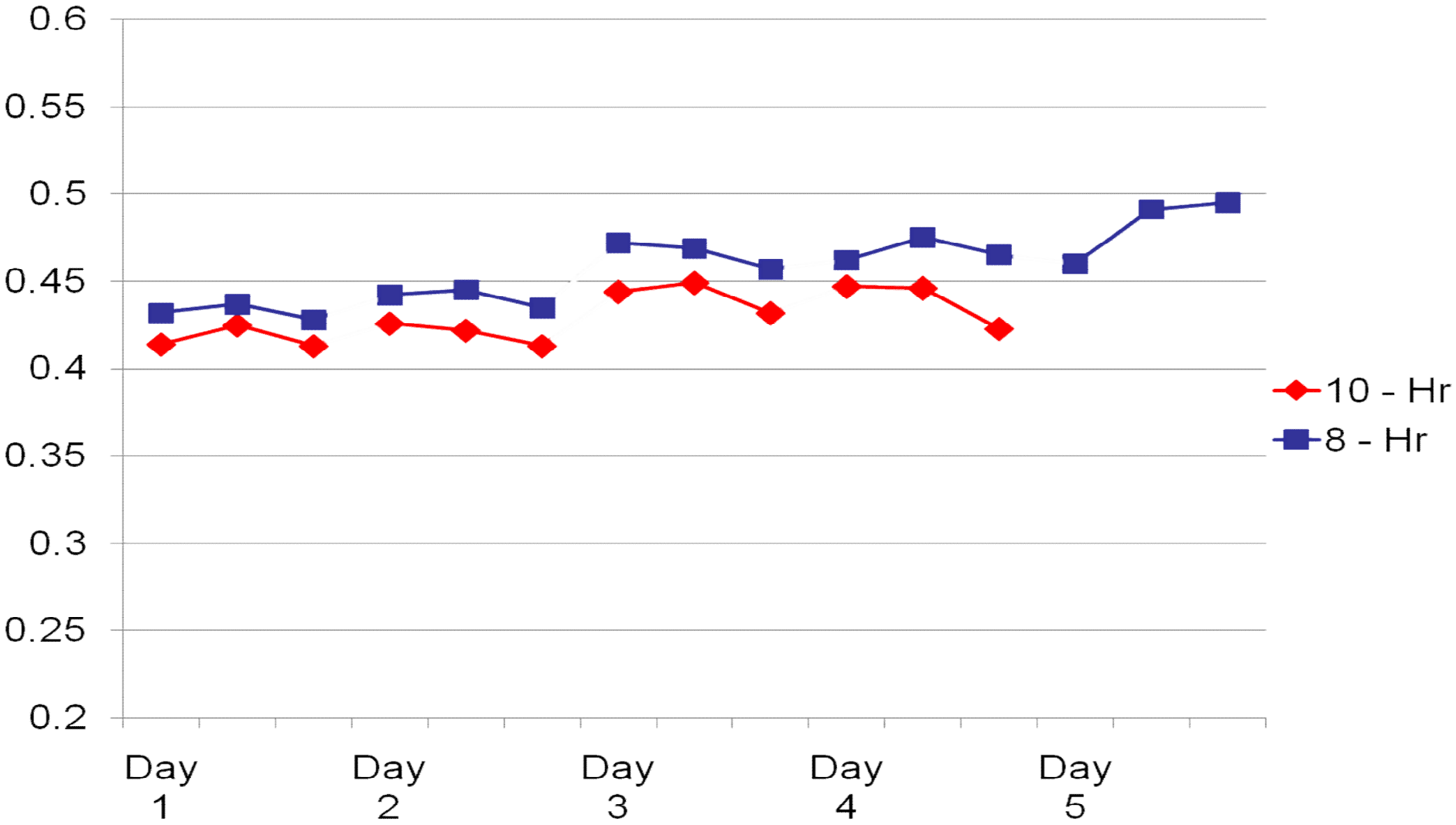
Average Sleep Duration By Day of Week



10-Hr AWS Study; 2 ARTCC Facilities

- **10-hour, 4-day rotating shift schedule compared to traditional 8-hour, 2-2-1 rapidly rotating schedule.**
- **10-hour shift did not differ from the 8-hour schedule for any NIOSH parameters**
- **Test performance notably poorer on the mid-shift (night) on the final (fifth) day of the 2-2-1; 8-hour schedule**
- **Both schedules showed changes in alertness within work days and across days of the week**
- **Changes in test performance and mood ratings corresponded to decline in self-reported sleep time across the work week**

Choice Reaction Time



Bright Light Study, Brooks AFB TX

- 60 min light pulse; 1000/500/30 lux, full spectrum vs. green; @ 0200.
  - All light conditions suppressed normal nocturnal melatonin.
  - Effect was not maintained beyond the duration of the light pulse.
  - Level of suppression did not translate easily into improvements in cognitive performance or subjective mood.

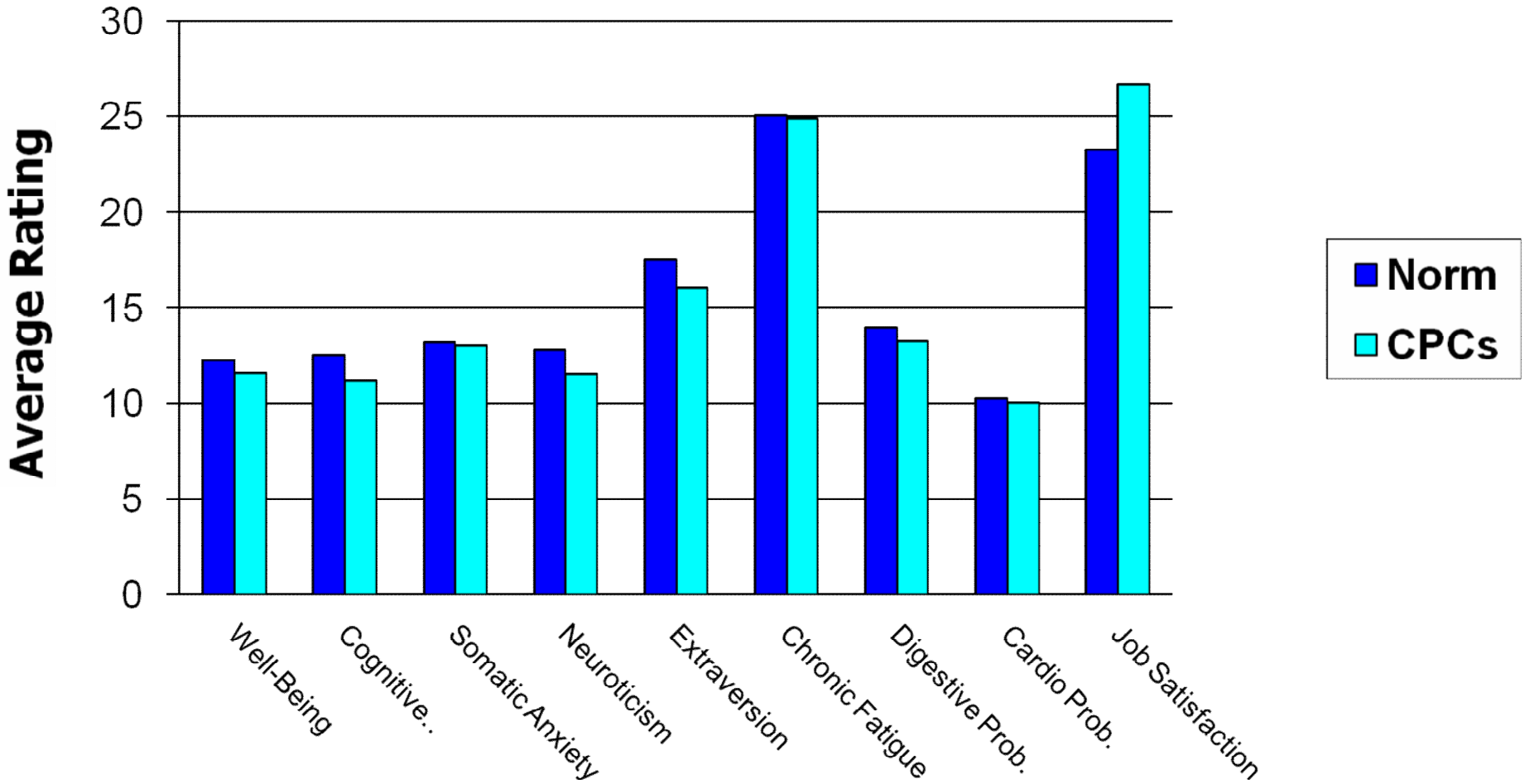
Congressional ATCS Shiftwork & Fatigue Study (1999)

- To determine the effects of fatigue and current shift and rotation pattern-practices on the ATCS workforce
- Three Projects:
  - Comprehensive survey of air traffic control workforce
  - Field Study to corroborate survey findings
  - Laboratory study to compare clockwise and counter-clockwise rapidly rotating shift schedules.

Survey

- **Comprehensive survey of air traffic control workforce**
  - Modified Standard Shiftwork Index (SSI) Measures included:
    - **Shiftwork History**
    - **Sleep and Fatigue**
    - **Health and Well-Being**
    - **Social and Domestic Situation**
    - **Coping**
    - **Circadian Type**
    - **Background/Biographical**
  - 23,000 surveys mailed out; 29% returned

FAA CPCs and Shiftworkers



General Survey Results

- **Shiftworking vs. non-shiftworking sample**
  - More fatigued and disrupted
  - Poorer sleep quality
  - Younger sample
  - Experienced more frequent driving issues following shifts
- **Gender**
  - Females more fatigued
  - Younger sample
- **Age**
  - Older, less fatigued, “morning-larks”
  - Greater cardiovascular problems
  - Worked fewer rotations

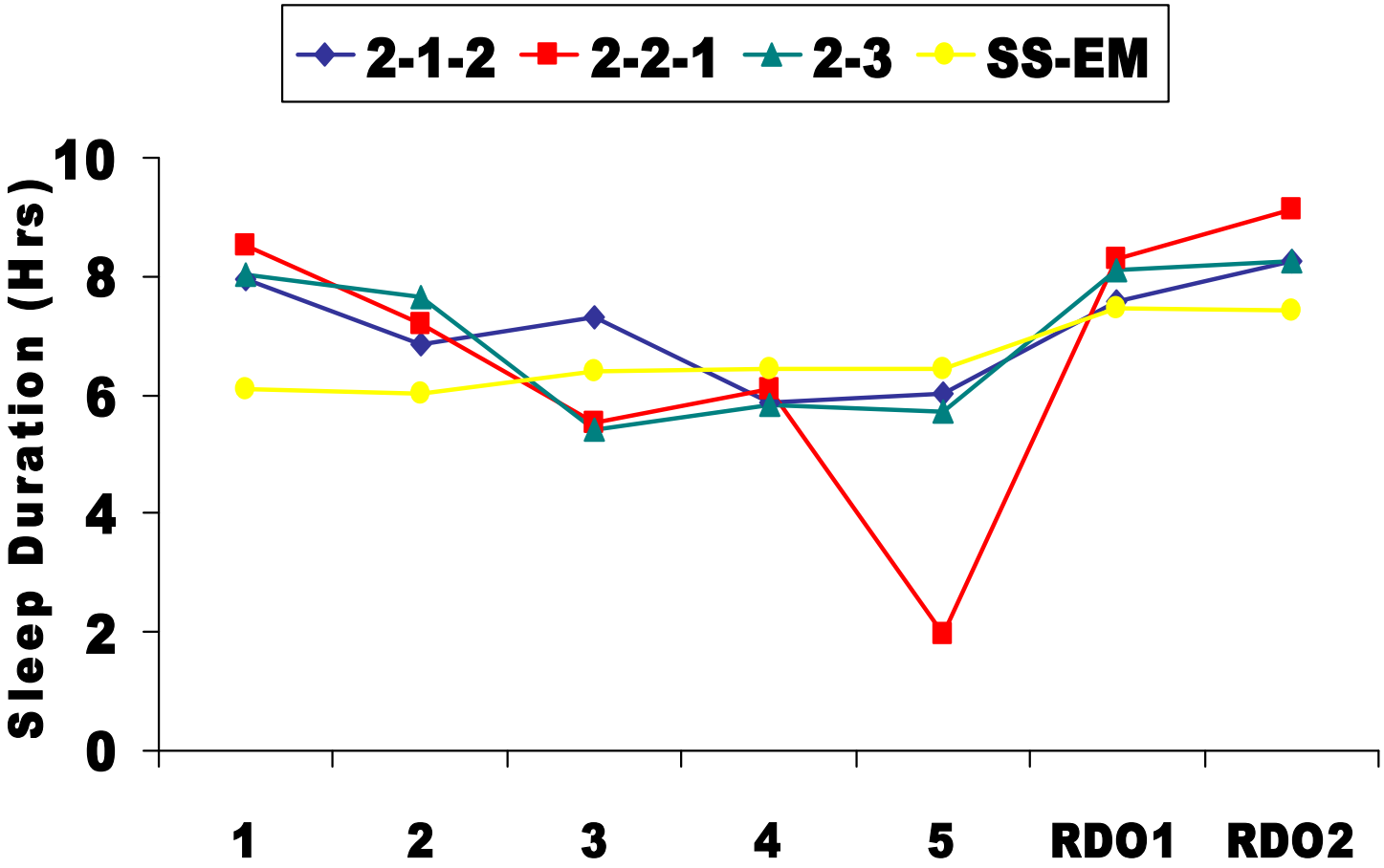
Air Traffic Shiftwork & Fatigue Evaluation (AT-SAFE)

- Integrated 3-wk protocol w/72 ATCSs from Terminal and Center
- Computer-based performance, actigraphy, and logbooks
- Majority of shift schedules were counter-clockwise & rapidly rotating
- 4 primary schedules:
  - 2-2-1: 2 Afternoons, 2 Early Mornings, 1 Midnight
  - 2-1-2: 2 Afternoons, 1 Midday, 2 Early Mornings
  - 2-3: 2 Afternoons, 3 Early Mornings
  - EM: 5 Straight Early Morning Shifts

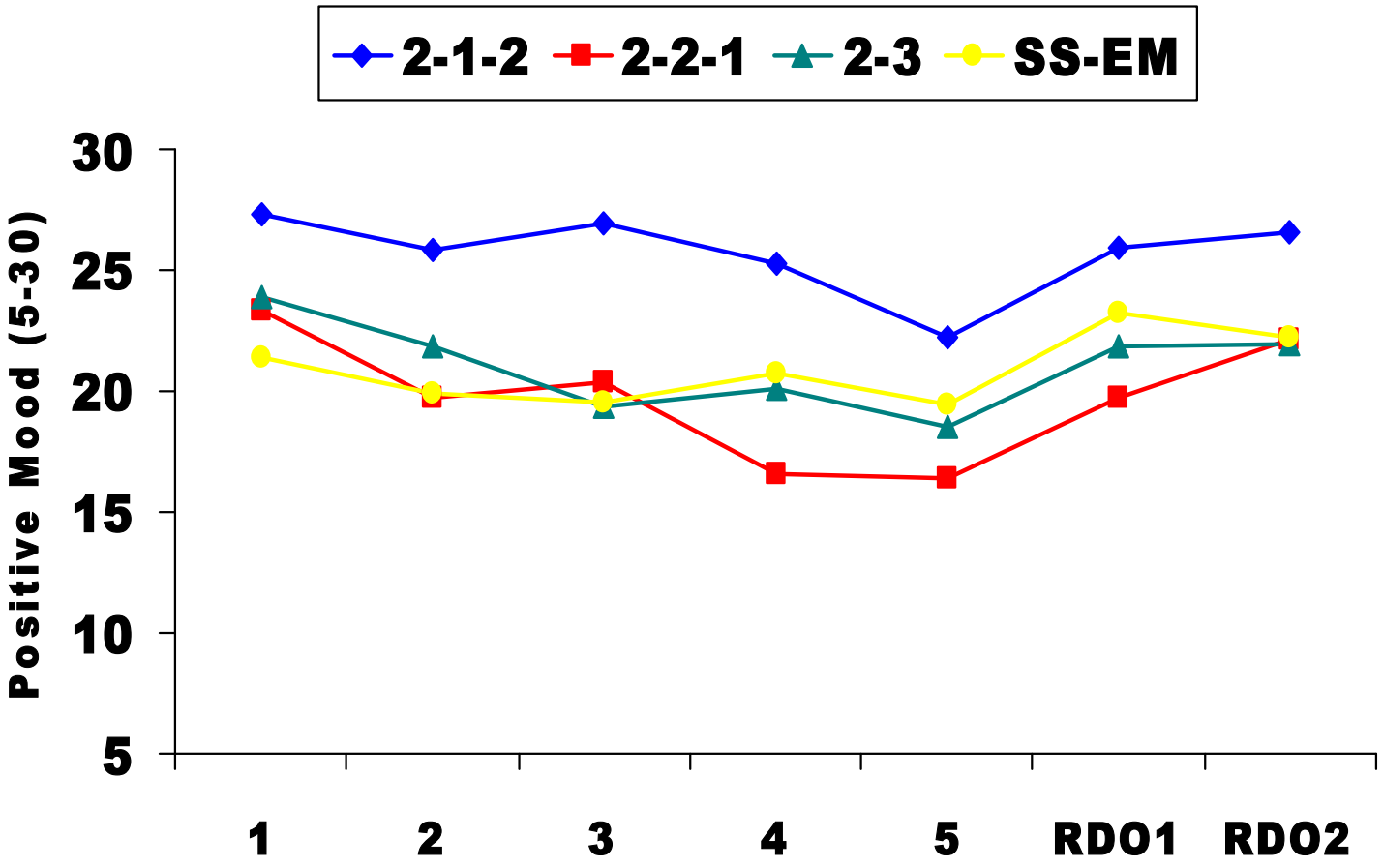
General AT-SAFE Results

- Sleep duration & quality, mood and sleepiness appeared to be a function of shift start time
- Quick-turn rotations >12 hr off allowed more sleep and resulted in better performance and subjective reports
- Normal age-related performance changes also found
  - Timed measures and working memory most affected, followed by measures of long-term memory

Sleep Duration by Day



Positive Mood Ratings by Day



2-2-1 Shift Rotation Lab Study

Method

- Clockwise vs. Counter-Clockwise Rotation
- 3-week protocol (1 week day shifts, 2 weeks shiftwork)
- 28 non-controllers, ages 20-55, M=41.2 yrs.
- No smoking, alcohol, medication, caffeine.
- ATCS matching requirements
  - FAA Class II Medical
  - Minimum WAIS-R equivalent of 104

Study Schedules

Clockwise	Counter-Clockwise
0600-1400 (16 hrs. off)	**1400-2200** (16 hrs. off)
0600-1400 (24 hrs. off)	**1400-2200** (8 hrs. off)
1400-2200 (16 hrs. off)	**0600-1400** (16 hrs. off)
1400-2200 (24 hrs. off)	**0600-1400** (8 hrs. off)
2200-0600 (48 hrs. off)	**2200-0600** (80 hrs. off)

Sleep Duration Results

	Clockwise	Counter-Clockwise
Early Morning 1	5.6h	5.5h
Early Morning 2	6.3h	6.5h
Evening 1	7.9h	8.5h
Evening 2	7.7h	8.1h
Midnight	7.7h+1.5h nap	6.5h+2.9h nap
Nap after Mid	4.3h	4.4h
Recovery	8.4h	8.9h

General Performance Results

- Few differences between rotation conditions
- The few exceptions indicated performance was better in the counter-clockwise condition
- Performance was maintained on afternoon shift, reduced on early morning shift, and dramatically impaired on midnight shift—*regardless of condition*

Rotation Study Conclusions

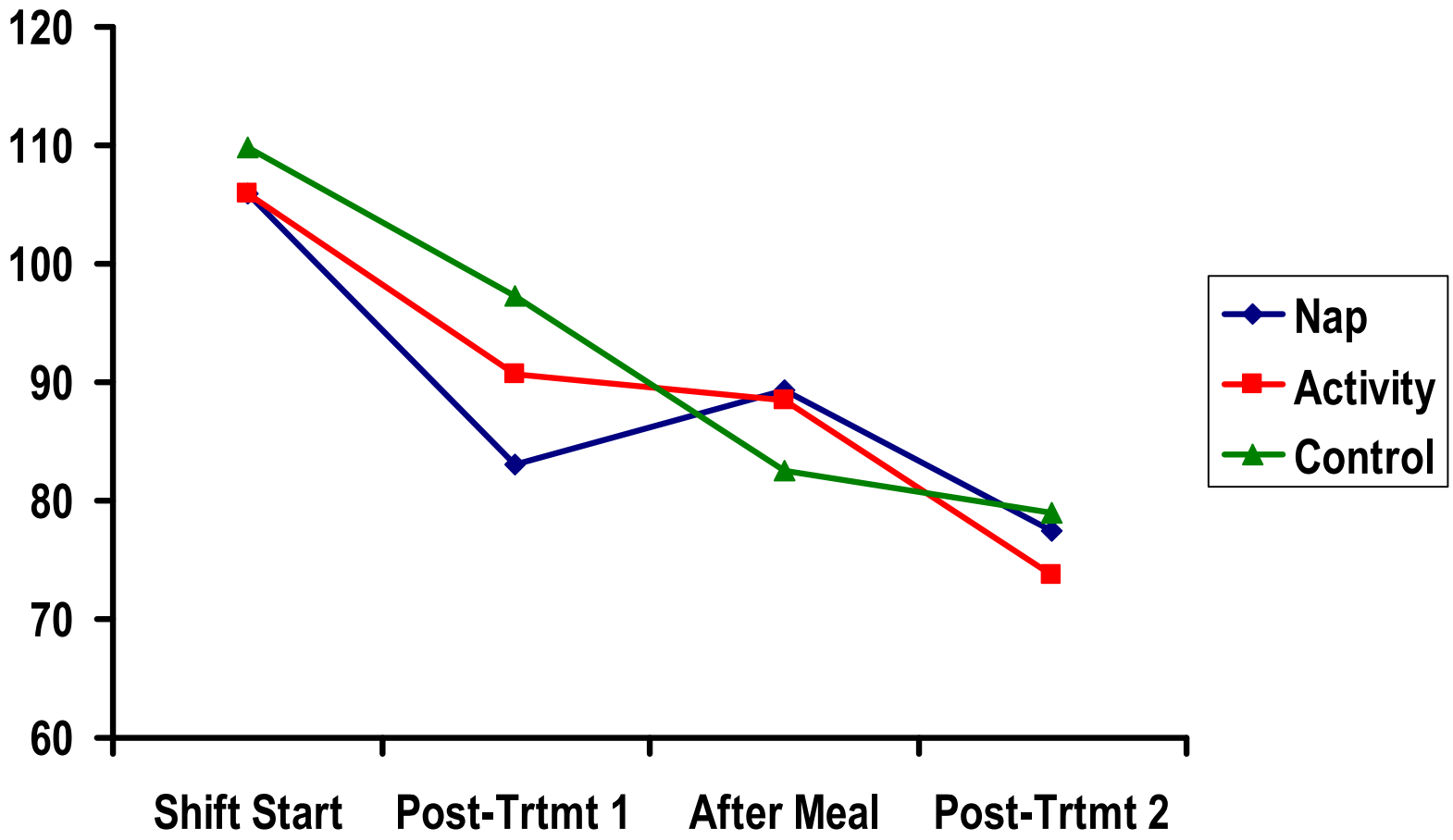
- The effects of the counter-clockwise 2-2-1 rotation schedule were no different than the clockwise variant.

- Early mornings and midnights remain a concern for maintaining performance in *either* rapidly rotating shift schedule
  - Prophylactic napping is highly recommended before midnight shift

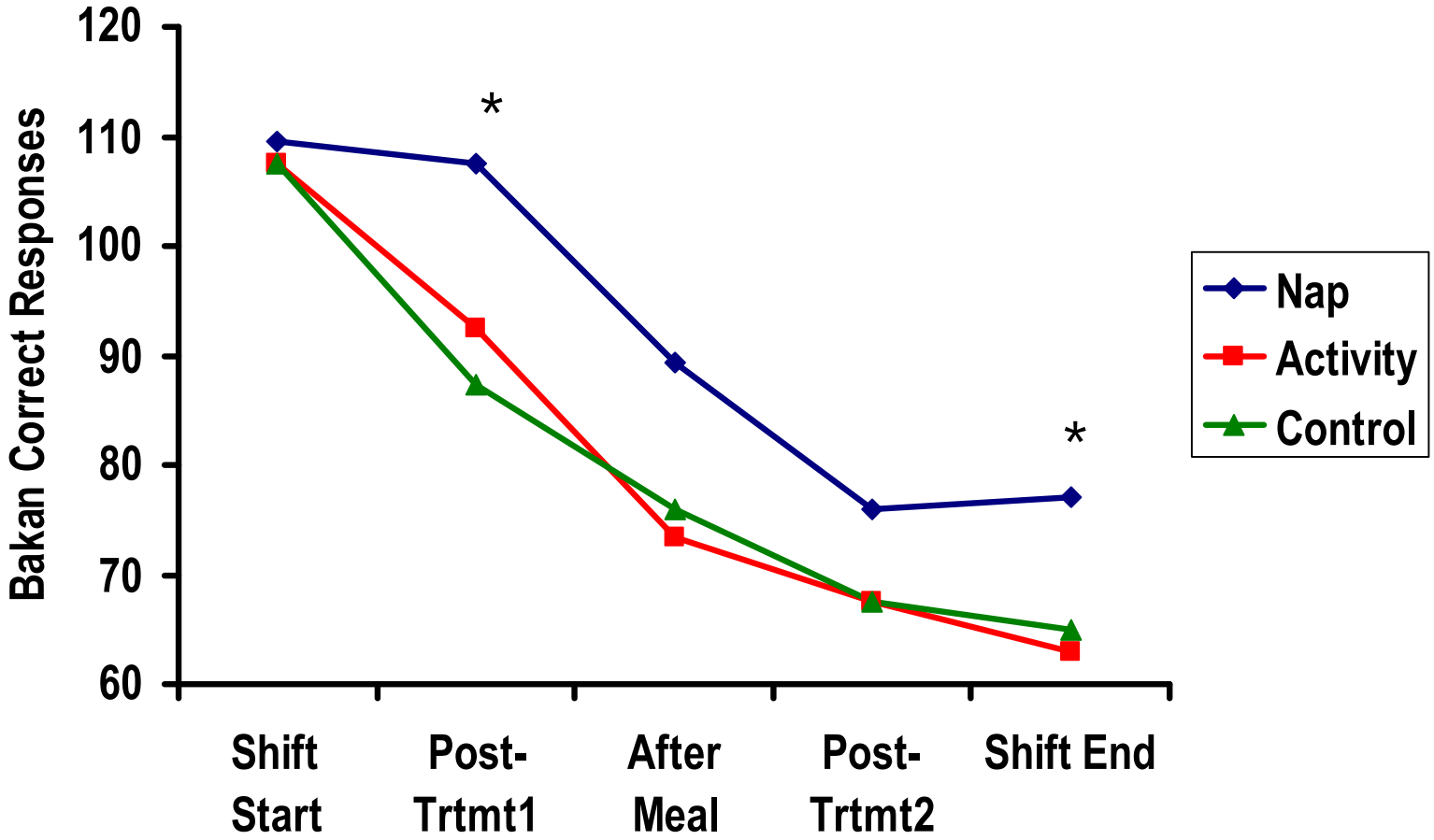
Midnight Shift Countermeasures Study

- Laboratory Study; 3 quick-turn-arounds from early morning (0600-1400) to midnights (2200-0600)
- Completely Within Design
  - Two 20-minute naps
  - Two 20-minute periods of mild exercise
  - Two controlled breaks
- Two experiments; Performance measured:
  - Exp 1: Immediately after treatment
  - Exp 2: 40 minutes after treatment.

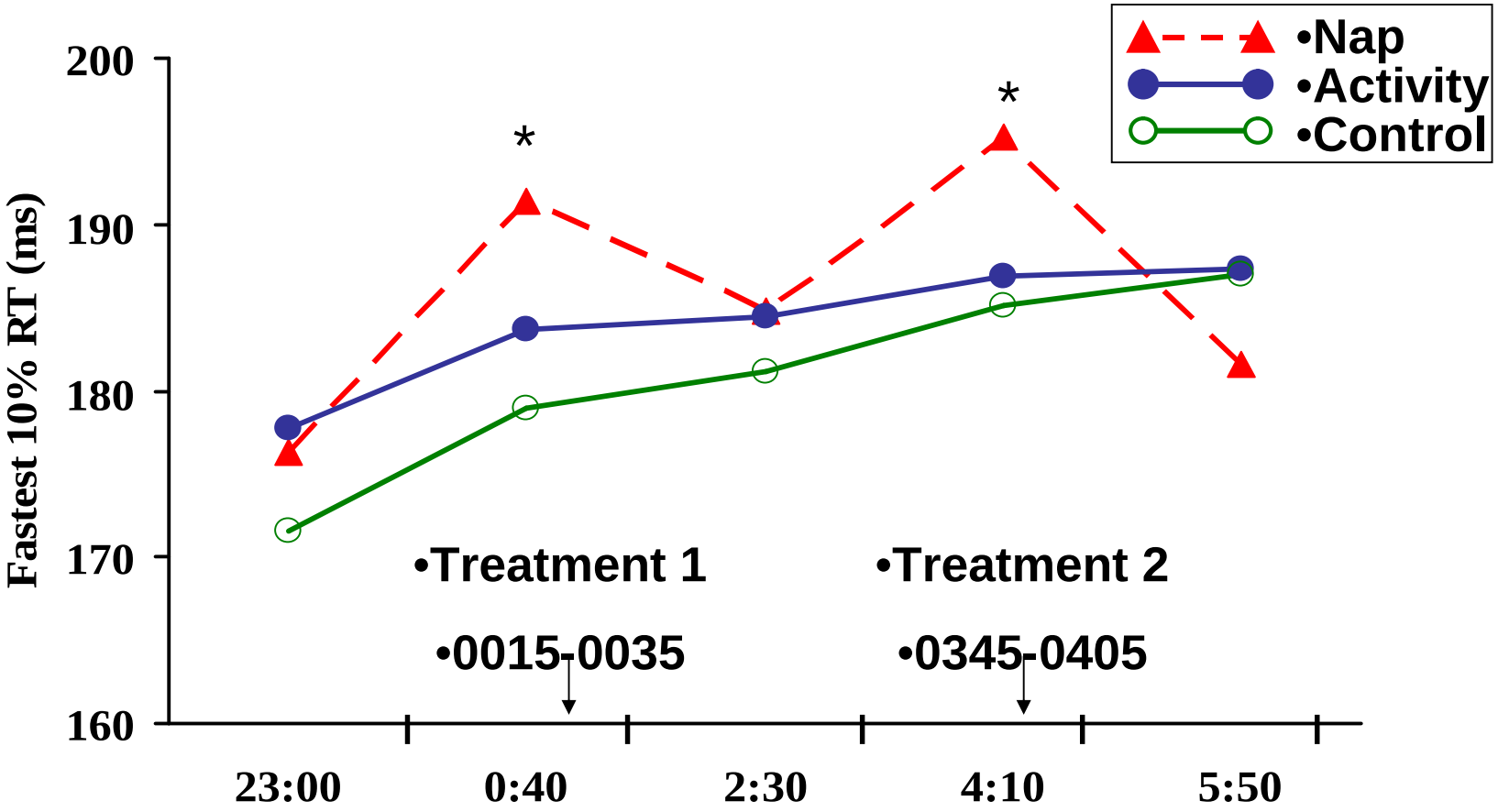
Experiment 1: Bakan Vigilance Task Results (Correct responses)



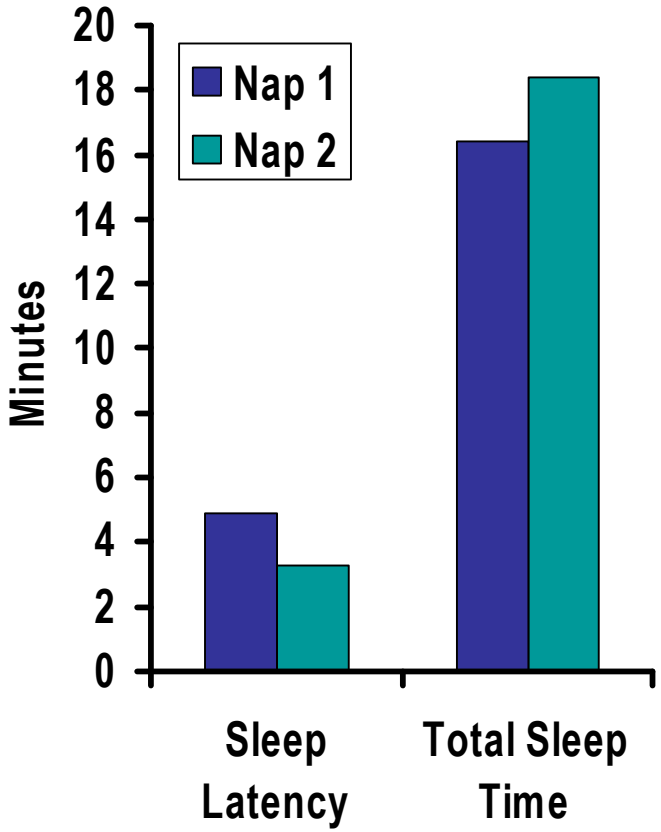
Experiment 2: Bakan Vigilance Task Results (40 min after treatment)

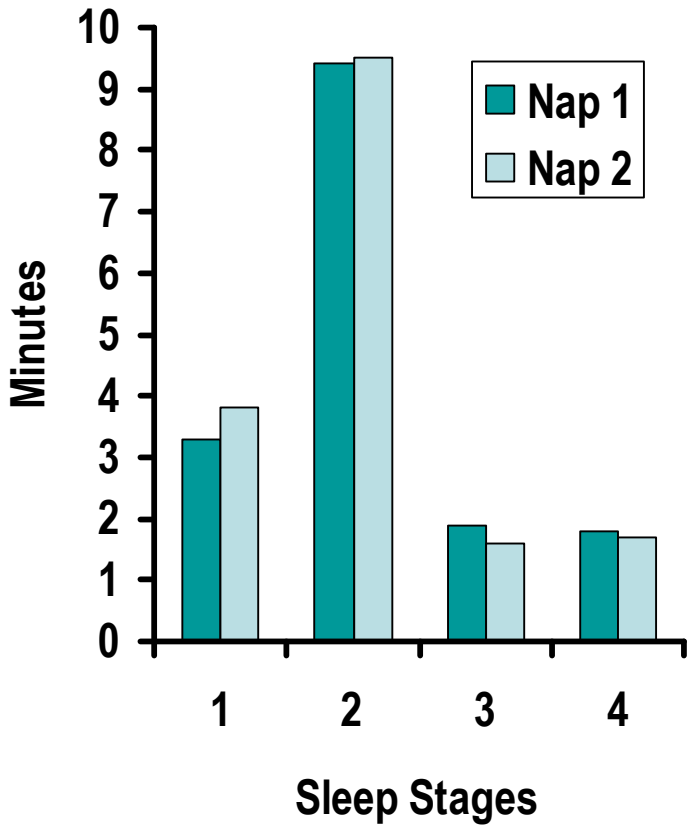


Experiment 2:
PVT Reaction Time (sleep inertia?)



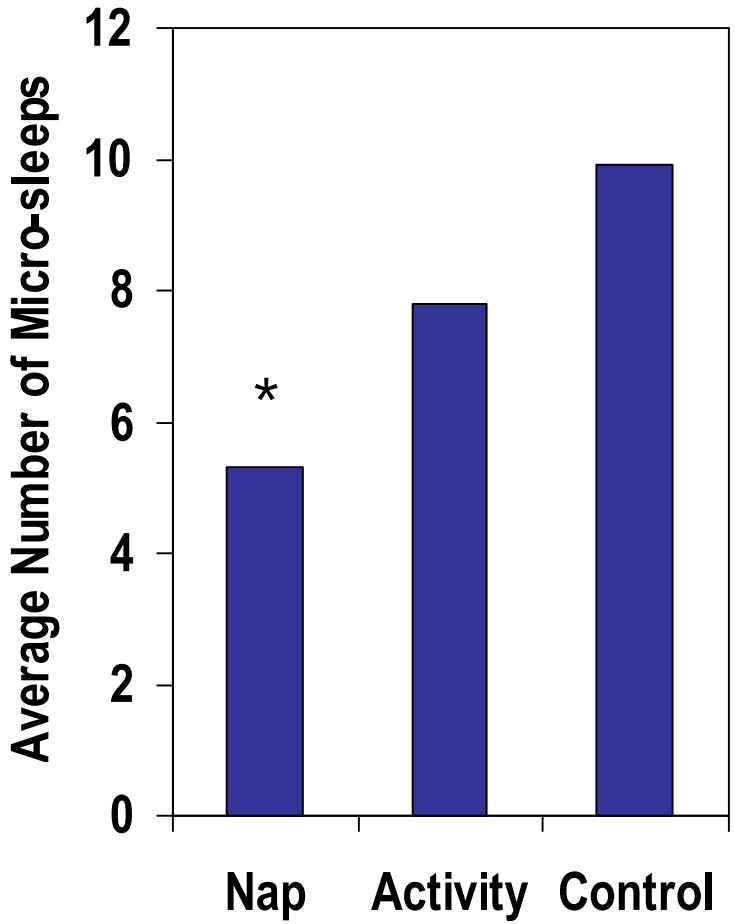
EEG Results (n=15)





Micro-sleep Analysis

- **Significantly fewer micro-sleeps found during performance testing following the napping treatment $t(13) = 3.2$, $p < .05$.**



Controller Operational Performance

- **Operational Error -** An occurrence attributable to an element of the air traffic control system in which:
  - Less than the applicable separation minima results between two or more aircraft, or between an aircraft and terrain or obstacles; or
  - An aircraft lands or departs on a runway closed to aircraft operations

Controller Operational Performance

- ASRS Analysis study (spanning 1988-1996)--2.7% of reports referenced controller-related fatigue
- OEDS database study--80% of OEDs between 0800-1900; nearly 50% of errors occurred within 30 minutes on-position, usually upon returning from a break
- Higher percentage of data posting errors occur on midnight shift
- Neither study revealed shift work variables as strong predictors of the severity of operational errors
- NTSB (2007) – present case studies of fatigue related incidents/accidents

Summary

- No single shift rotation plan can entirely resolve the work and rest scheduling demands placed on individuals
- Discussion of specific advantages and risks difficult due to great diversity of flexible and irregular hours
- Given the variability of flexible hours, focus should be on the actual working hours of employees and the timing of their sleep
- Modeling tools can assist in avoiding fatigue-inducing individual schedule revisions

Recommendations

- Employ ergonomic principles of scheduling as possible
- Shift rotation time should be no less than 10 hrs
- Utilize modeling and scheduling tools to assist in mitigating fatigue promoting schedules
- Educate schedulers and workforce about issues regarding shiftwork & fatigue
- Promote application of personal and operational counter-fatigue strategies

URLs for References

- CAMI research references can be downloaded from: http://www.faa.gov/library/reports/medical/oamtechreports/index.cfm
- DOT HFCC Operator Fatigue Management Program site for info on FAST and XIMES tools: http://scitech.dot.gov/research/human/ofm.html