Work Scheduling and Fatigue Management

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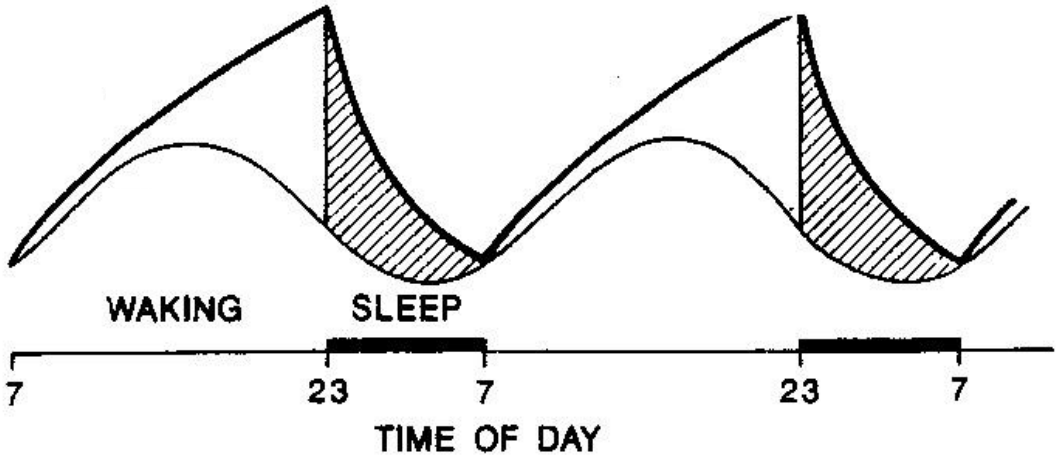
Physiological Limits to Performance

- Number of hours awake (acute sleep debt)
- Circadian time of day
- Cumulative sleep debt (chronic sleep restriction)
- Other factors:
  - Individual differences
  - Irregular work/sleep schedules
  - Workload/time on task
  - Sleep inertia
  - Sleep disorders
  - Combined effects



Borbely & Achermann, 2000

Fatigue Degrades Performance

- NTSB (Rosekind, 2013) estimates that fatigue* leads to:
  - **Degraded**
    - reaction time, judgment, communication, mood, memory, attention, situational awareness
  - **Increased**
    - microsleeps, apathy, attentional lapses, irritability, impulsivity, under-evaluation of threats
  - Magnitude of changes from 20-50%+

- NTSB investigations (n=182) between 2001-2012 found that 20% identified fatigue as “probable cause, contributing factor, or finding” (Marcus & Rosekind, 2017)

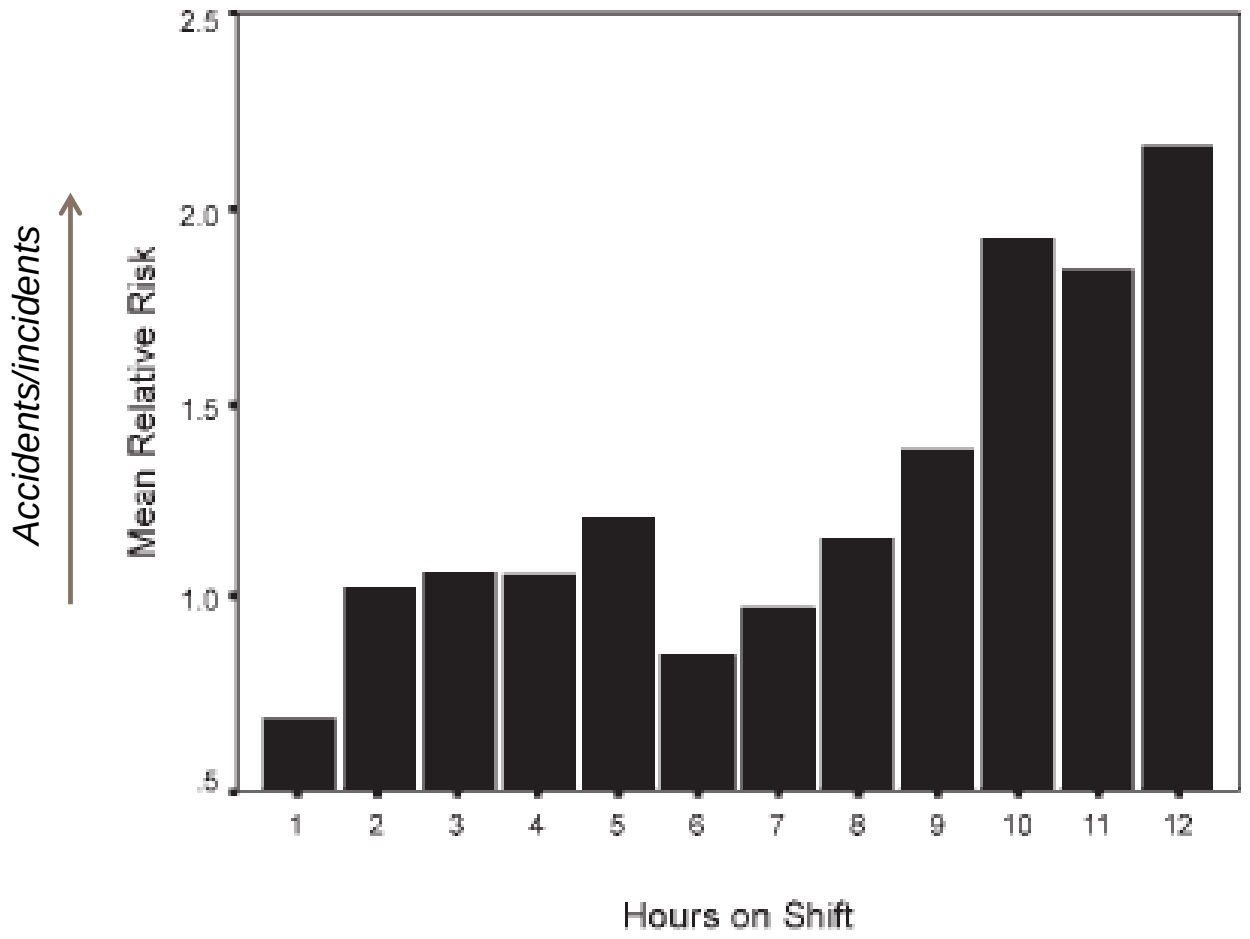
* Presence of one or more risk factors

Fatigue Management: Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive days/nights of work
- Minimum rest periods
- Recovery opportunities
- Predictability/stability
- Work extensions/changes

Scheduling Factors

- Length of work periods
  - Manage hours awake



Folkard & Tucker, 2003

Scheduling Factors

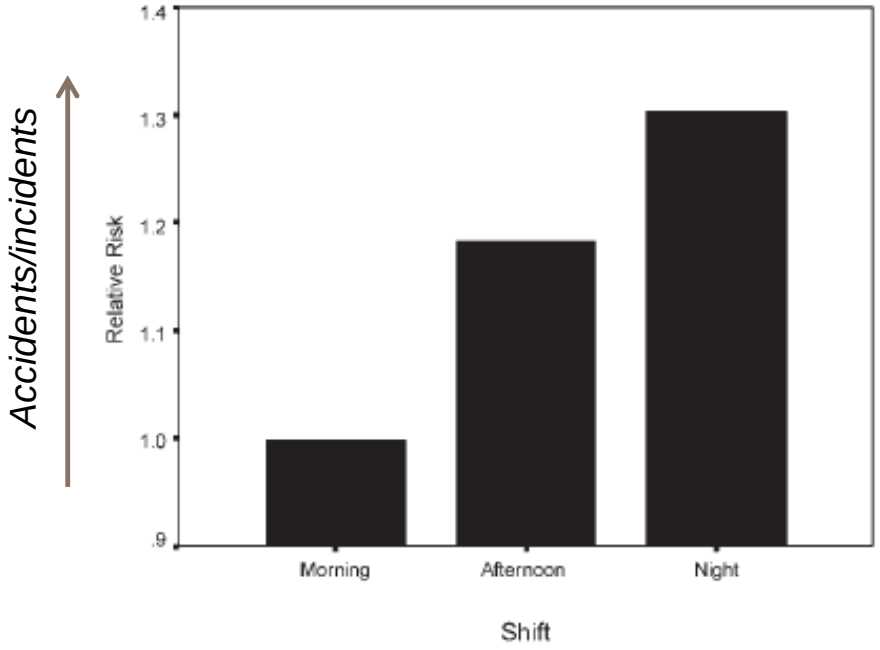
- Length of work periods
  - Manage hours awake

- USAF remote piloting operations
  - Changed from 8- to 12-hr shifts
  - About 30% of pilots reported feeling sleepy or very sleepy prior to mission
  - Fatigue increased over workweek
  - Reported being “spent” and “exhausted” when starting 4th shift in row
  - More fatigued for commute home
  - “primary cause of this fatigue centered on moving from 8- to 12-hr daily shifts”

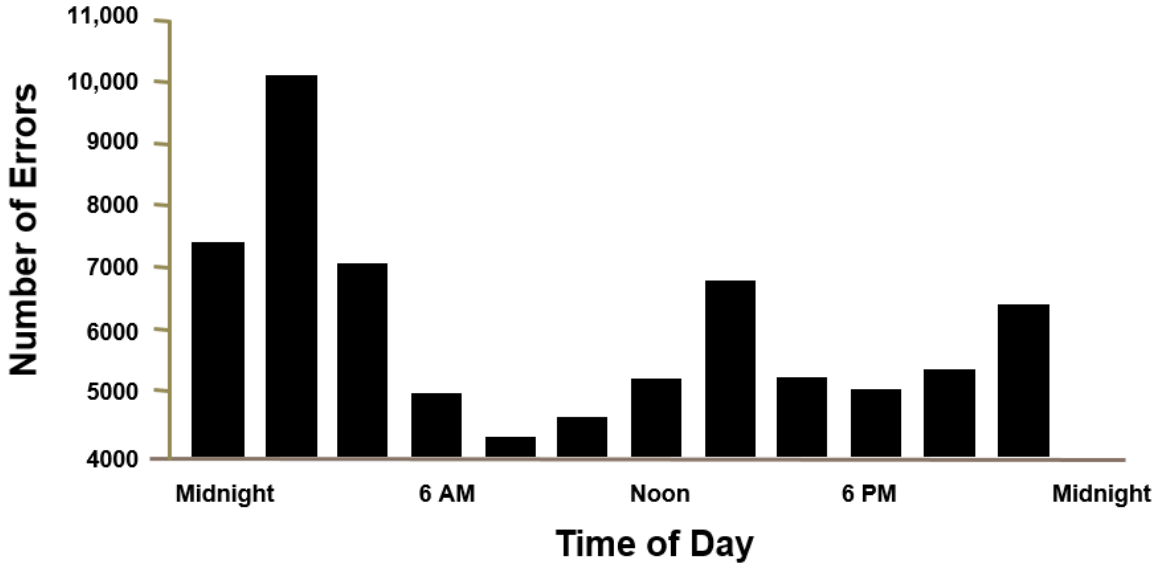
Scheiman, et al, 2018

Scheduling Factors

- Length of work periods
- Timing of work periods
  - Circadian nadir (night)
  - Early morning starts



Folkard & Tucker, 2003



Mitler, et al, Sleep 1988

Scheduling Factors

- Length of work periods
- Timing of work periods
  - Circadian nadir (night)
  - Early morning starts

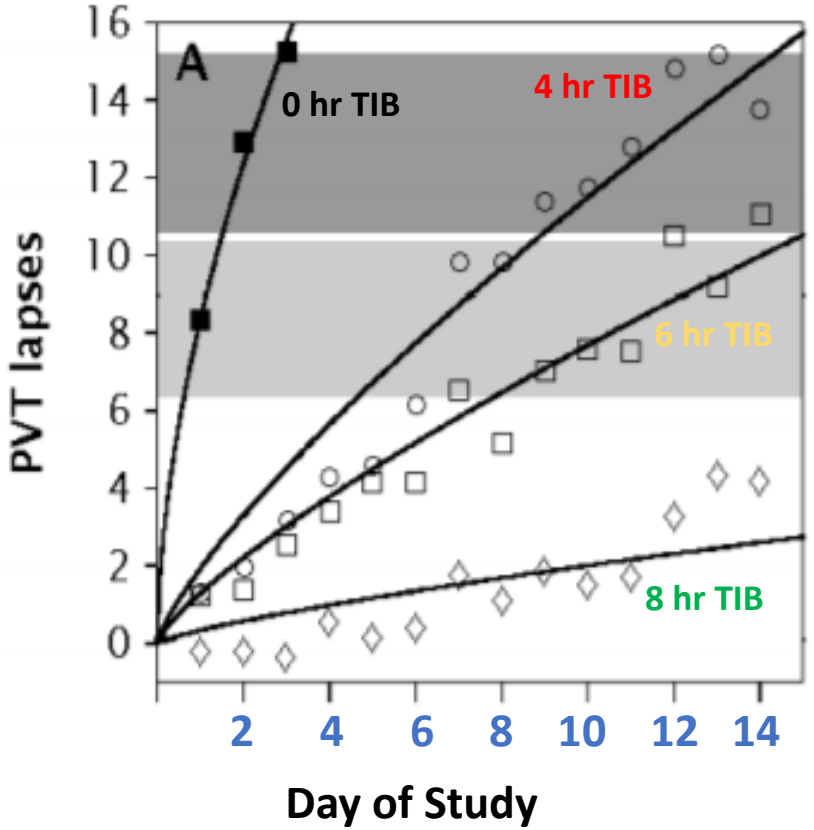
- Compared shift timing
  - S1: Morning 0600 start, Eve 1400, Nite 2200
  - S2: Morning 0700 start, Eve 1500, Nite 2300
- Sleep quantity and quality increased for 0700 start
- Sleepiness measures improved with 0700 start, poorer for nights

Site 1	E E E E R	M M M M R	N N N N	R R R
Start-end times	1400–2200	0600–1400	2200–0600	
Site 2	M M M R	E E E R	N N N	R R R
Start-end times	0700–1500	1500–2300	2300–0700	

Rosa, et al, 1996

Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive work periods
  - Chronic sleep restriction
  - Cumulative workload



Van Dongen, et al, Sleep 2003

Scheduling Factors

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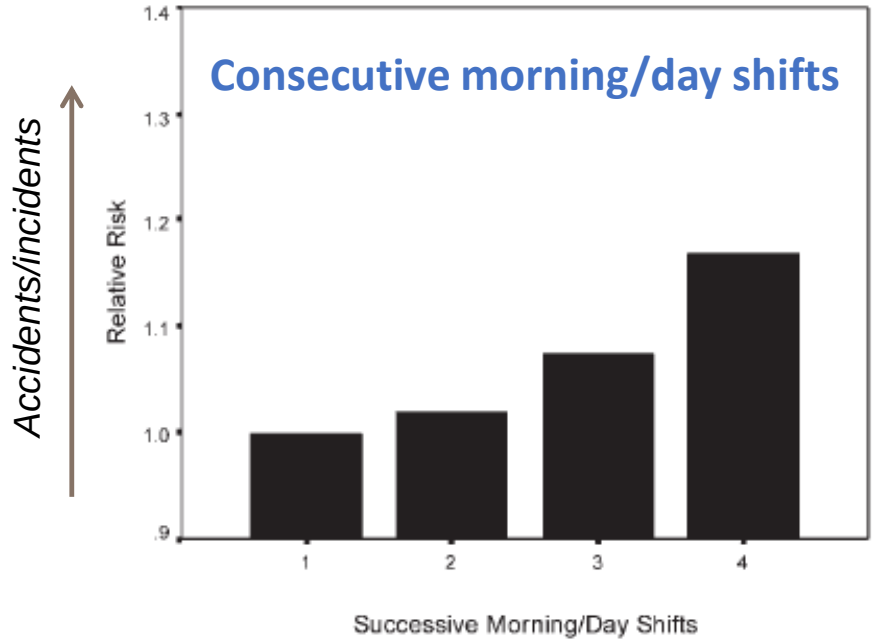

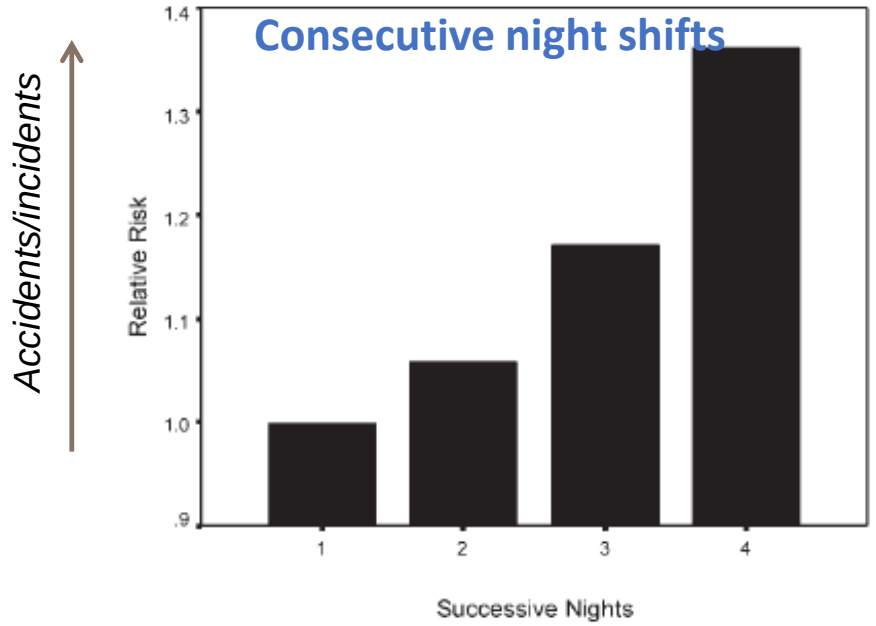

Folkard & Tucker, 2003

Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive work periods
- Rotation of work periods
  - Forward rotation in sync with clock
  - Circadian adaption is gradual

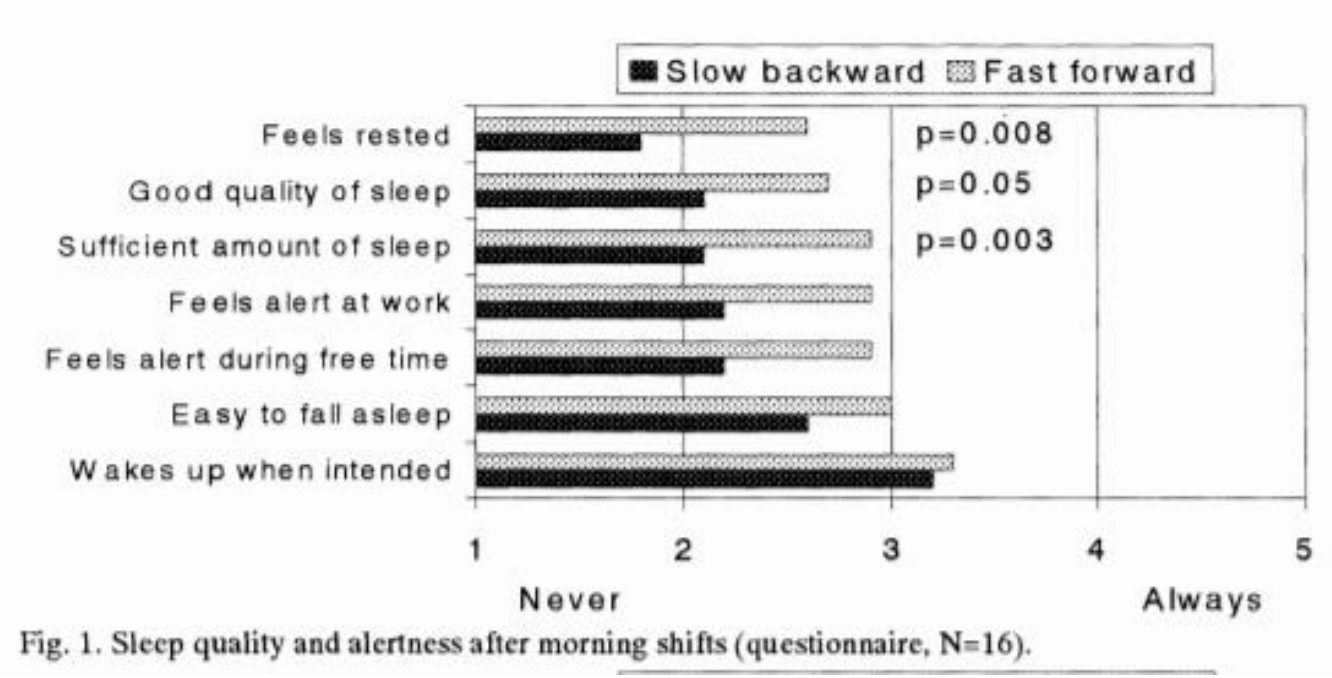

Fig. 1. Sleep quality and alertness after morning shifts (questionnaire, N=16).

Hakola & Härmä, 2001

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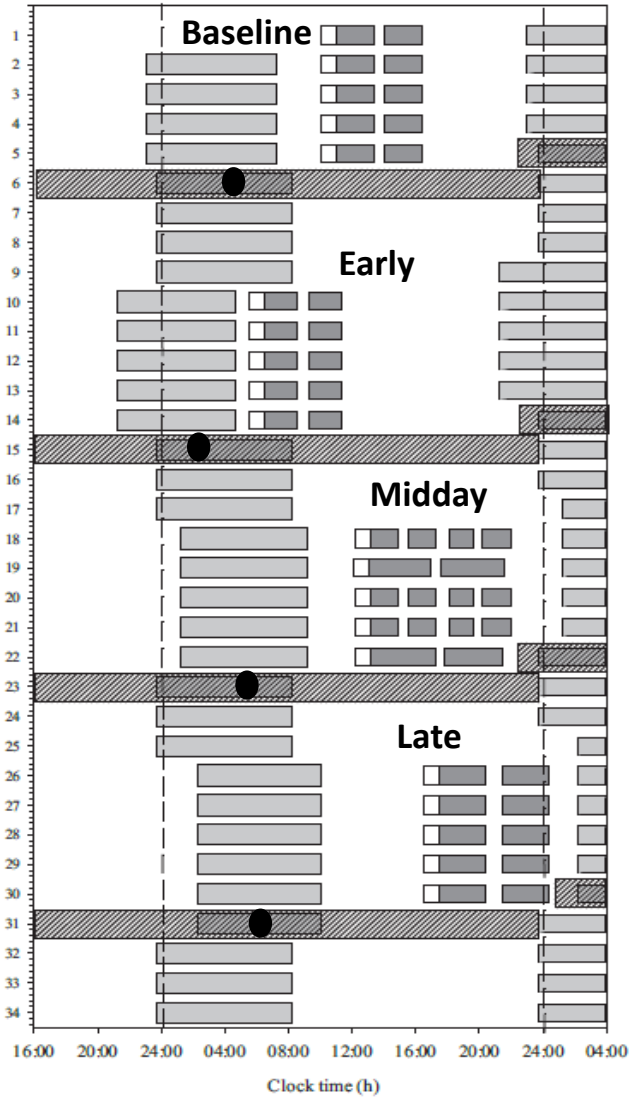
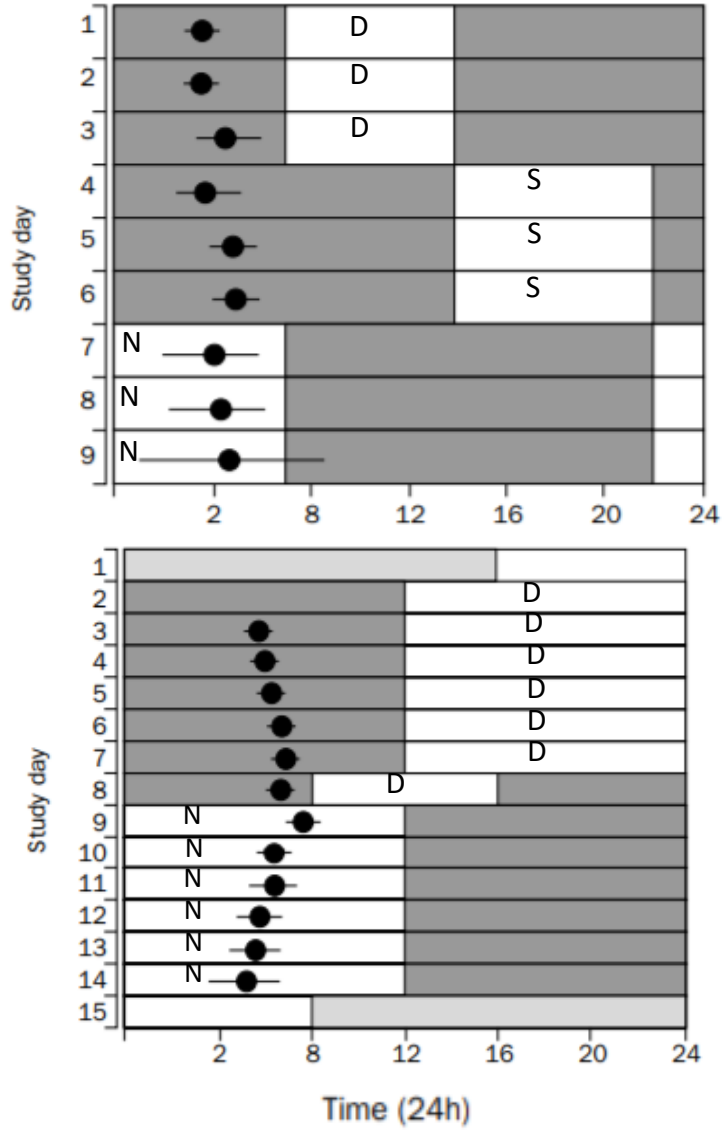


Melatonin peak
Sleep period
Flight duty period

Flynn-Evans, et al, Sleep Health 2018



Melatonin peak
Off-duty period

Rajaratnam & Arendt, Lancet 2001

Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive work periods
- Rotation of work periods
- Total work hours
  - Chronic sleep restriction
  - Cumulative workload
  - Overtime
  - Scheduling changes

Hours worked/ week	Average number of hours worked	Number of workers interviewed 2004–08[a]	Est. number of work-related injuries annually[b]	Est. number of workers annually	Est. annual incidence/ 100 workers
Total	40.3	177,576	3,634,446	129,950,376	2.80
≤20 h	14.9	14,785	229,343	11,286,527	2.03
21–30 h	27.2	13,333	298,900	9,929,180	3.01
31–40 h	39.3	101,442	1,746,467	71,388,048	2.45
41–50 h	47.4	28,396	761,163	22,042,456	3.45
51–60 h	57.9	13,448	387,346	10,433,206	3.71
>60 h	72.1	6,172	211,227	4,870,959	4.34

Lombardi, et al 2010

Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive work periods
- Rotation of work periods
- Total work hours
  - Chronic sleep restriction
  - Cumulative workload
  - Overtime
  - Scheduling changes

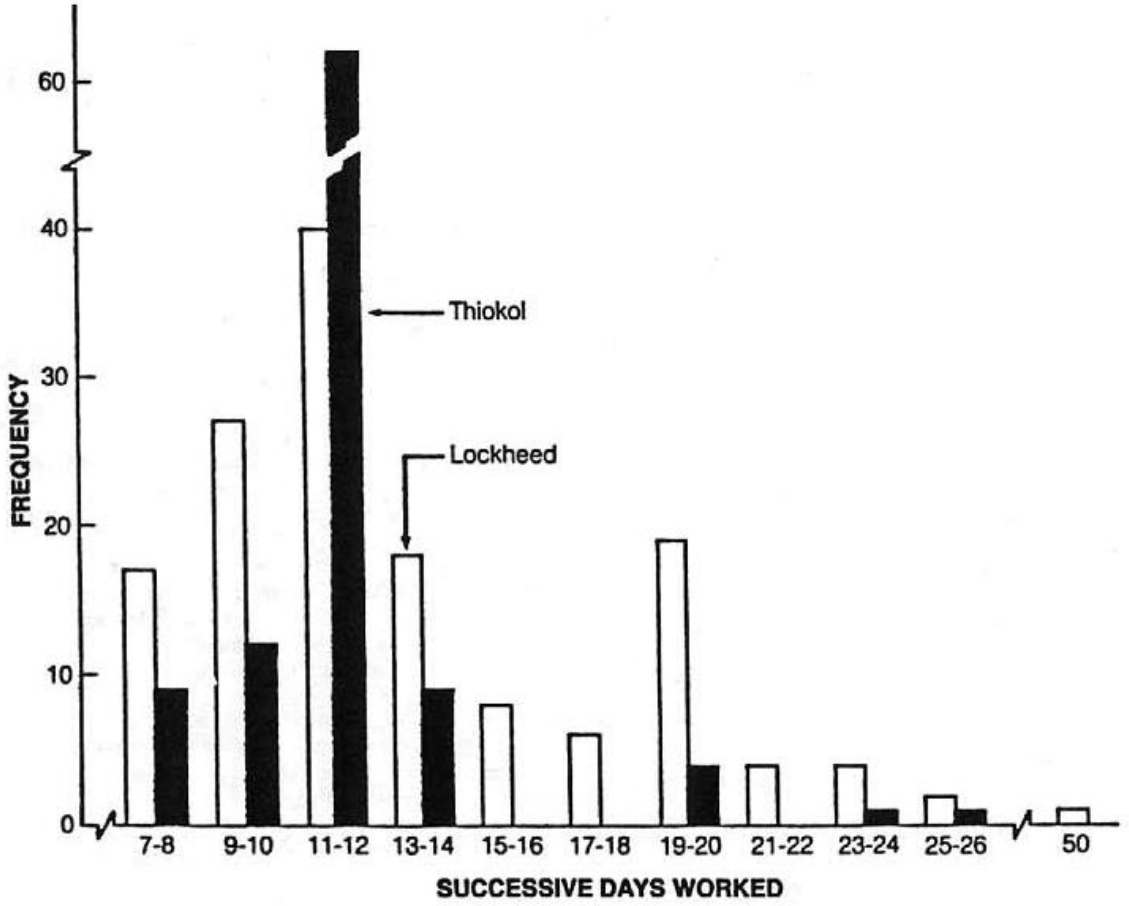
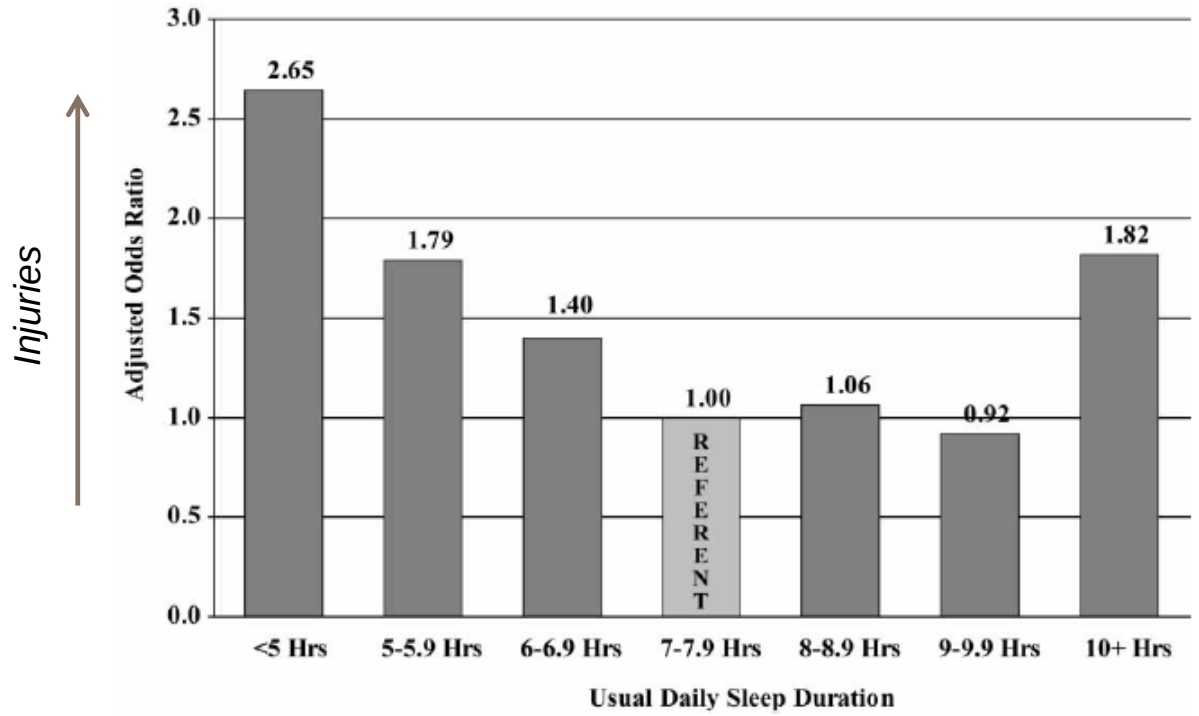


Figure 1—Incidence of more than six consecutive workdays among a group of Lockheed (N = 93) and Thiokol (N = 48) shiftworkers at Kennedy Space Center. Time period of sample varies from seven to ten weeks extending from October 26, 1985 to January 24, 1986.

Report of the Presidential Commission on the Space Shuttle Challenger Accident – Volume 2: Appendix G

Scheduling Factors

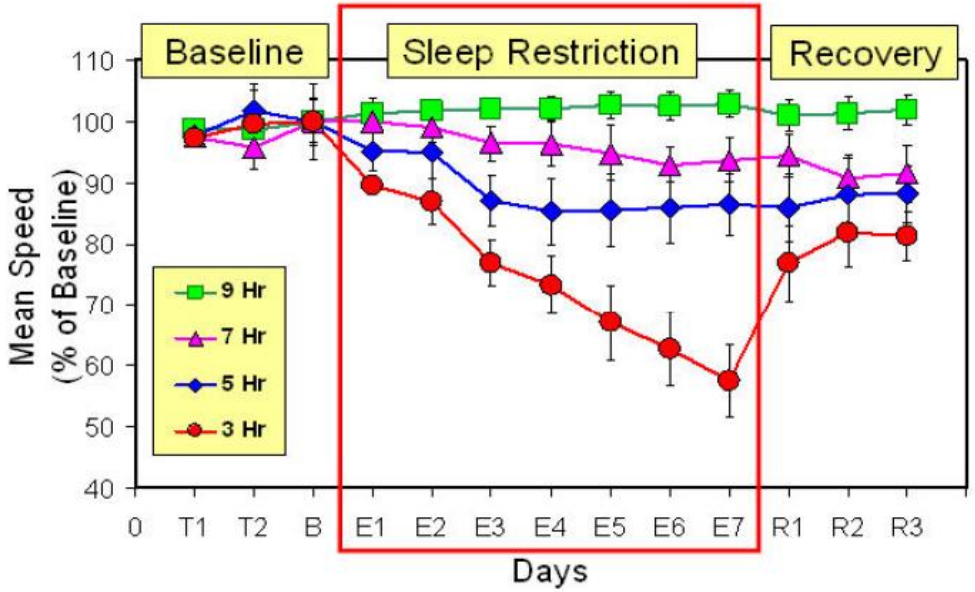
- Length of work periods
- Timing of work periods
- Consecutive work periods
- Rotation of work periods
- Total work hours
- Work extensions/OT/changes
- Length of off-duty periods
  - Adequate sleep opportunities
  - Manage acute sleep loss
  - Nighttime sleep better quality/quantity



Lombardi, et al 2010

Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive work periods
- Rotation of work periods
- Total work hours
- Work extensions/OT/changes
- Length of off-duty periods
- Protected recovery periods
  - Successive recovery sleep periods
  - Manage chronic sleep loss



Adapted from Belenky, et al 2003

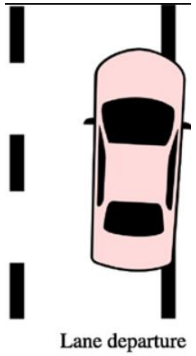
Table 4. Crude and adjusted logistic regression analyses with excessive sleepiness as the dependent variable.

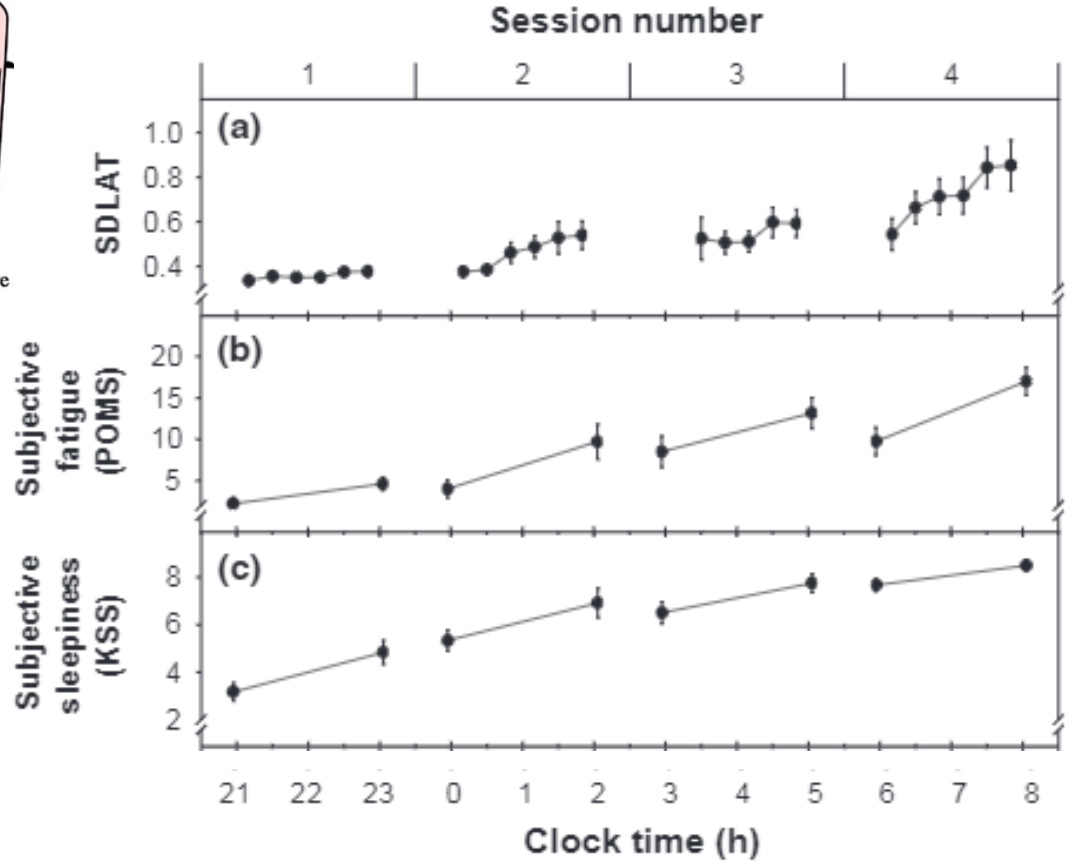
Number of quick returns past year	0	1.00	1.00
	1–30	**1.68 (1.18–2.40)**	**1.53 (1.05–2.23)**
	>30	**1.93 (1.36–2.72)**	**1.78 (1.24–2.57)**

Eldevik, et al 2013

Scheduling Factors

- Length of work periods
- Timing of work periods
- Consecutive work periods
- Rotation of work periods
- Total work hours
- Work extensions/OT/changes
- Length of off-duty periods
- Protected recovery periods
- Combined effects
  - Time on task
  - Hours awake
  - Time of day





Phipps-Nelson, et. al. J Sleep Res 2011

Other Considerations

- Breaks during work periods
  - Shorter, more often provide benefit
  - Manage time on task/workload

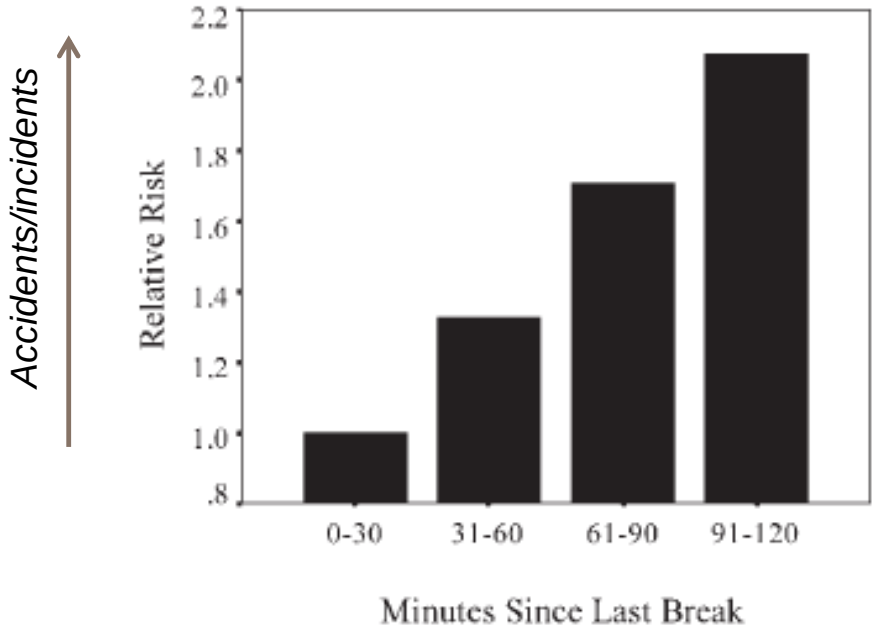


Figure 7. The trend in relative risk between breaks

Folkard & Tucker, 2003

Other Considerations

- Breaks during work periods
- Timing of critical tasks within shift
  - Hours on task, on shift
  - Hours awake
  - Time of day

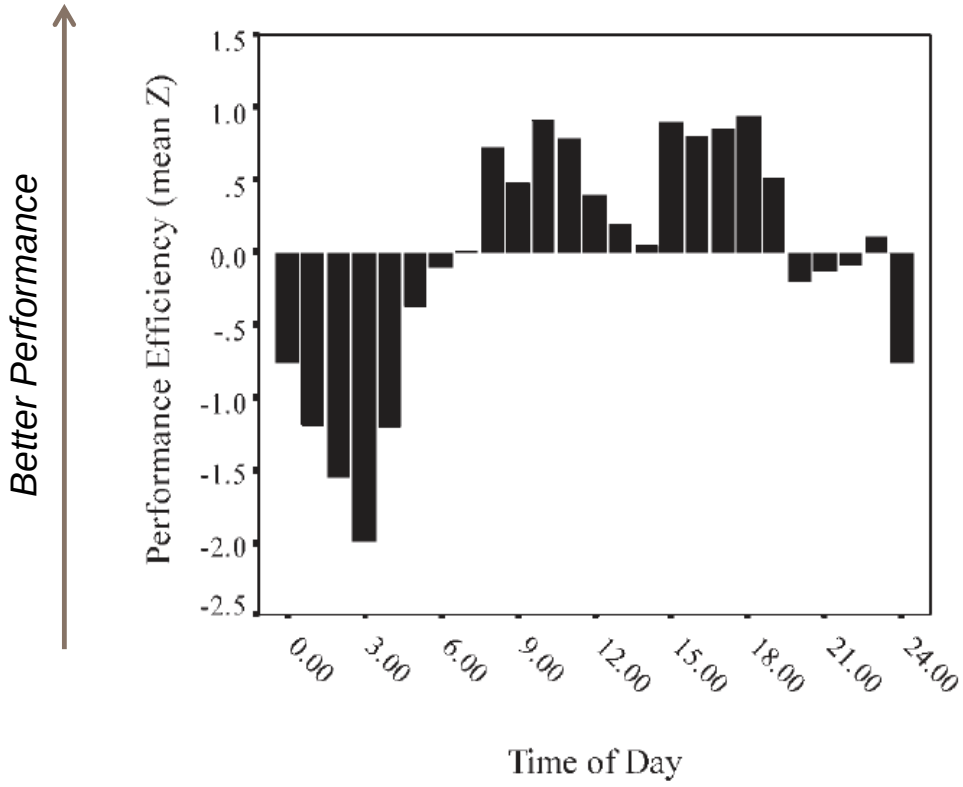
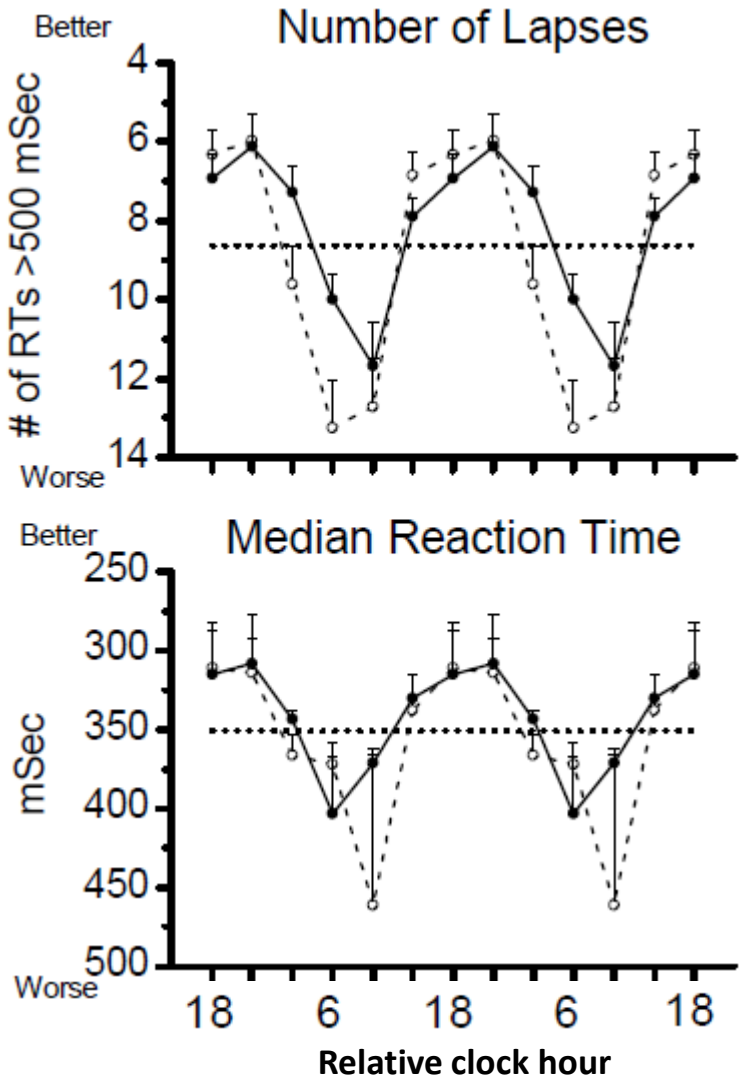


Figure 1. Industrial performance efficiency over the 24 h day.

Folkard & Tucker, 2003

Other Considerations

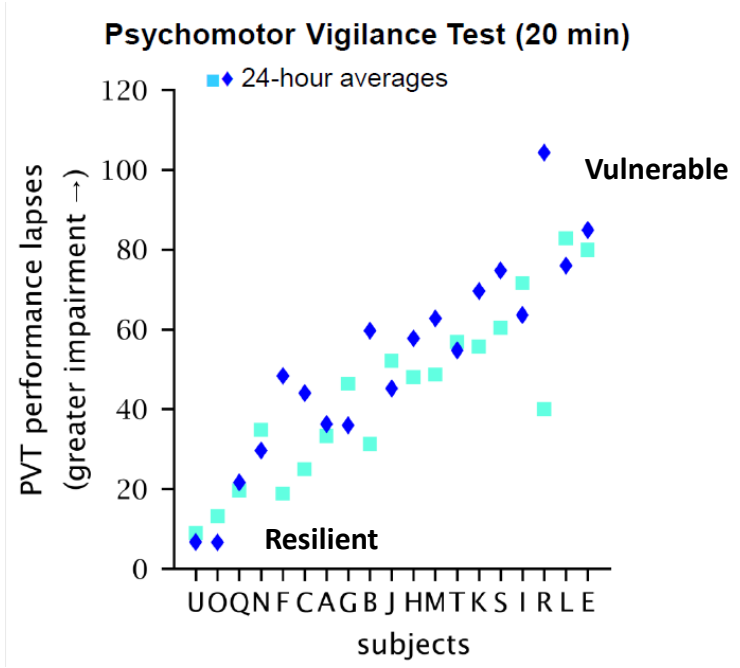
- Breaks during work periods
- Timing of critical tasks within shift
  - Hours on task, on shift
  - Hours awake
  - Time of day

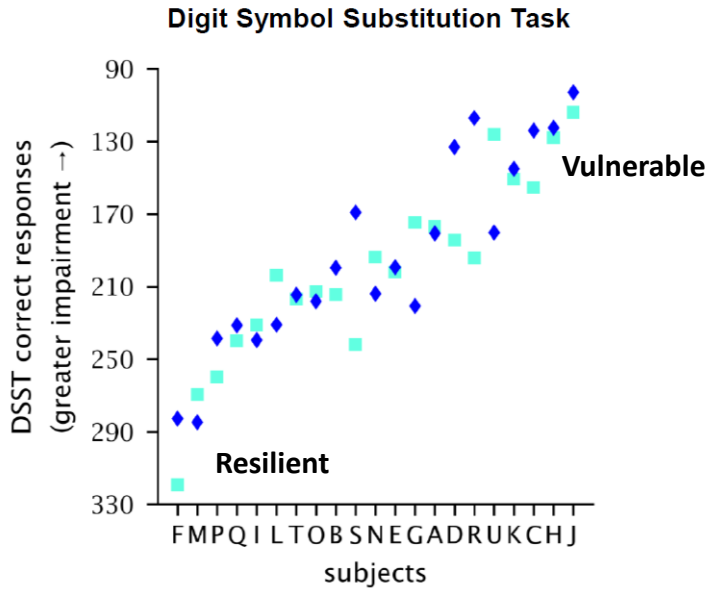


Adapted from Wright, et al, AJPRICP 2002

Other Considerations

- Breaks during work periods
- Timing of critical tasks within shift
- Individual differences
  - Resilience/vulnerability to shiftwork
  - Morning/evening
  - Age, experience





Van Dongen, Sleep 2004

Fatigue Management: NASA NPR 1800.1D

- Employees in critical positions limited to:
  - 12 hours (16 in emergency* situations with approval**)
  - 60 hours/week
  - 7 consecutive days
    - 18 days with pre-approval, then need 2 days off**
  - 240 hours/4-week period
  - 2500 hours/rolling 12-month period

* “Emergency or extremely unusual circumstances can require work performance essentially at endurance capacity…invoked only for life-threatening emergencies, natural disasters, mass casualty accidents, or war” (1800.1D.2.14.3.6)

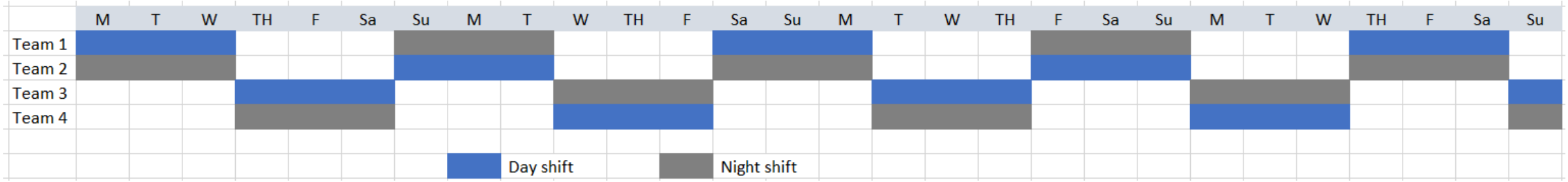
** “pre-approval is required for deviations by a supervisor after consideration of human factors safety issues for the Critical Position” (1800.1D.2.14.3.3.e)

Fatigue Management: NASA NPR 1800.1D

- 12 hour work schedules (1800.1D.2.14.3.11)
  - 2 on/2 off, 3 on/3 off, 4 on/4 off
  - 3 consecutive 12-hr shifts “are optimal”
  - “Working more than 4 consecutive 12-hour shifts is associated with excessive fatigue and strongly discouraged”
- Min allowable time off between shifts = 8 hr
  - 10 hr off duty preferred
  - 12 hr or more “optimal to accommodate employee commute time and domestic and sleep needs” (1800.1.D.2.14.3.9)
- Shift work schedules require additional time off between shifts
  - Allow circadian rhythms time to adapt to changes in timing of work shifts
  - Forward rotating: days > evening > night better for adaptation (1800.1.D.2.14.3.10)

Scheduling Factors	NPR 1800.1D
• Length of work periods	• 12 hr
• Consecutive work periods	• 3 (12-hr)
• Rotation of work periods	• Forward: D > E > N
• Total work hours	• 60 hr/week
• Work extensions/OT/changes	• 16 hr (emergency w/ approval)
• Length of off-duty periods	• 10 hr
• Protected recovery periods	• X on/X off (12 hr)

Fatigue Management: 3 x 12 Schedule



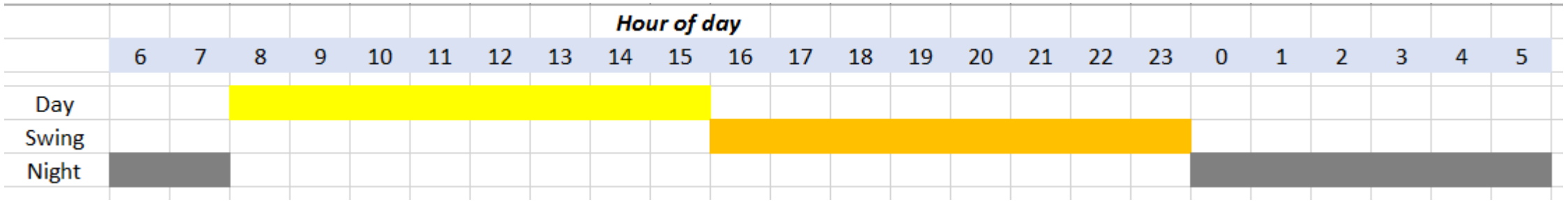
- Day/night 12-hr shifts
- 3 on/3 off
- Max = 48 hr weeks
- Shift timing?
- Pros: regular blocks of days on, days off; 3 night shifts in a row
- Cons: 12-hr night shifts; shift handover time makes for 12+

Fatigue Management: 3 x 8 shift Schedule

	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su
Team 1	D	D	D	D				S	S	S	S				N	N	N	N				D	D	D	D			
Team 2				D	D	D	D				S	S	S	S				N	N	N	N				D	D	D	D
Team 3	N	N	N	N				D	D	D	D				S	S	S	S				N	N	N	N			
Team 4				N	N	N	N				D	D	D	D				S	S	S	S				N	N	N	N
Team 5	S	S	S	S				N	N	N	N				D	D	D	D				S	S	S	S			
Team 6				S	S	S	S				N	N	N	N				D	D	D	D				S	S	S	S

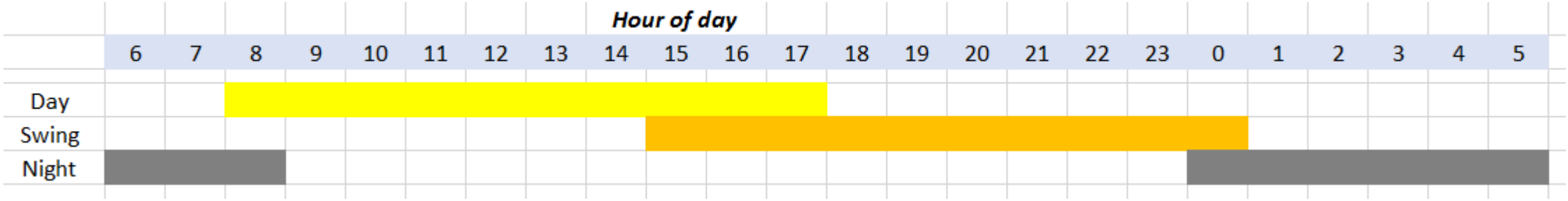
- 4 on/3 off pattern
- All teams overlap schedules one day a week
- 36-hr work weeks (w/ 8.5-hr shifts)
- Pros: Shift length; opportunity for staff/project meetings on overlap days
- Cons: 4 nights in a row; 4 nights in a row followed by 3 days off; some teams work weekends, some don’t

Fatigue Management: 3 x 8 shift Schedule



- 3 x 8-hr shifts
- Shift handover time would make for 8.5 hr shift (0745-1615, etc)
- Pros: Shorter shifts than 12 or 10; day shift timing; shift handover time accounted for
- Cons: May need more personnel to staff 3 shifts

Fatigue Management: 3 shift Timing



- Day/swing 10-hr shifts, 9-hr night shift
- Pros: Day shift timing, night sleep opportunity following swing, shorter night shift, shift handover time accounted for
- Cons: May need more personnel to staff 3 shifts; commute following swing shift may touch into night circadian low

Fatigue Management: 3 shift Schedule + 1 off

	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su	M	T	W	TH	F	Sa	Su
Team 1	D	D	D					S	S	S					N	N	N					D	D	D	D				S	S	S	S				N	N	N	N			
Team 2				D	D	D	D				S	S	S	S				N	N	N	N					D	D	D					S	S	S					N	N	N
Team 3	N	N	N					D	D	D	D				S	S	S					N	N	N	N				D	D	D					S	S	S	S				
Team 4				N	N	N	N					D	D	D				S	S	S	S					N	N	N				D	D	D	D					S	S	S
Team 5	S	S	S					N	N	N	N				D	D	D					S	S	S	S				N	N	N					D	D	D	D				
Team 6				S	S	S	S					N	N	N				D	D	D	D					S	S	S				N	N	N	N					D	D	D

- 4 on/3 off alternates w/ 3 on/4 off
- No overlap days
- Max = 40-hr work weeks (36 hrs for nights week)
- Pros: Shorter shifts than 12-hr; regular blocks of 4 days off
- Cons: 4 nights in a row; 4 nights in a row followed by 3 days off; 4 night shifts occur less often

Fatigue Management

- Fatigue Risk Management System (FRMS)

"*A **data-driven** means of **continuously monitoring** and managing fatigue-related safety risks, based upon **scientific principles** and knowledge as well as **operational experience** that aims to ensure relevant personnel are performing at **adequate levels of alertness***" ICAO, 2011

- Pioneered in aviation
- Relevant to any 24/7 safety-critical operations
- No one-size-fits-all

Fatigue Management: Best Practices

- Provide education to workforce and managers
  - Raise awareness
  - Provide understanding of underlying physiology
  - Drowsy driving cautions
  - Present effective strategies and countermeasures for use
- Scheduling practices that minimize fatigue risks
  - Limit hours awake, provide maximum rest opportunities
- Considerations for extensions/exceptions
  - Provide compensatory rest periods
- Being proactive
- Assessment and monitoring
- Shared responsibility

Fatigue Management: Considerations

- Provide time for adequate shift handovers
  - If 12-hr shifts used, 12.5 hr shift time may be necessary
- Provide opportunities for regular breaks
- Ensure food availability for all shifts/workers
- Be proactive in ensuring workers are able to get home safely

Fatigue Management: Considerations

- Recognize that workers commitment to getting job done and time pressures will be stressful = common cause of insomnia
- Look for fatigue/sleep loss as potential factor in mishap investigations
- Managers should ‘walk the walk’ in managing fatigue

Fatigue Management: Wrap Up

- Any shift scheduling practice has strengths and weaknesses
  - Length of work and rest periods
  - Consecutive night shifts that are needed
  - How often to rotate shifts?
- 3 shifts/8 hours
  - Provides limit on work hours and potential for extended wake hours
  - Forward rotation from day -> swing -> night recommended
  - Compensatory time off between shift changes advised for adaptation
- 12-hour shifts
  - Limit to 3-on/3-off
  - Consider additional breaks and monitoring

The ‘Right Stuff’ ≠ Fatigue Management

Managers at Risk: The Human Factors of Launch Pressures

on engineering judgments. However, other factors may have impeded or prevented effective communication and exchange of information.

One factor which may have contributed significantly to the atmosphere of the teleconference at Marshall is the effect on managers of several days of irregular working hours and insufficient sleep.

The extent of sleep loss was documented by Commission investigators who conducted interviews with the teleconference participants at Marshall and Kennedy specifically to reconstruct their daily activities during the five days preceding the accident. As shown in Figure 2, these interviews revealed that because of the launch scrub on January 27 certain key managers obtained only minimal sleep the night before the teleconference or had arisen so early in the morning that they had been awake and on duty for extended periods. [25]

The willingness of NASA employees in general to work excessive hours, while admirable, raises serious questions when it jeopardises job performance, particularly when critical management decisions are at stake.

– Report of the Presidential Commission on the Space Shuttle *Challenger* Accident, July 1986 [1].

Report of the Presidential Commission on the Space Shuttle Challenger Accident – Volume 2: Appendix G

Thank you!

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https://hsi.arc.nasa.gov/groups/fatigue/