



NERC's Third Annual Conference  
Improving Human Performance on the Grid

# Fatigue and Human Performance

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Cheryl MacKenzie, Investigator Team Lead

Questions or Feedback? Want a copy of the slides?  
Email: [cheryl.mackenzie@csb.gov](mailto:cheryl.mackenzie@csb.gov)



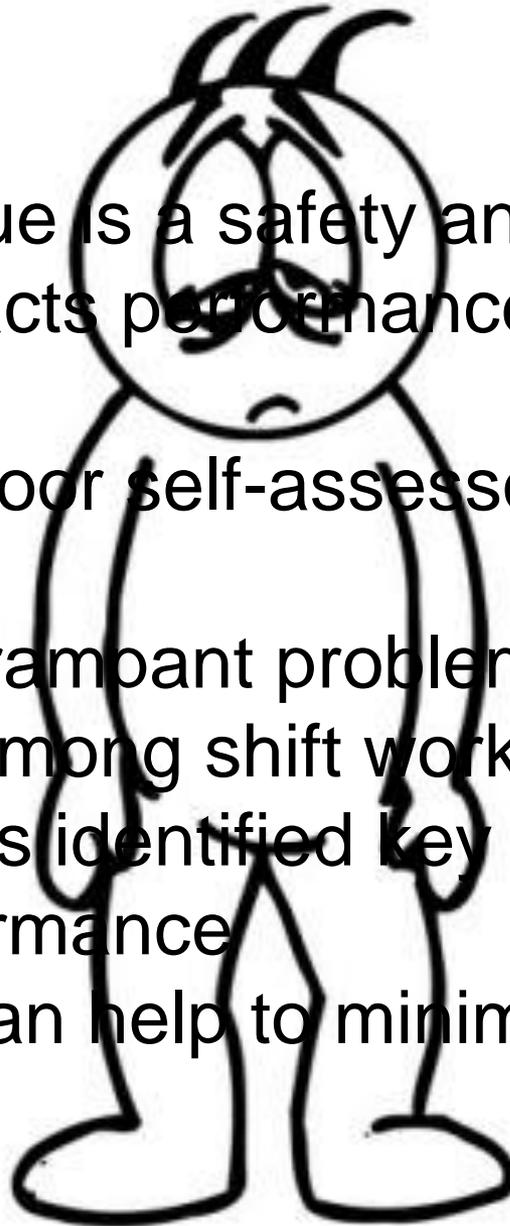
# The U.S. Chemical Safety Board

- Independent federal agency with a presidential appointed Board
  - Investigates chemical accidents to determine root causes
  - Makes recommendations for safety change to industry and federal, state, and local regulators
  - Conducts safety studies on specific hazards
  - Advocates and conducts outreach to share lessons learned
-



## Key Points

1. Human fatigue is a safety and reliability issue
2. Fatigue impacts performance capabilities and health
3. People are poor self-assessors of how fatigued they are
4. Fatigue is a rampant problem in the US, particularly among shift workers
5. Research has identified key fatigue factors that impact performance
6. Individuals can help to minimize the impact of fatigue





# Fatigue Defined

- A feeling of tiredness and being unable to perform work effectively (UK HSE)
- A decreased capacity to perform mental or physical work (Queensland Government)
- A biological drive for recuperative rest (Williamson et al., 2001)



“Fatigue can degrade every aspect of human capability.”

-Mark Rosekind, Board Member, National  
Transportation Safety Board

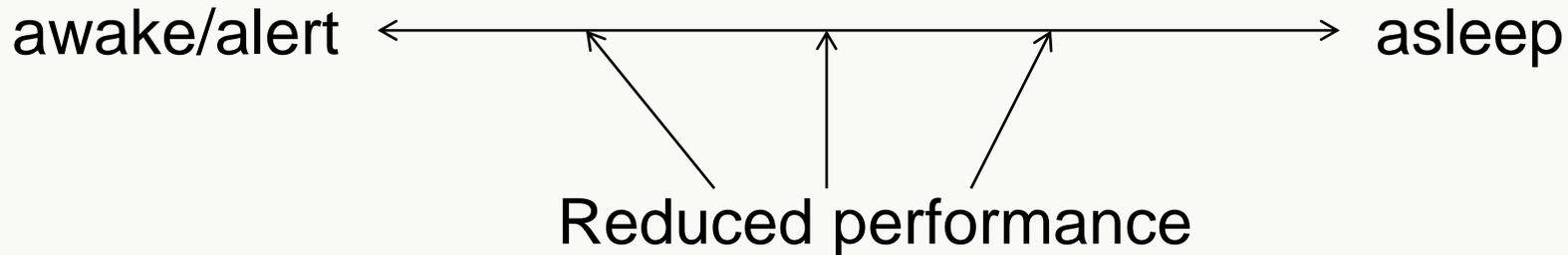


Artist: Robert Weber

*"It's just exhaustion, sweetie. Everybody's got it."*



# Variable Performance as Fatigue Increases



*Source: NTSB, Mark R. Rosekind, PhD, Member,  
presentation to Aviation Safety Coordinators Conference,  
Ashburn, VA, July 24, 2013*







Newark Star-Ledger / Aristide Economopoulos



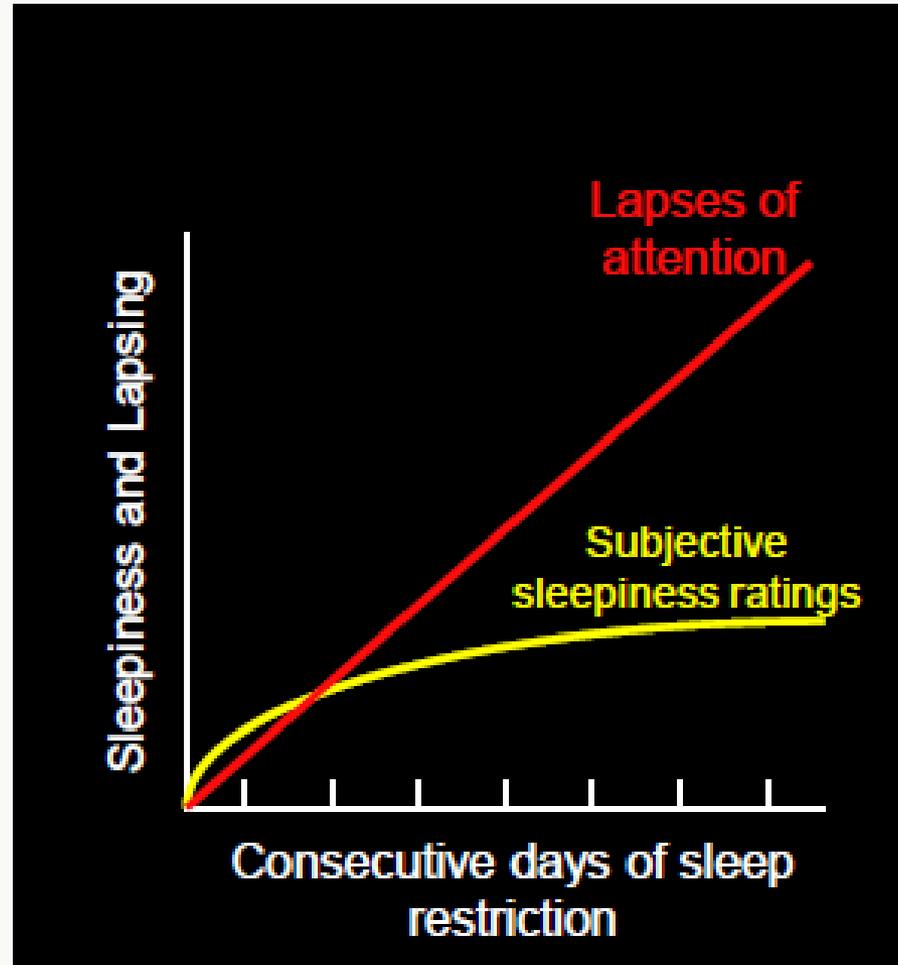




# Fatigue – Poor Self-Assessors

Individuals are poor judges of their own fatigue impairment

Impaired judgment increases as sleep loss increases



DF Dinges, 'Sleep, Sleep Disorders, and Circadian Rhythms,'  
presentation, NTSB Training Course, 28 Sept 2010

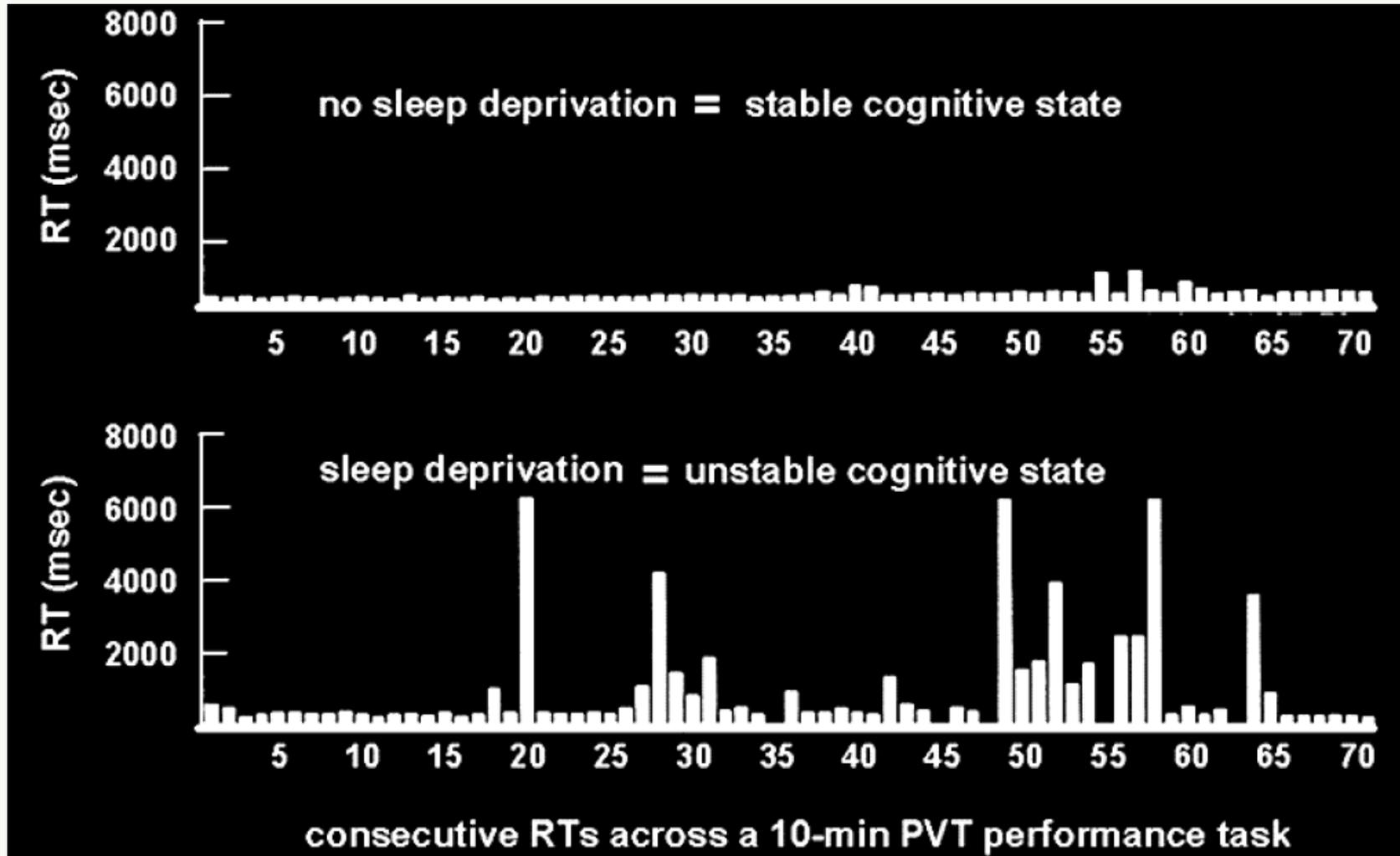


“People have difficulty believing that humans can make a fatigue-related error while performing an over-learned task under highly-motivated (even life-threatening) conditions. But it happens because fatigue is a risk state that degrades behavioral efficiency.”

-Dr. David Dinges, University of  
Pennsylvania School of Medicine  
'Alertness and Performance' presentation  
NTSB Training Course, 28 Sept 2010



# Fatigue – Impacts Cognition



Doran, et al., 2001, as cited by NTSB, Rosekind, 24 July 2013



# Fatigue – Akin to Alcohol Impairment

- You wouldn't consider it safe to work while intoxicated, right?
- Relatively moderate levels of fatigue impair performance *equal or greater than* what is currently acceptable for alcohol intoxication (Dawson, Reid, 1997)
  - Subjects kept awake for 28 hours, OR consumed 10-15 g of alcohol every 30 min until mean blood alcohol concentration reached 0.10%
  - Hand-eye coordination tested
  - Performance decreased significantly in both conditions



# Health and Performance Effects

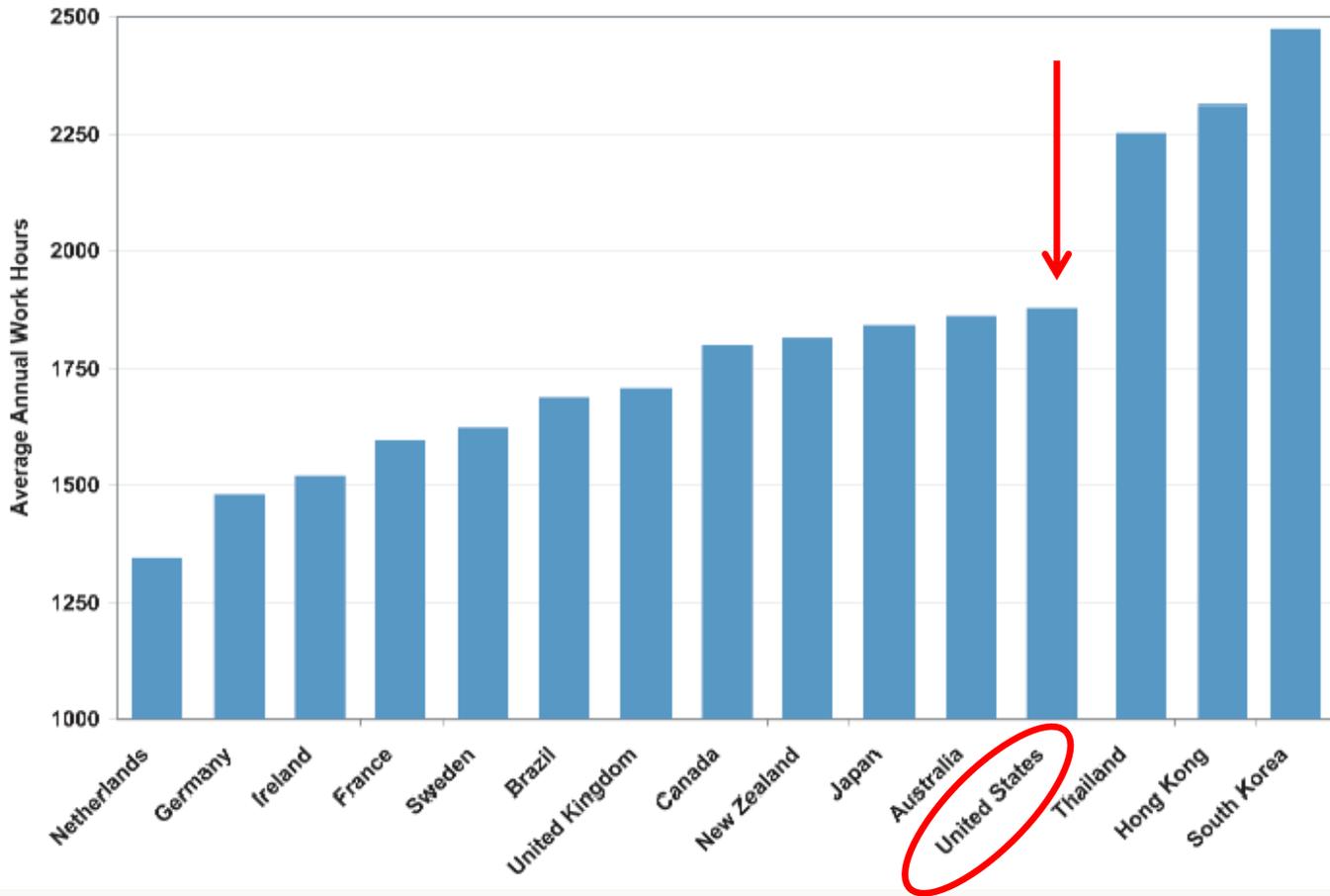
Short-term Impacts	Long-term Health Effects
Impaired judgment, decision-making, and problem-solving	High blood pressure
Slowed reaction time	Anxiety
Lapses in memory, recall, and attention	Gastrointestinal problems
Difficulty concentrating, communicating, and controlling emotions	Increased risk of: <ul style="list-style-type: none"><li>- Depression</li><li>- Obesity</li><li>- Diabetes</li></ul>
	[Sources: HSE, NTSB, others]

Higher incidence of sick leave among shift workers, especially those on rotating shifts

(Occupational Safety and Health Service New Zealand, 1998)



# US is 4<sup>th</sup> in hours worked per year

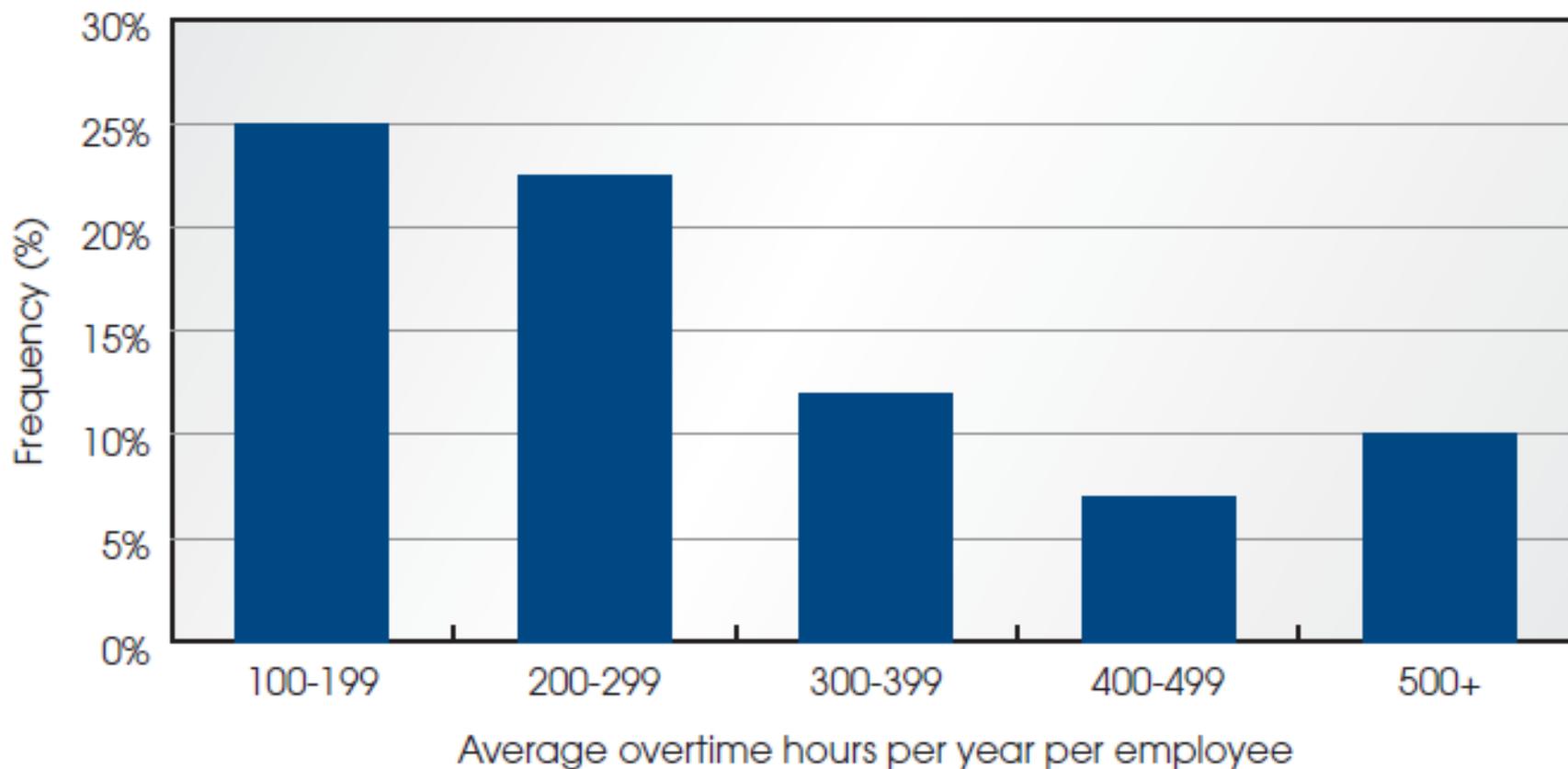


Average Annual Work Hours by Country  
 (International Labour Office, 2003, as cited in NIOSH 2004)



# Employee Overtime Hours

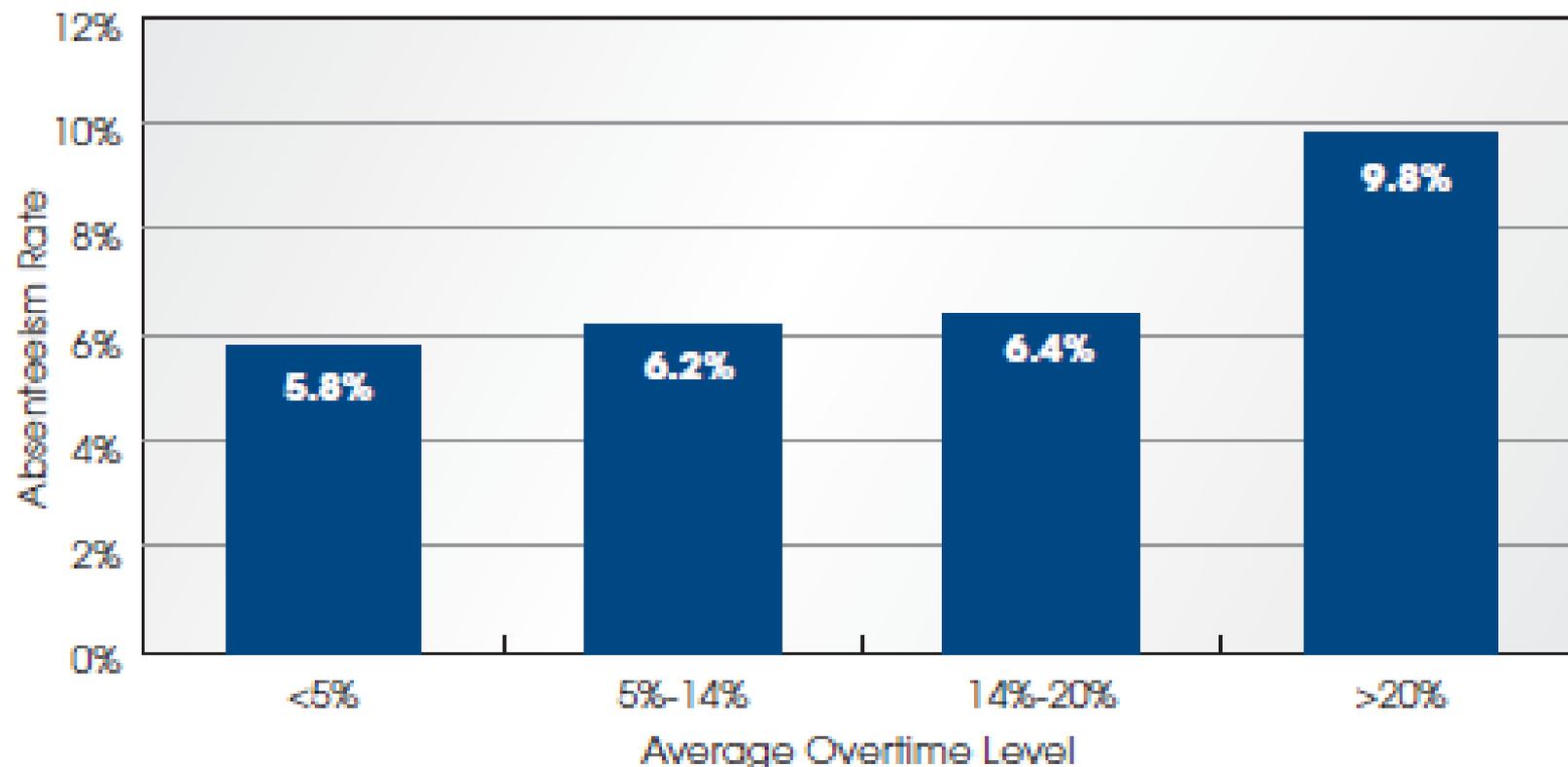
Average employee hours of overtime per year in North American shiftwork operations.



(Kerin, 2003, as cited in Sirois & Moore-Ede, 2013)



# How Overtime Affects Absenteeism



Interrelationship between the absenteeism rate and overtime percentage. (Source: Aguirre & Moore-Ede, "Shiftwork Practices", 2007).

(Cited in Sirois & Moore-Ede, 2013)



# Fatigue and Shift Work

- Risk of injury is 30% higher on night shift compared with morning, risk is highest in the first few hours, and risk increases over consecutive night shifts so that the 4<sup>th</sup> night shift is 36% higher risk than 1<sup>st</sup> (Hobson, 2004)
- 60-70% of shift workers will report difficulty with sleep, sleepiness on the job, or actually falling asleep unintentionally while at work (Rosekind, 2005)
- Fatigue has been estimated to be the key factor in as many as 41% of accidental injuries and deaths caused by human error (Sallinen, 1997)

(All cited in Energy Institute, 2006)



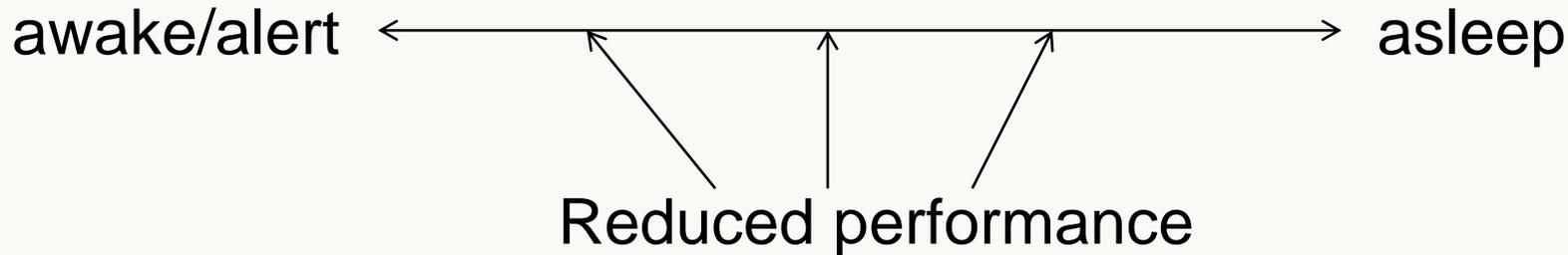
# Comparison of Hours of Sleep to Injury Rates

	Estimated Annualized Injury Rates/100 Workers						
Hours of sleep	<5	5–5.9	6–6.9	7–7.9	8–8.9	9–9.9	<10
Injury rates	7.89	5.21	3.62	2.27	2.50	2.22	4.72

(Lerman, S. et al., 2012, “Fatigue Risk Management in the Workplace,” JOEM, adapted from Lombardi, et al., 2010)



# Factors Affecting Performance



What are the factors that adversely affect performance and alertness?



# Fatigue Factors Affecting Performance

- Physically or mentally demanding work



# Fatigue Factors Affecting Performance

- Physically or mentally demanding work
- Prolonged period awake (>16 hours)
- Inadequate time for sleep (<7 hours TIB)

## Acute Sleep Loss



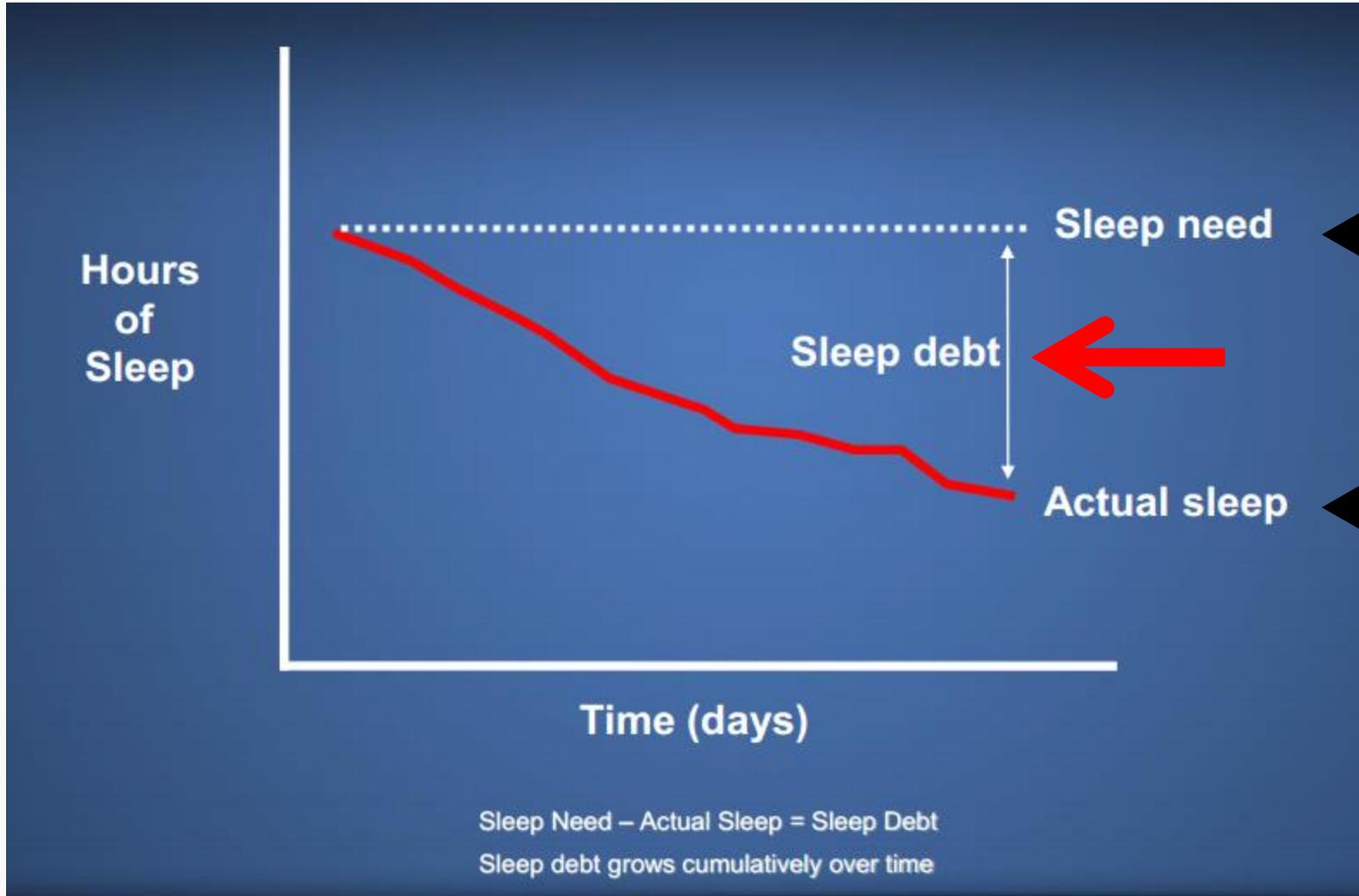
# Fatigue Factors Affecting Performance

- Physically or mentally demanding work
- Prolonged period awake (>16 hours)
- Inadequate time for sleep (<7 hours TIB)
- Inadequate sleep over consecutive 24-hour periods

## Cumulative Sleep Debt



# Cumulative Sleep Debt

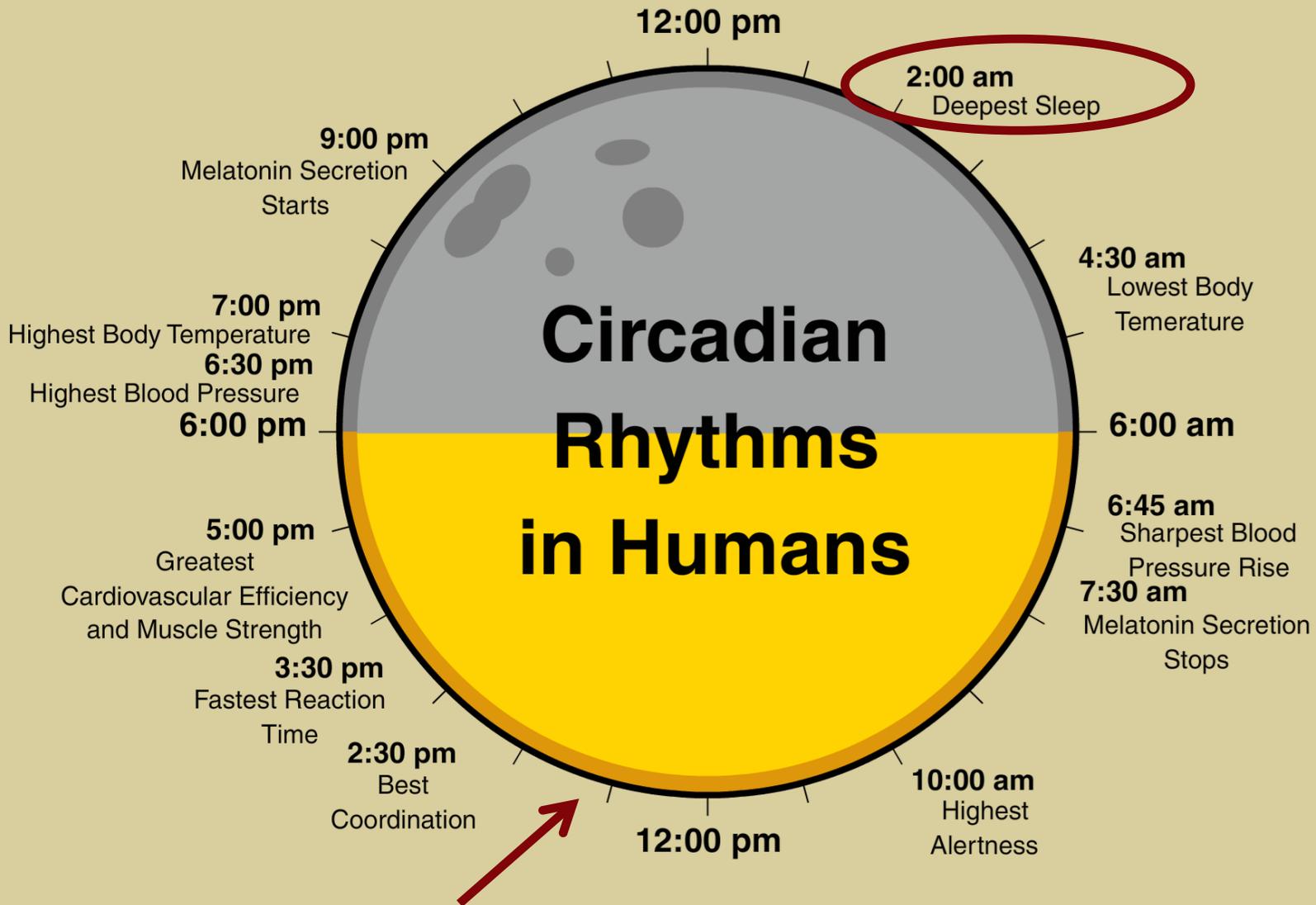


(Rosekind, M., NTSB, Harvard Sleep and Shift Work Symposium, 9/27/12)



# Fatigue Factors Affecting Performance

- Physically or mentally demanding work
- Prolonged period awake (>16 hours)
- Inadequate time for sleep (<7 hours TIB)
- Inadequate sleep over consecutive 24-hour periods
- Active at (and around) an adverse circadian phase
  - The biological clock and circadian rhythm





# Fatigue Factors Affecting Performance

## Circadian Rhythm Research

- Injuries increase from morning to afternoon, then from afternoon to night shift
- Accidents increase as the number of consecutive night shifts increase
- Shift work requires that the individual try to override the basic circadian pattern of sleeping at night and being awake during the day
- Body clock is receiving conflicting time cues and doesn't ever fully adjust



# Fatigue Factors Affecting Performance

- Physically or mentally demanding work
- Prolonged period awake (>16 hours)
- Inadequate time for sleep (<7 hours TIB)
- Active at (and around) an adverse circadian phase
- Medical conditions and drugs/medication
  - There are over 90 known sleep disorders (e.g. sleep apnea)



# Fatigue Factors Affecting Performance

- Physically or mentally demanding work
- Prolonged period awake (>16 hours)
- Inadequate time for sleep (<7 hours TIB)
- Active at (and around) an adverse circadian phase
- Drugs/medication and medical conditions
- Critical moderating factors in the work environment
  - Heat, lighting, etc.



# Importance of Fatigue Management in the Workplace

- Improved health and safety
- Reductions in absenteeism and staff turnover
- Improved performance and productivity
- Reductions in accidents and injuries



# Contributors of Fatigue in the Workplace

- Work schedule
- Working time and duration
- Frequency or lack of work breaks
- Workload and staffing
- Environmental conditions
- Individual conditions



# Fatigue and Performance Effects

- Good sleep hygiene
- Presleep routine
- Relaxation techniques
- Effective use of caffeine & exercise
- Napping
- Sleep disorder screening/ treatment



Fatigue makes fools of us all. It robs you of your skills and your judgment, and it blinds you to creative solutions. It's the best-conditioned athlete, not the most talented, who generally wins when the going gets tough.

**Harvey Mackay**

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