Machine Learning to Predict and Prevent Fatigue-Related Accidents in Mining

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17 April 2024

FATIGUE
SCIENCE

FATIGUE
SCIENCE

Green Cross
Safety Innovation Award Winner
an nsc award

30
TIA 2023 TECHNOLOGY IMPACT AWARDS
Celebrating 30 years of BC Innovation

Growth Company of the Year
2023 WINNER

25K
workers protected daily

5M+
shift worker sleeps analyzed

21%
typical first-year reduction in fatigue

-13%
est. reduction in Lost-Time Incidents

Solving Fatigue is a "Win-Win" Opportunity

Safety

65% **of haul truck accidents**
in surface mining are attributable to fatigue

2007 study Caterpillar Global Mining

14x **Microsleeps**
Per duty hour, when operating fatigued impaired

Fatigue impairment indicated by operator's ReadiScore < 70, compared with >85. 2020 Fatigue Science study using Guardvant cameras and wearables producing ReadiScore, n= 254 haul truck drivers and 131,027 hours

Productivity

3.2% **Slower Dig Rate**
when operating fatigued impaired

Fatigue impairment indicated by operator's ReadiScore < 70, compared with >85. 2020 Fatigue Science study using haul truck telematics and wearables producing ReadiScore, n = 21 shovel operators and 3,181 duty hours

3.3% **Spot Time Efficiency**
When operating fatigued impaired

Fatigue impairment indicated by operator's ReadiScore < 70, compared with >85. 2020 Fatigue Science study using haul truck telematics and wearables producing ReadiScore, n = 262 haul truck drivers and 38,494 drive hours

What exactly is fatigue?

How does it relate to employee wellness?
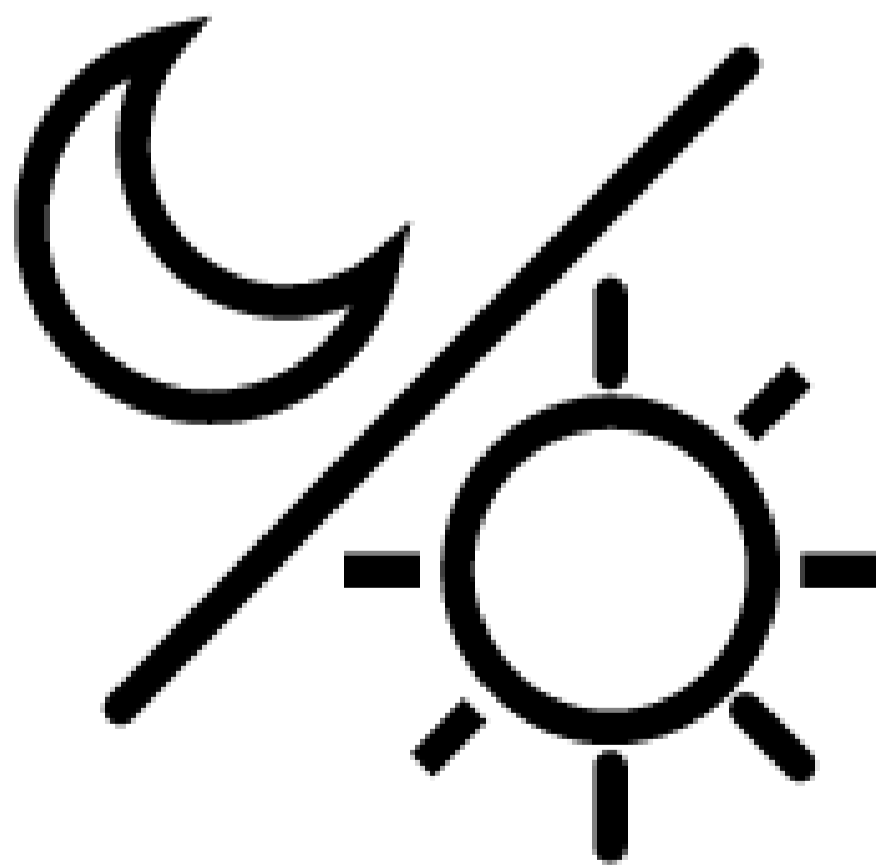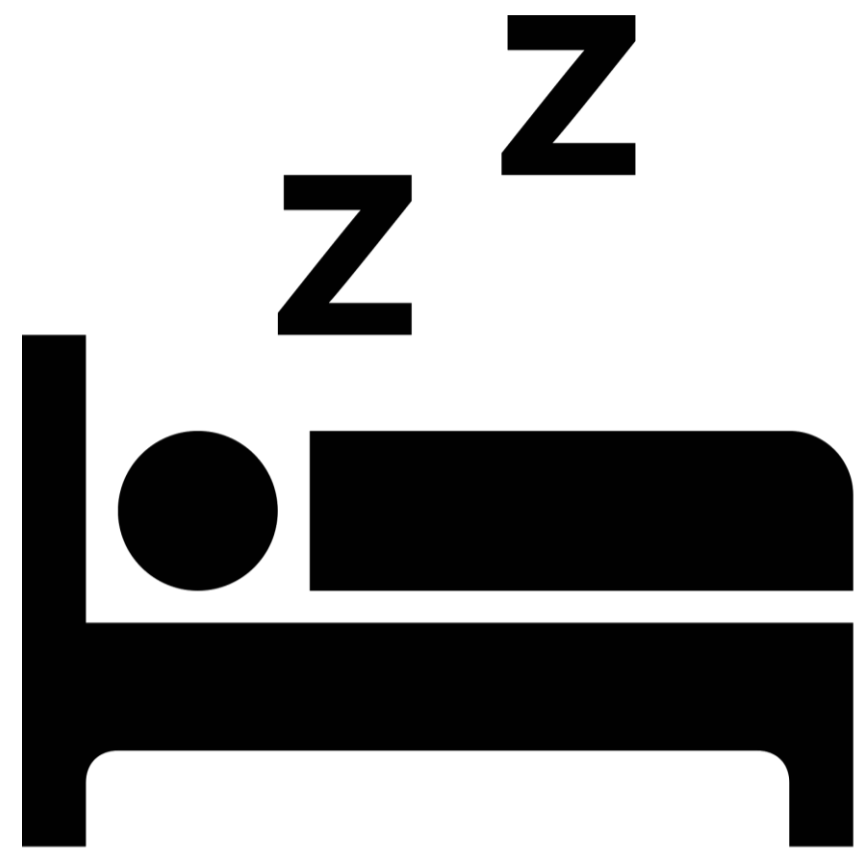
Fatigue is a physiological condition that we all face when confronted with a **lack of sleep** or wakefulness outside of **normal daylight hours.**
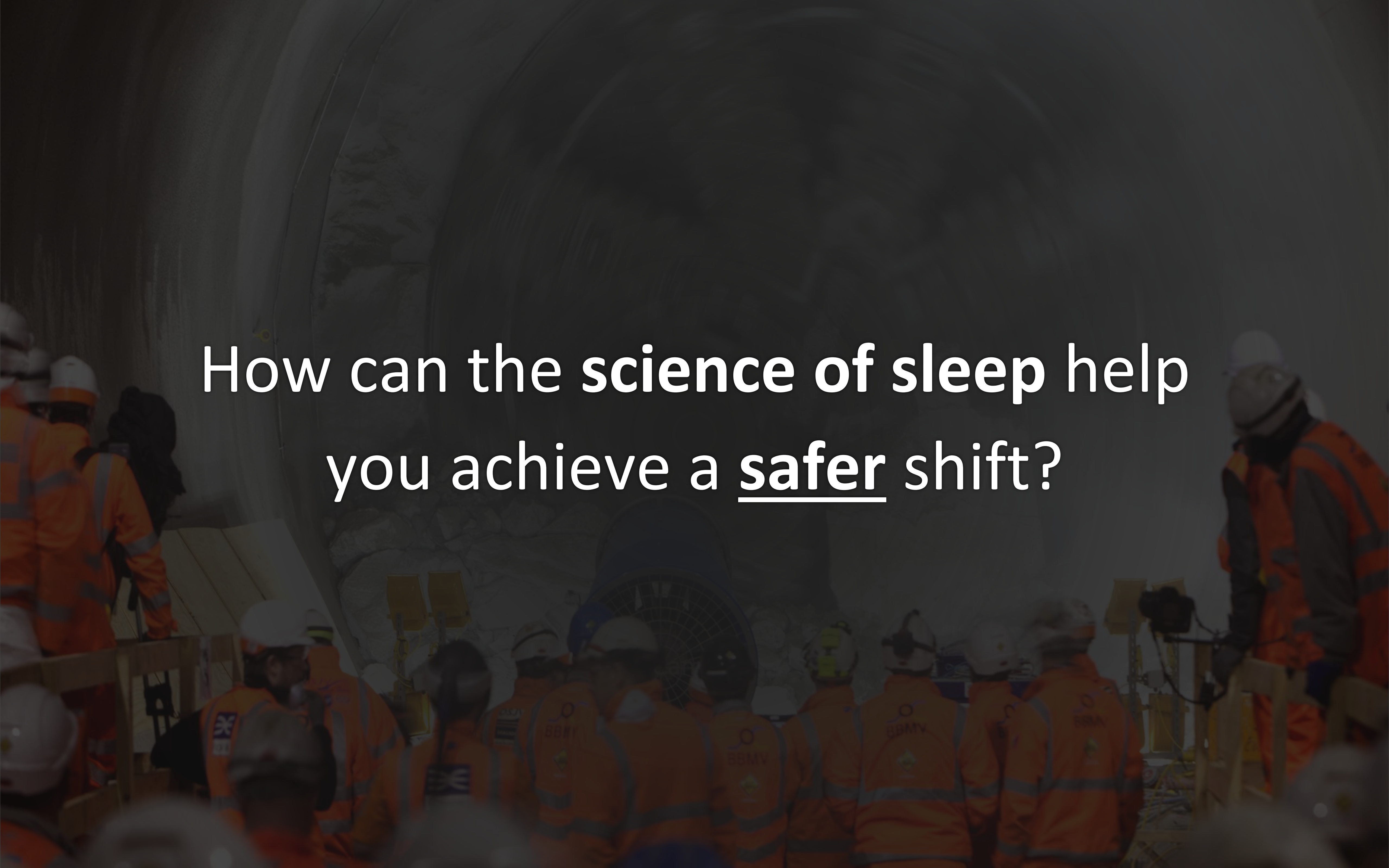
Fatigue hinders the **brain's ability to interact** with the body.

Physiologically, it has similar effects as **alcohol.**

US Department of Transportation, Analysis of the Relationship between Operator Effectiveness Measures and Economic Impacts of Rail Accidents, May 2011
Fatigue Models for Applied Research in Warfighting, Hursh SR, et al., Aviat Space Environ Med 2004

Fatigue's wide range of effects

EMOTIONAL	COGNITIVE	SOMATIC
Increased irritability	Reduced concentration	Loss of reaction time
Mood fluctuations	Reduced communication	Metabolic abnormalities
Increased anxiety	Reduced attention	Bodily sensations of pain or cold
Depressed mood	Reduced multitasking	Risk of cardiovascular disease
Increased frustration	Reduced recall of events	Risk of cancer
Bouts of anger	Decreased memory	Microsleeps
Increased impulsivity	Reduced socialization	Weight gain
Increased stimulant use	Reduced creativity	Risk of diabetes
Alcohol use / misuse	Reduced decision-making	Reduced immunity
	Reduced performance	

How can the **science of sleep** help you achieve a <u>safer</u> shift?

The US Army Research Lab spent
over 25 years researching this question.

SAFTE™ Fatigue Model

Exclusive to Fatigue Science

25

YEARS OF RESEARCH
AND DEVELOPMENT

$37M

ESTIMATED
DEVELOPMENT COST

Their research found that sleep's impact on fatigue is **<u>cumulative</u>** – and more complex than it may seem.
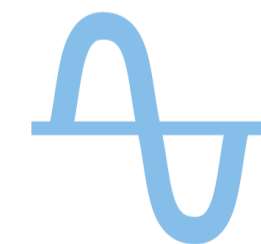
Quantity of Sleep

Quality of Sleep

Consistency in Timing

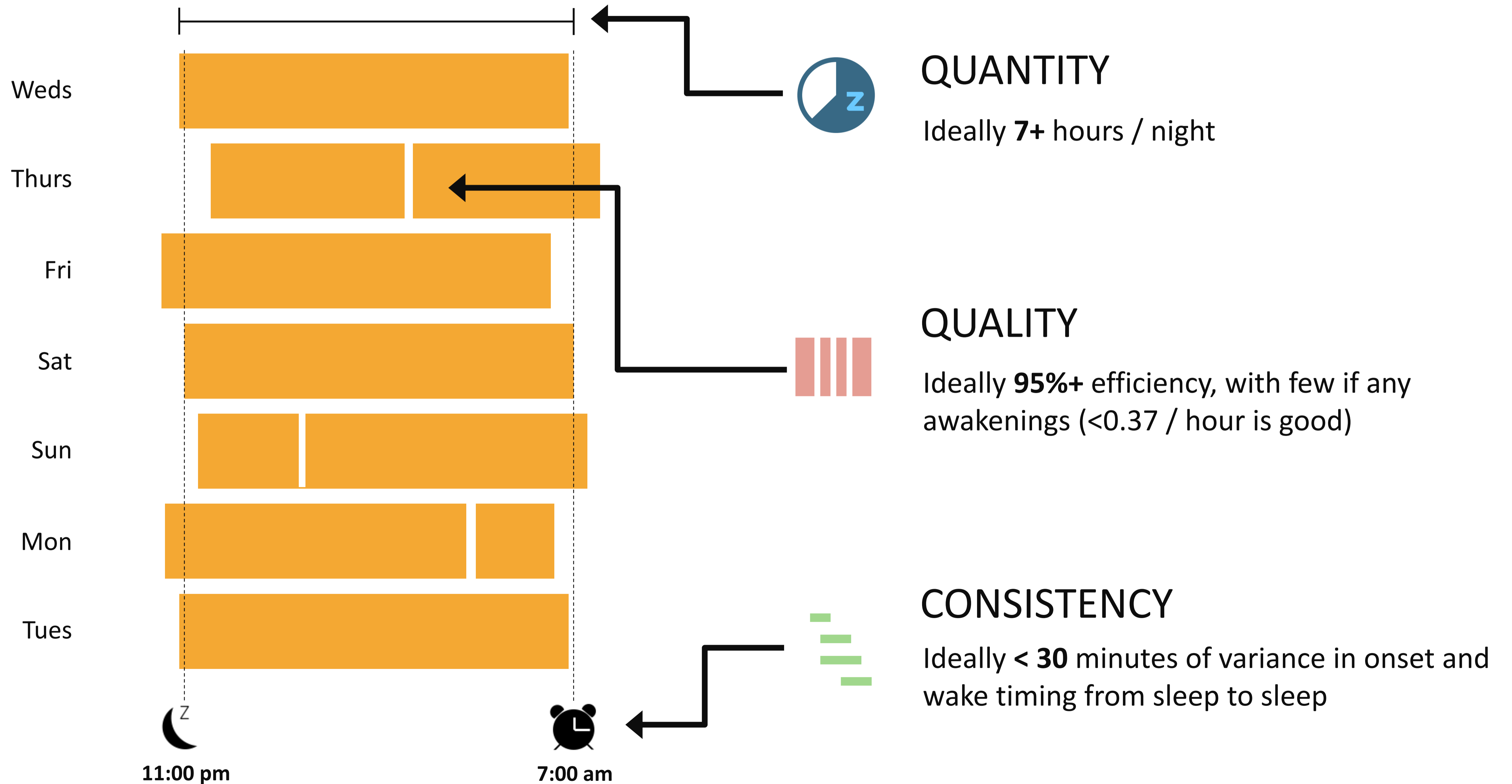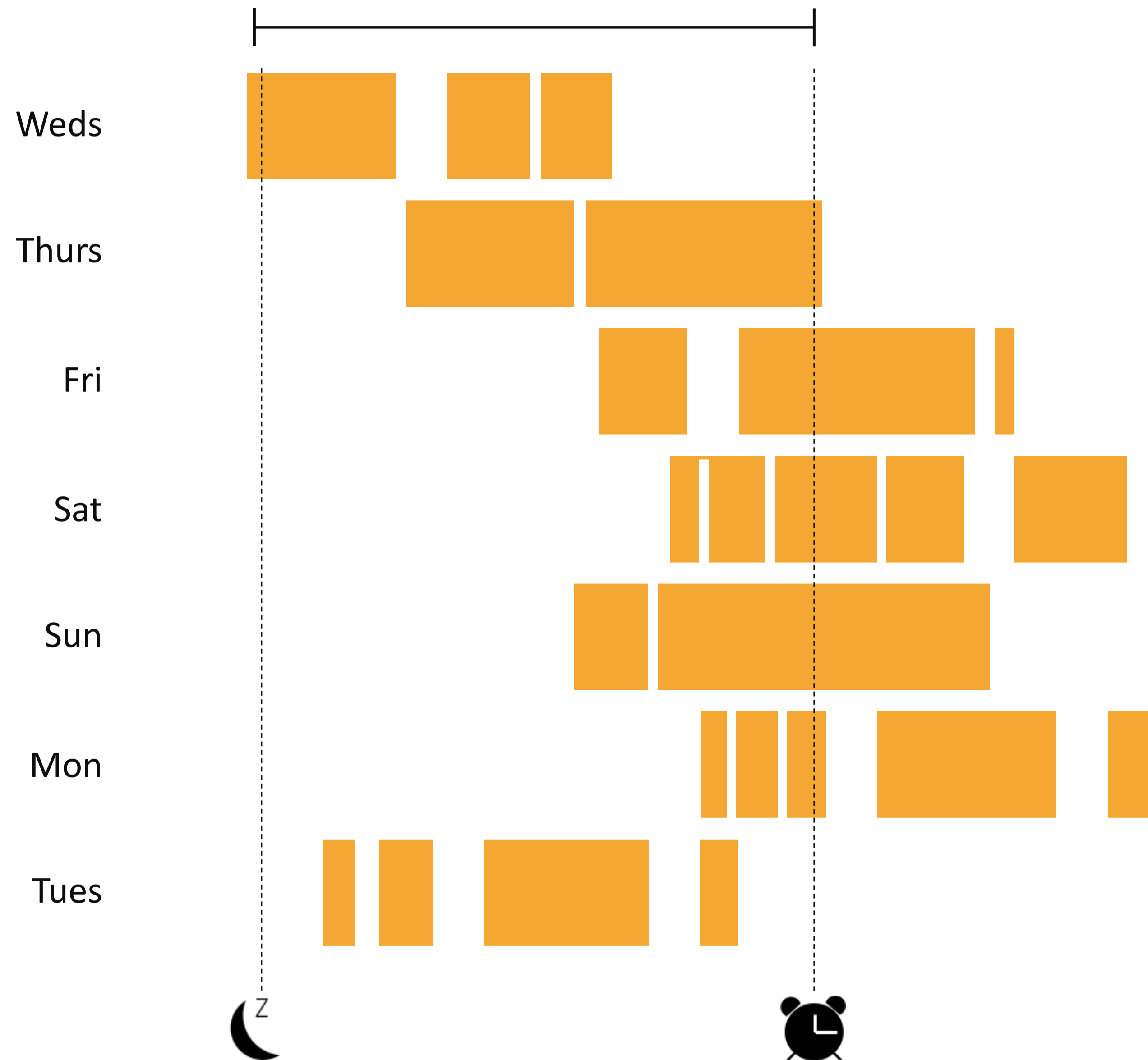Cumulative Sleep Debt

Time of Day

Circadian Rhythm

"Ideal sleep" is **hard to come by.**

QUANTITY

Ideally **7+** hours / night

QUALITY

Ideally **95%+** efficiency, with few if any awakenings (<0.37 / hour is good)

CONSISTENCY

Ideally **< 30** minutes of variance in onset and wake timing from sleep to sleep

Weds
Thurs
Fri
Sat
Sun
Mon
Tues

11:00 pm
7:00 am

A **more realistic** picture for shift workers.

- Limited Sleep Opportunity

- Highly Variable Sleep Schedule
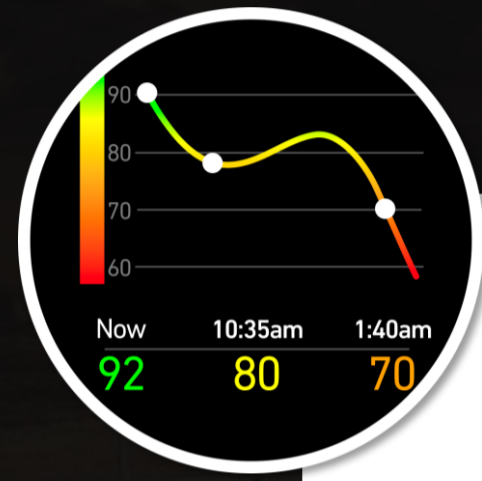
- Many More Awakenings

Weds
Thurs
Fri
Sat
Sun
Mon
Tues
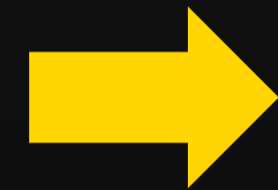
Readi /

Sleep Data → **Fatigue Model** → Readi / Score™
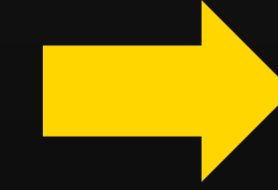
Readi /Score™

Validated, Personalized Prediction of Fatigue Risk

Now 10:35am 1:40am
92 80 70

ReadiScore	Cogn. Effectiveness	Reaction Time	Lapse Index		Dig Rate	Spot Time	Microsleeps	Accident Cost	Harsh Braking	Speeding
100	-0%	+0%	1.0x							
90	-10%	+11%	1.5x		+3.2%	-3.3%				
80	-20%	+30%	3.7x							
70	-30%	+43%	5.2x							
60	-40%	+67%	8.0x				+14x	+5x		
50	-50%								+4x	+8x

Lowest Risk, Highest Performance

Fatigue Risk

Lab Validation
13 Published Papers

Real-World Industrial Data
Telematics, In-Cab Video, Recorded Incidents
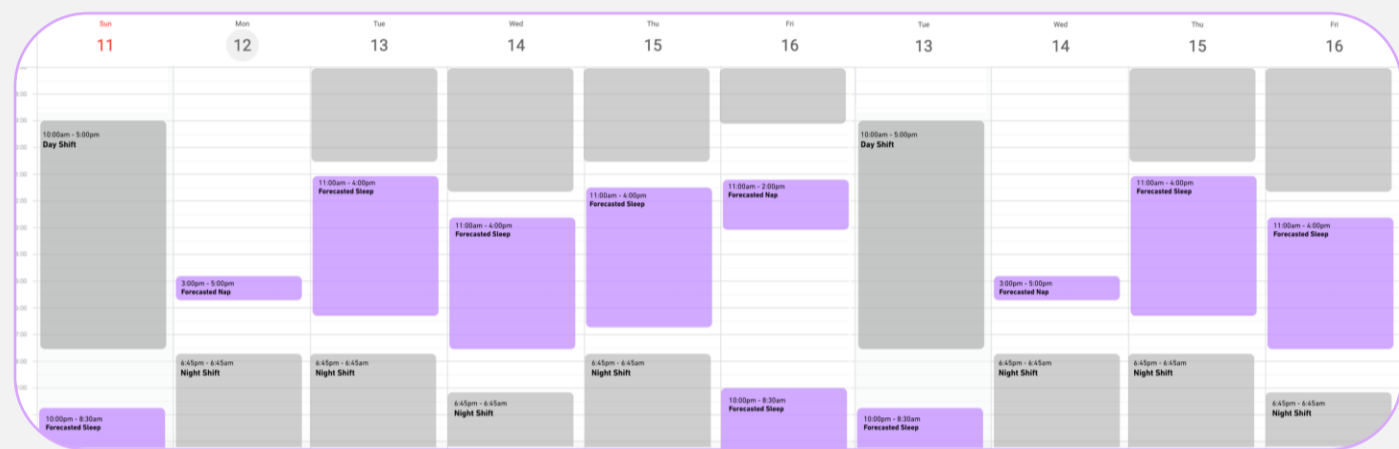
What does a typical **pattern of fatigue** look like for a shift worker?

Readi flags critically fatigued operators based on a personalized **hour-by-hour prediction** of their fatigue risk.

SHIFT
START

⚠️ High fatigue risk around 12:00am

SHIFT
END

ReadiScore

100

90

80

70

60

90
4pm

92
5pm

93
6pm

92
7pm

90
8pm

87
9pm

82
10pm

77
11pm

72
12am

⚠️

67
1am

63
2am

61

61

62

63
6am

64
7am

65
8am

66
9am

65
10am
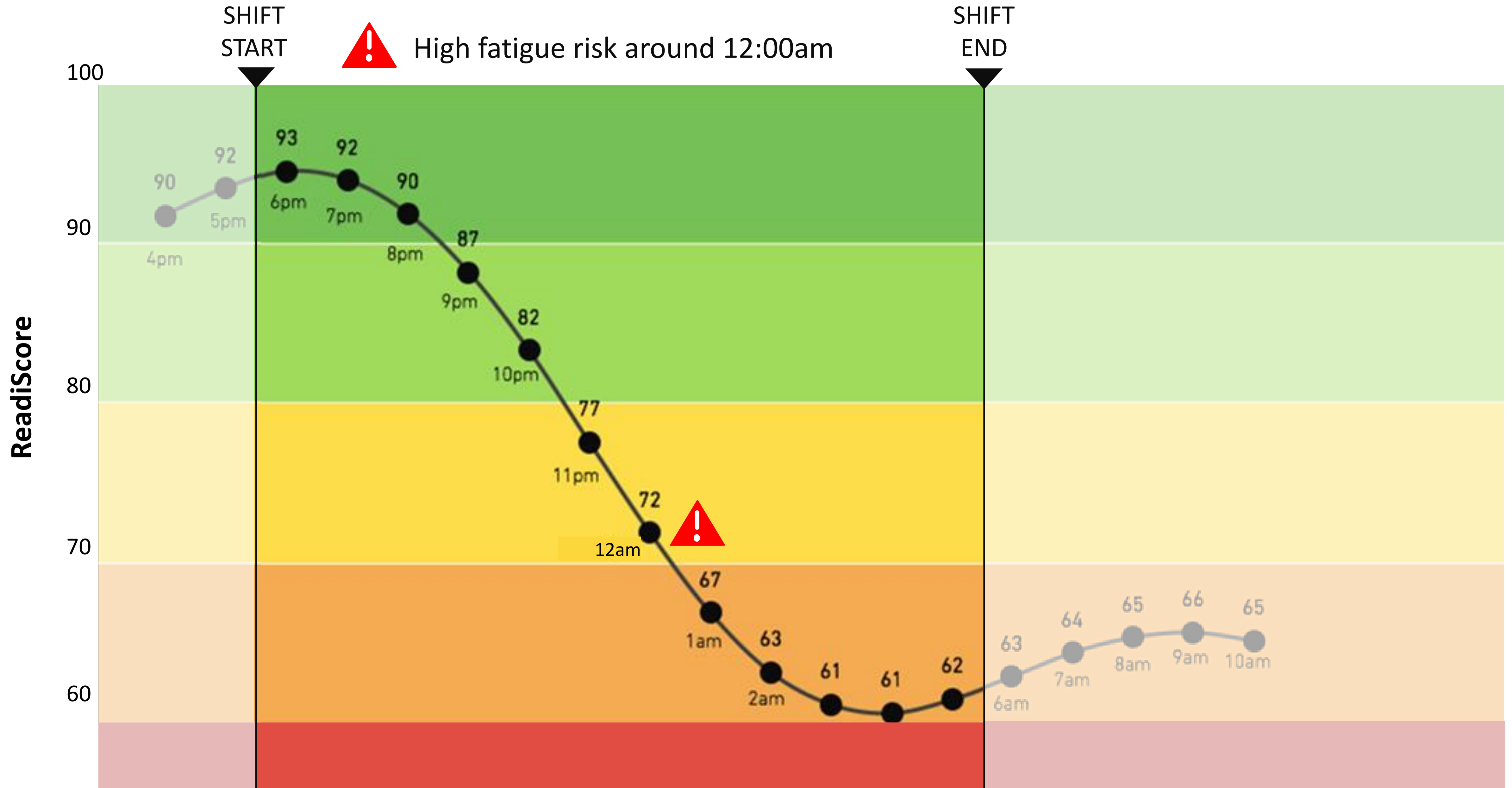
Readi / Data Flow

10-Day Sleep History

Estimations

ML analyzes recent work hours, via API or schedule, and one-time questionnaire.

or

Wearables

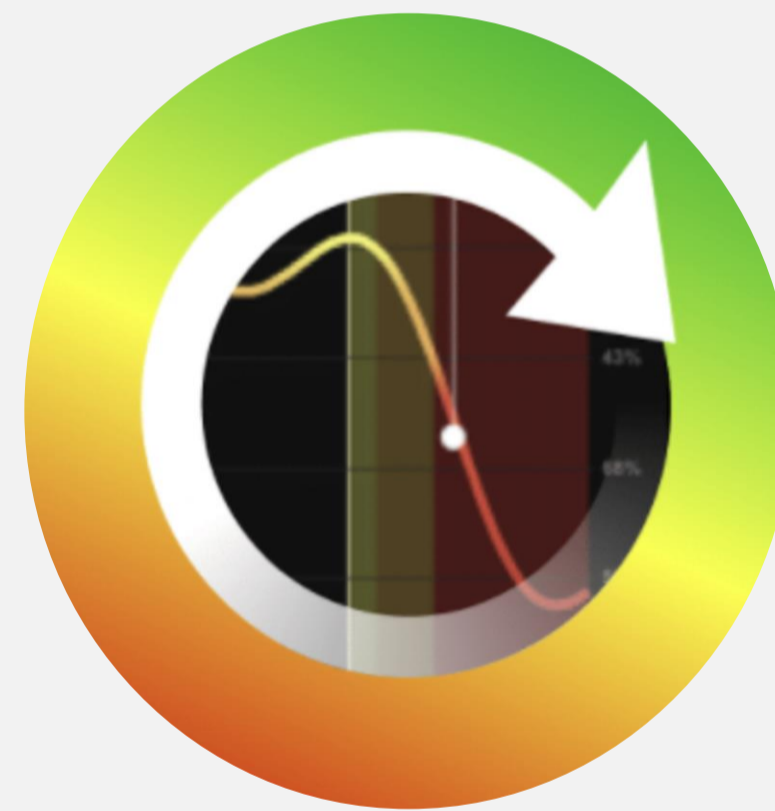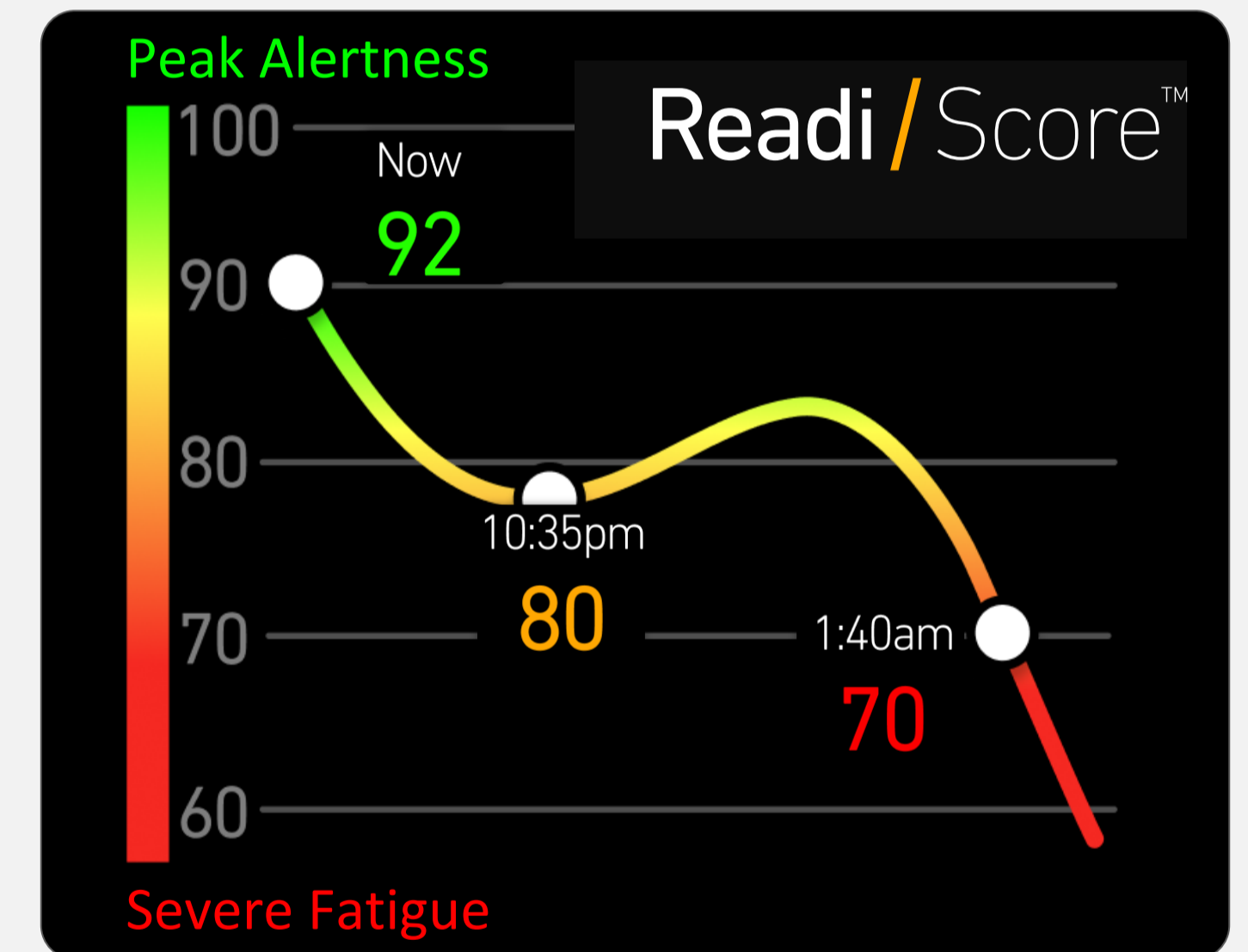**Optional.**
Sleep data from ReadiWatch, Fitbit, or Garmin

Fatigue Model

Validated SAFTE™ Model from US Army

Daily, Personalized Fatigue Prediction

Readi / Score™

Peak Alertness

Now **92**

10:35pm **80**
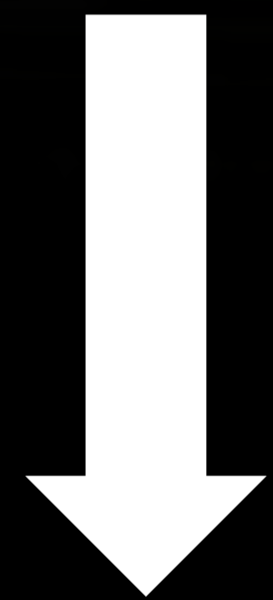
1:40am **70**

Severe Fatigue

Readi™ / ✦ ML

ML Engine powered by unrivaled data set from worldwide install base of wearables at industrial sites:
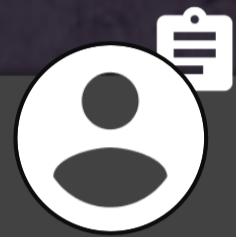
5 million data points

⬇

Unique advantage:

Personalized fatigue risk prediction without requiring wearables.
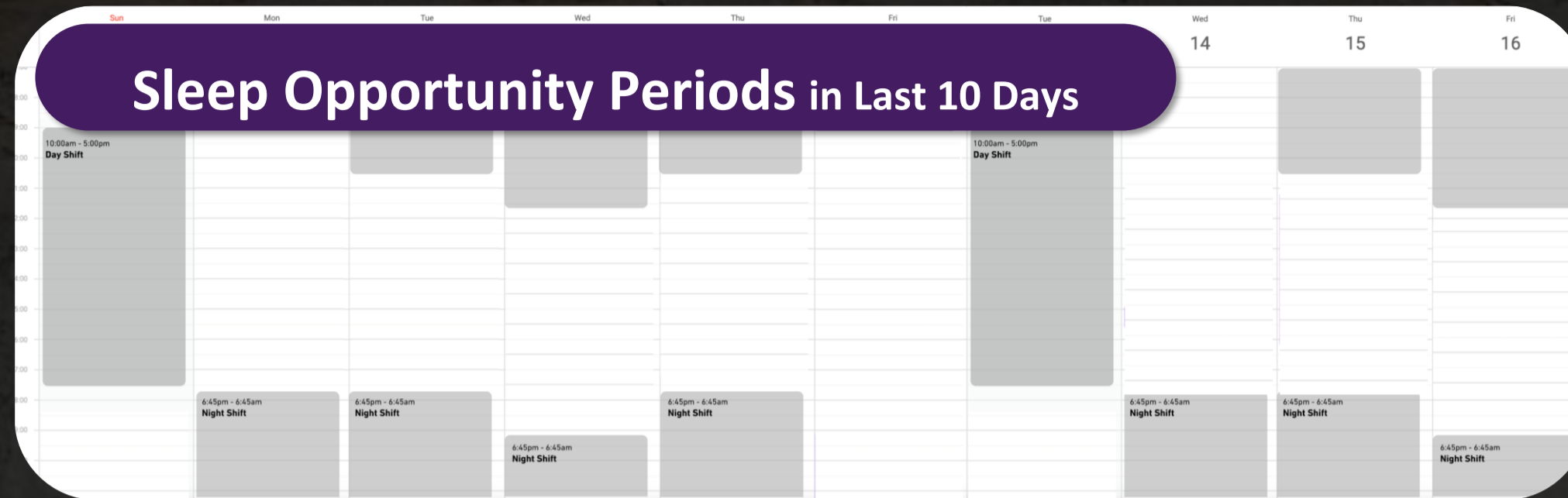
How SleepML Estimates Sleep

Worker's Data

Work Hours

Personal Data

Sleep Opportunity Periods in Last 10 Days

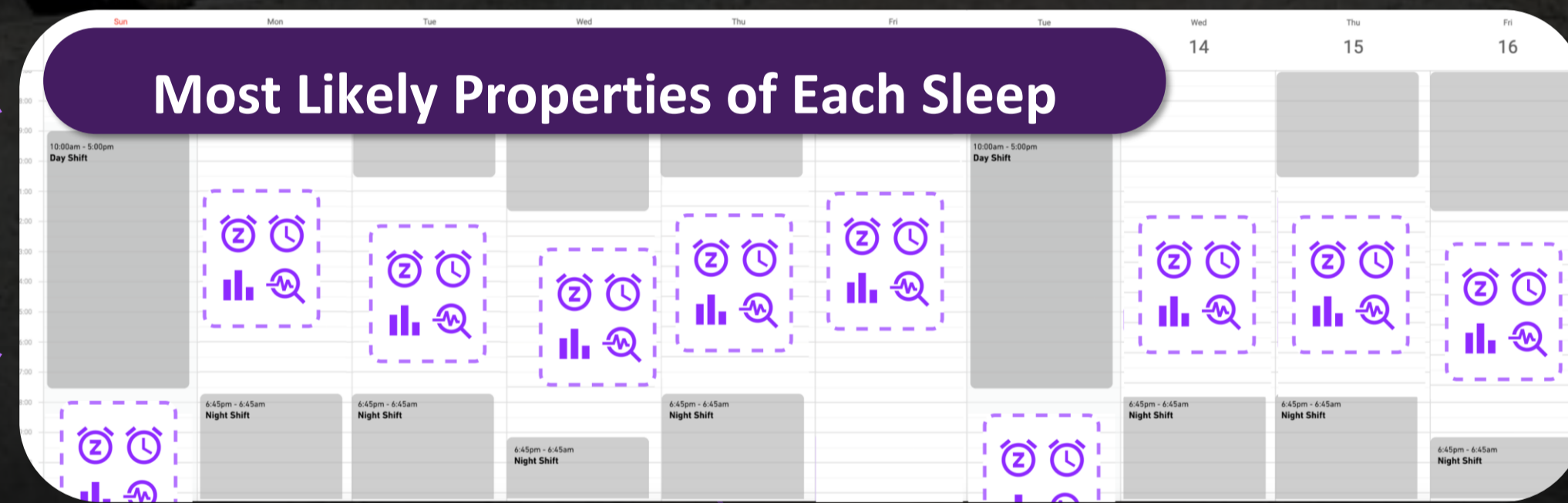✓ Accounts for commutes + other buffers

Personal Sleep Profile

Proprietary Anonymized Data

5M+ wearable sleeps

…from people with **similar sleep profiles**

…and with **similar work hours**

Most Likely Properties of Each Sleep

Onset
Wake
Quality
Quantity

Estimated Sleeps in Last 10 Days

Includes ML adjustments for:
✓ reconciliation of any real sleep data
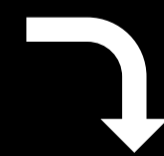✓ cumulative sleep debt

Machine Learning enables Readi to predict 80% of cases of fatigue, as compared with cases detected via wearables.

Supervisor's Visibility
into Fatigue

80%
of cases

All fatigue
cases
determined by
wearable

No visibility

No predictive
tech in use

Cases Predicted by
ReadiML

All Cases

Based on the analysis of 14,814 shifts across 5 mining sites, 80% of fatigue cases detected by wearable devices (ReadiScore < 65 during the shift) were predicted by a machine learning model that was 'blind' to the data from the wearable device for testing purposes. Of the cases flagged by the ML model as fatigued, the false positive rate was 9% – meaning 86% of the time ((100 – 9)/ 100 = 91%) that someone is flagged as fatigued, this is a correct determination. False positives are defined as cases where the corresponding ReadiScore from the wearable data was > 72, i.e. 7 points higher than the flagging threshold of 65.

Strengths and Limitations of ML

Fatigue That Fits a Pattern

Cases of fatigue caused by the interaction of factors common in shift workers:

- Moderate to severe sleep health issues
- Rest times inconsistent from day to day
- Rest times changed unexpectedly
- Overtime
- Delayed start
- Long commutes
- Scheduled rest times are biologically difficult
- Time zone travel / jet lag
- Unexpected downtime / delays

✓ **Predictable with ML**

Random
Cases of Fatigue

- Multiple recent days of partying
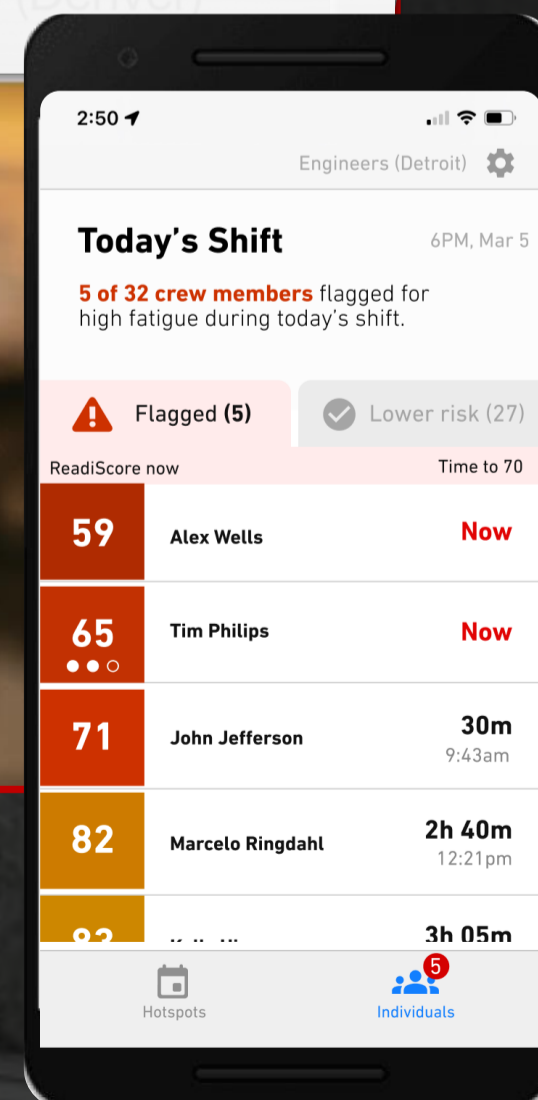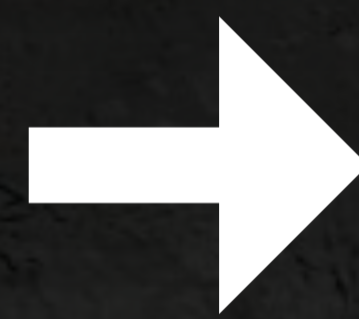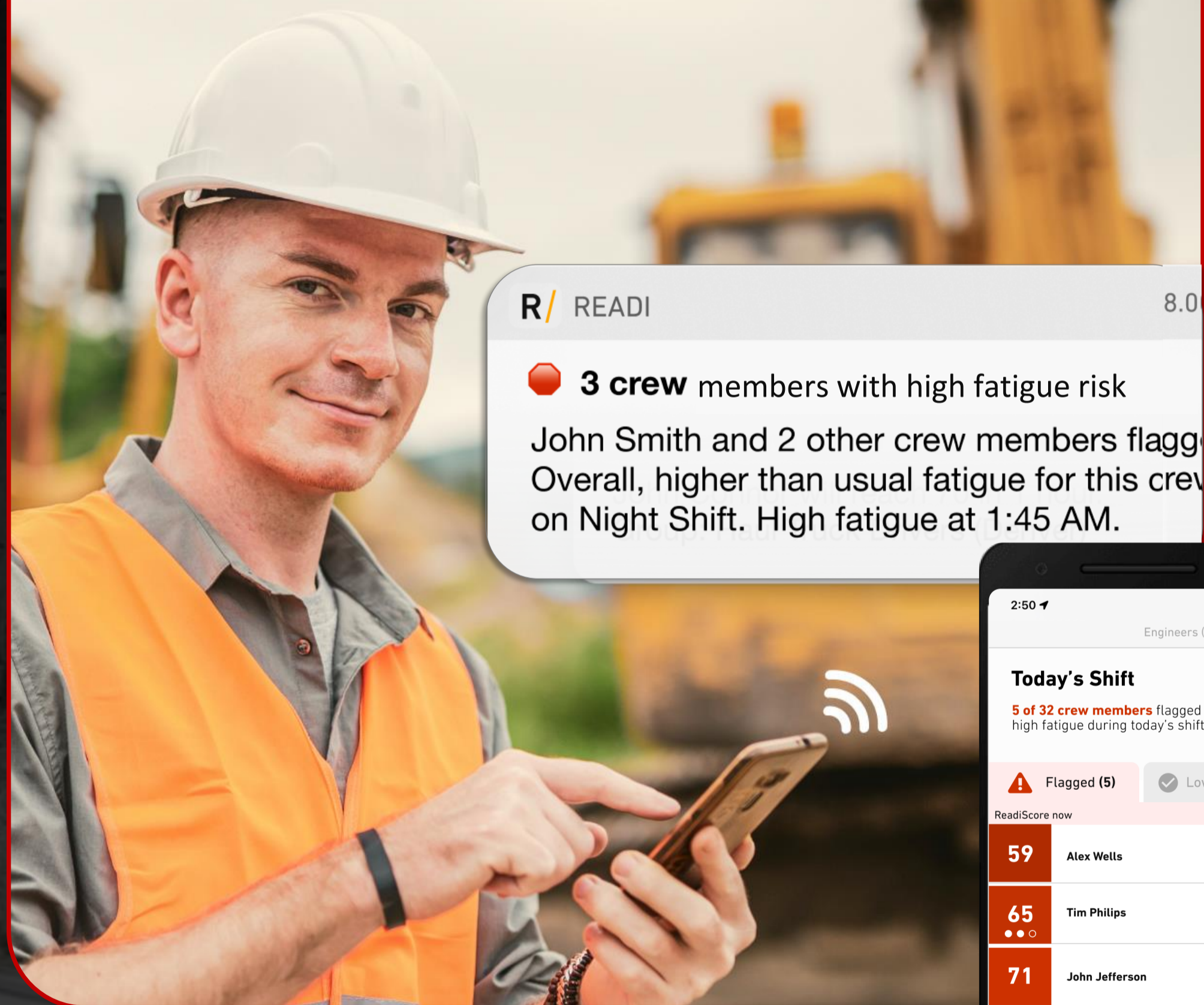- Repeated rare disturbances (earthquake, animal intrusion, etc.)

Require Wearables to Predict

Tying it all together

At the start of each shift, ReadiSupervise **informs supervisors** of **which crew members** have been flagged for high fatigue risk, enabling proactive countermeasures such as **targeted rest breaks.**

Reduce Camera Alarms by 50%

Copper Mine Case Study, 2023

Readi /

Case Study:
Readi Reduces Fatigue Camera Alarms
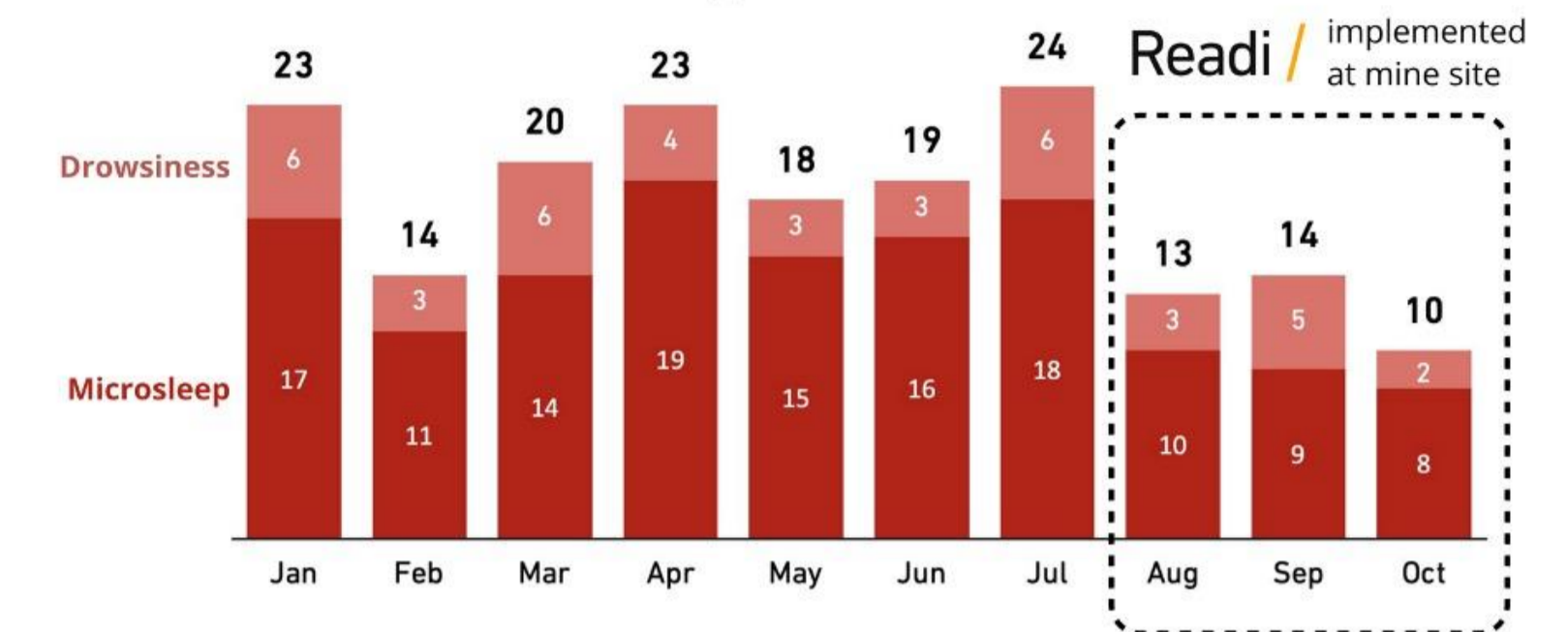by 50% at Major Copper Mine

March 2023

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3.2 Results: Impact of Readi on Incidence of Camera Alarms

The implementation of Fatigue Science's Readi system at the Central American copper mine site led to a significant reduction in the number of DSS camera fatigue events.

DSS Camera Fatigue Events in Haul Trucks
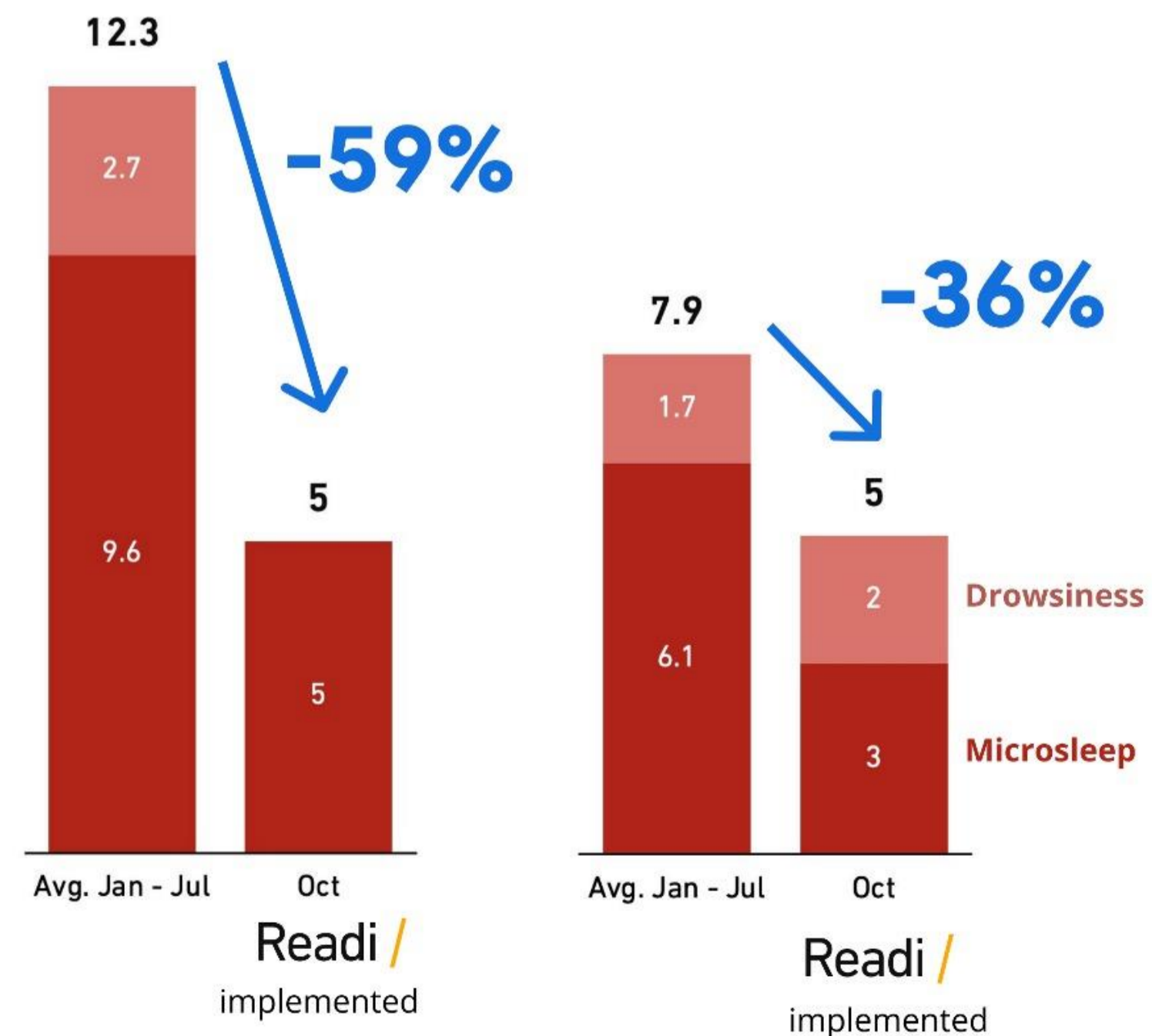2022, All Shifts, Central American Copper Mine

Readi / implemented at mine site

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Total	23	14	20	23	18	19	24	13	14	10
Drowsiness	6	3	6	4	3	3	6	3	5	2
Microsleep	17	11	14	19	15	16	18	10	9	8

DSS Camera Fatigue Events in Haul Trucks
2022, Central American Copper Mine

🌙 **Night Shift**   ☀ **Day Shift**

-59%

-36%

Night Shift	Avg. Jan - Jul	Oct
Total	12.3	5
Drowsiness	2.7	
Microsleep	9.6	5

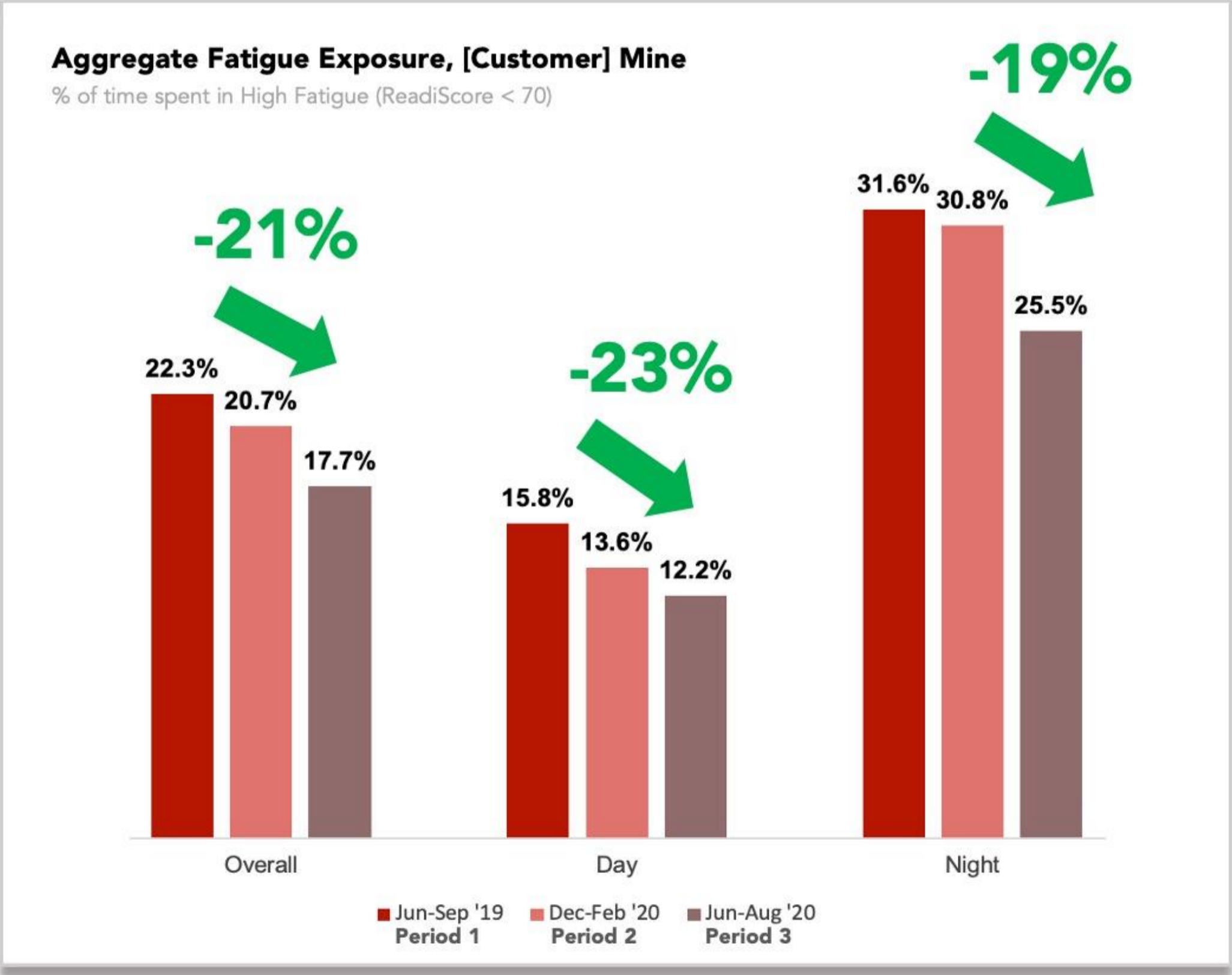| Day Shift	Avg. Jan - Jul	Oct
Total	7.9	5
Drowsiness	1.7	2
Microsleep	6.1	3

Readi / implemented

Readi / implemented

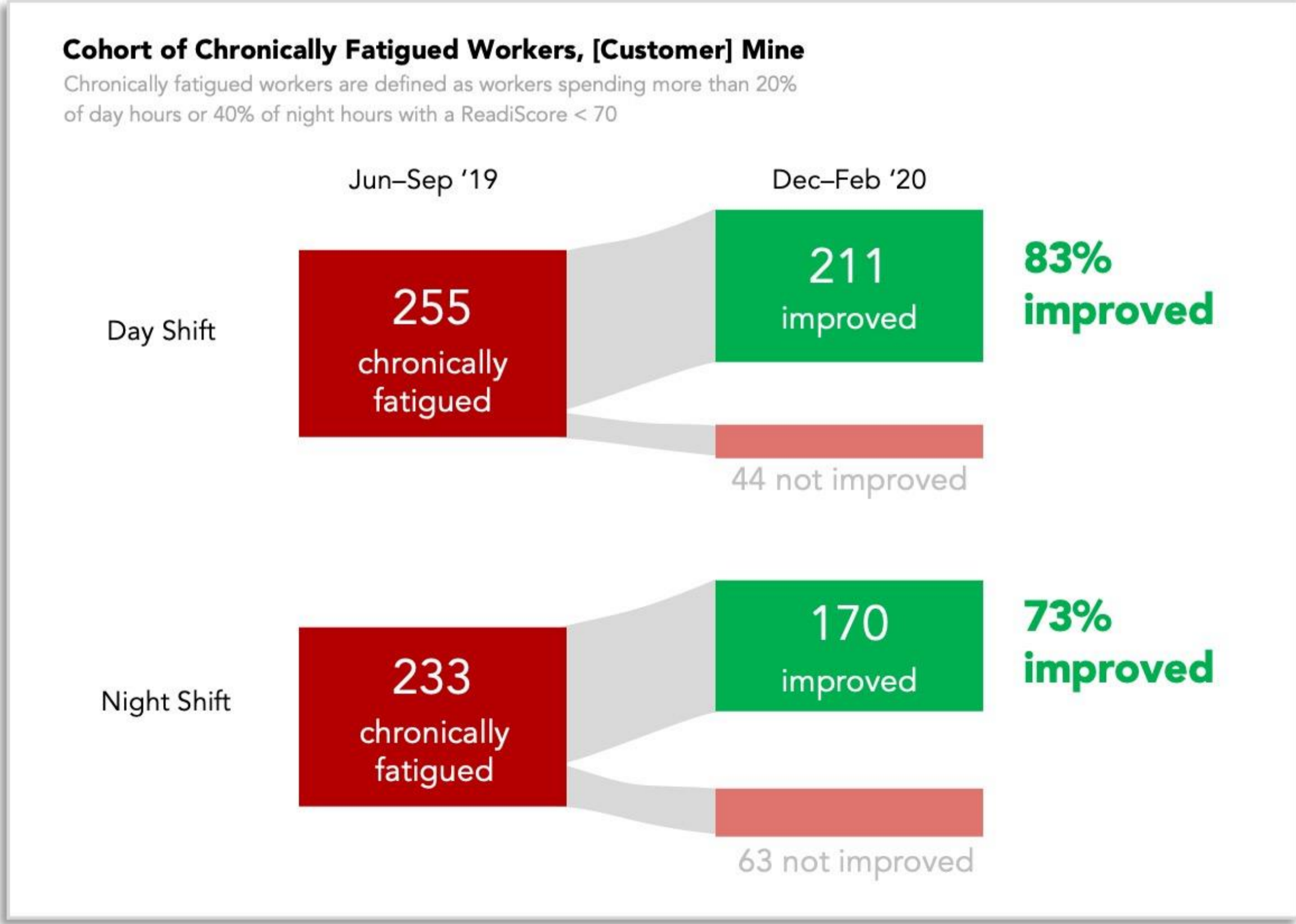# Fatigue Reduction: Case study from major mining customer

/ Aggregate Fatigue Reduction

Fatigue Risk Assessments conducted for [customer] compared showed a **21% overall fatigue reduction** among Readi participants over a 14-month period.

Aggregate Fatigue Exposure, [Customer] Mine
% of time spent in High Fatigue (ReadiScore < 70)

-21%   -23%   -19%

22.3% 20.7% 17.7%   15.8% 13.6% 12.2%   31.6% 30.8% 25.5%

Overall   Day   Night

Jun-Sep '19   Dec-Feb '20   Jun-Aug '20
Period 1   Period 2   Period 3

/ Individual Improvements

78% of chronically fatigued workers demonstrated significant improvement in fatigue between assessment periods due to behavioral change and guidance from [Customer] medical staff enabled by Readi data and the app experience.


Cohort of Chronically Fatigued Workers, [Customer] Mine
Chronically fatigued workers are defined as workers spending more than 20% of day hours or 40% of night hours with a ReadiScore < 70

Jun–Sep '19   Dec–Feb '20

Day Shift   255 chronically fatigued   211 improved   **83% improved**   44 not improved

Night Shift   233 chronically fatigued   170 improved   **73% improved**   63 not improved

Thank You

Contact us at www.FatigueScience.com
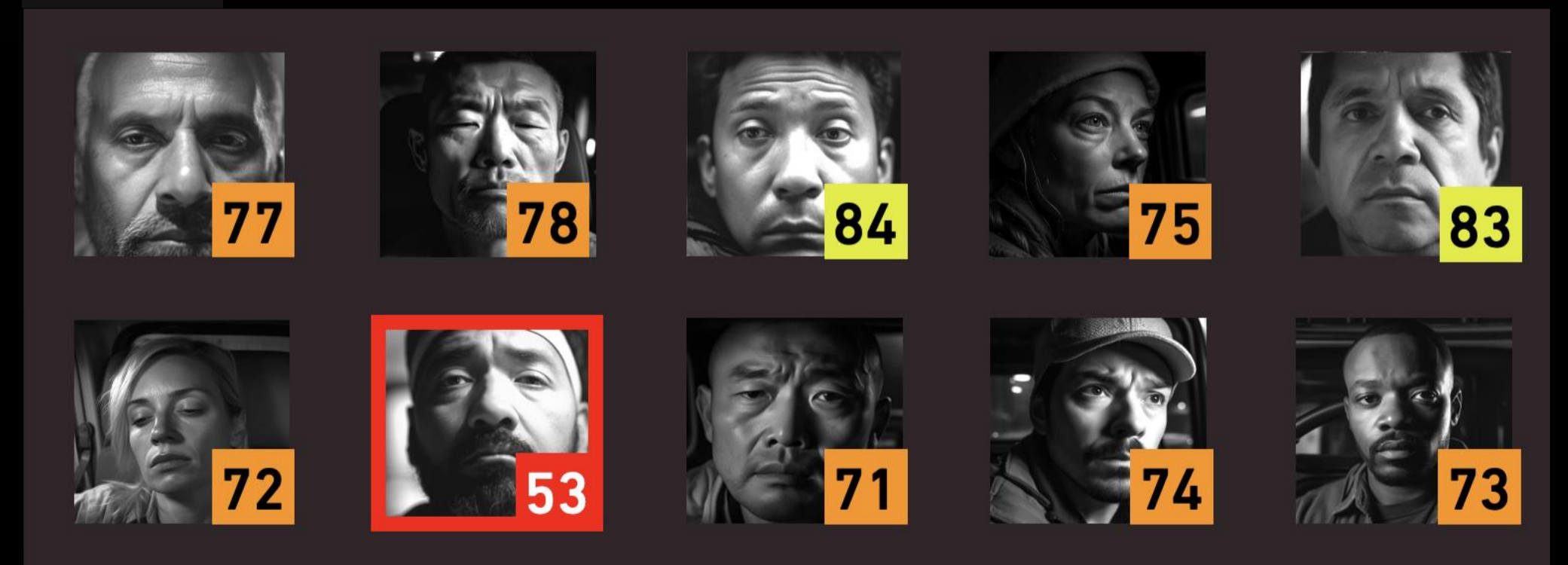
FATIGUE
SCIENCE

Appendix

The ReadiScore provides an additional source of fatigue risk data, helping to distinguish true vs. false alarms from in-cab cameras.
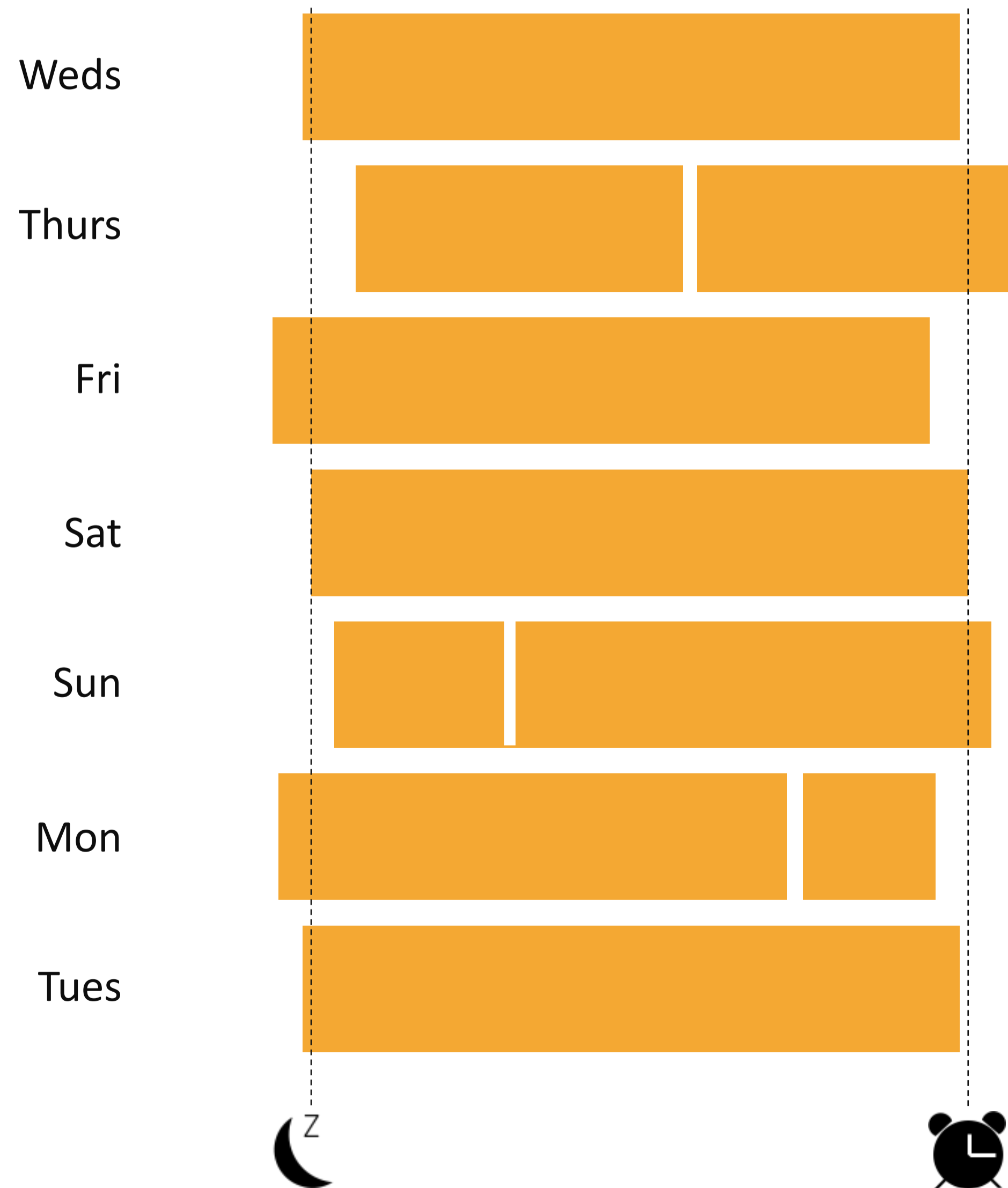
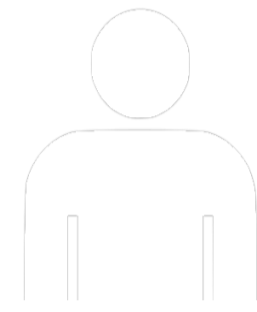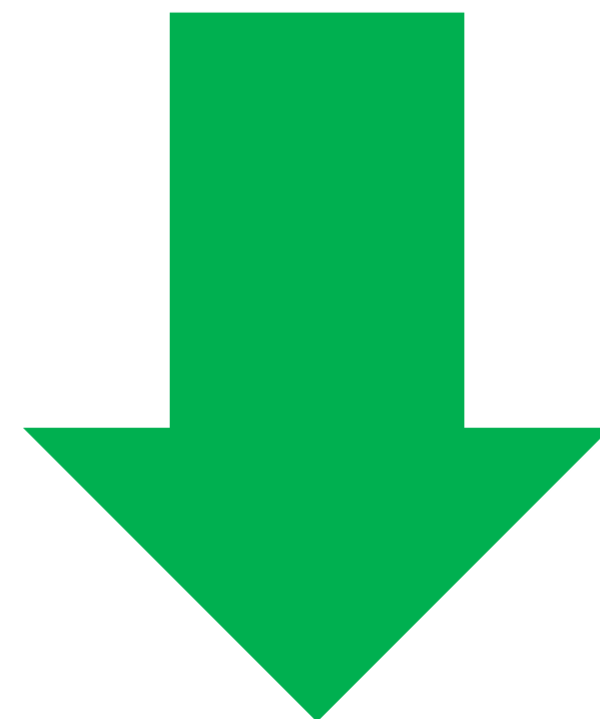Act on the **most critical** events, while **minimizing disruption**.
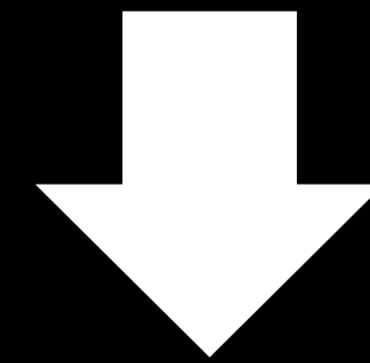
It's not just about **last night's sleep.**

Weds	
Thurs	
Fri	
Sat	
Sun	
Mon	
Tues	

Scientifically, your **last 10 days** of sleep have a predictable impact on your fatigue risk today.

What can you as an **individual** to **reduce** fatigue risk?

Not all sleep habits are controllable, but some may be **easier to change** than you may think.

Sleep Planning

Sleep Hygiene

Sleep Environment

Sleep Planning

Sleep habit mistakes:

- **under-estimating** how much time you really need in bed.

- It's easy to forget to account for the **sleep you'll likely lose** due to awakenings.

When possible, plan to **give yourself that extra time** in bed.

Sleep hygiene is about all the things you can do while **awake** to improve your time **asleep**.

It can help you **fall asleep faster** and **reduce awakenings** that rob you of time asleep.

Sleep Hygiene

- ❑ Avoid late-day caffeine
- ❑ Cut down on alcohol & cigarettes
- ❑ Drink enough water during the day
- ❑ Avoid heavy meals before bedtime
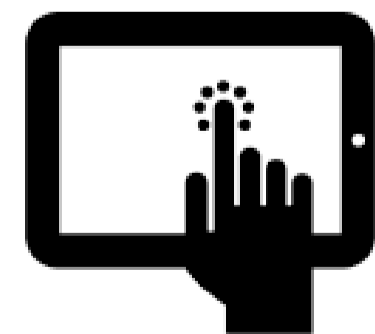
- ❑ Avoid digital devices before bed
- ❑ Exercise daily
- ❑ Go to sleep at a consistent time
- ❑ Winding down routine

Like sleep hygiene, improvements in sleep environment can help you **fall asleep faster** and **reduce awakenings.**
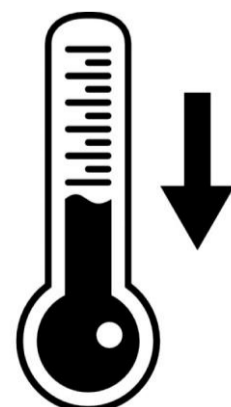
Sleep Environment

Lighting
❑ Dim the lights an hour before bed
❑ Block out remaining light with a sleep mask or blackout curtains

Sound
❑ Block out sound with ear plugs

Temperature & Comfort
❑ Keep your bedroom 15.5 – 19.5ºC
❑ Ensure a comfortable pillow & mattress

Reducing LTIs by 13% or more

Our **whitepaper** based on 2 case studies from mining customers estimates that 13% lower Lost Time Incidents can be achieved through the use of Readi.