SLEEP & SLEEP INERTIA

CASSIE J. HILDITCH, PHD
SAN JOSE STATE UNIVERSITY

FATIGUE COUNTERMEASURES LABORATORY
NASA AMES RESEARCH CENTER

SRS Virtual Seminar Series
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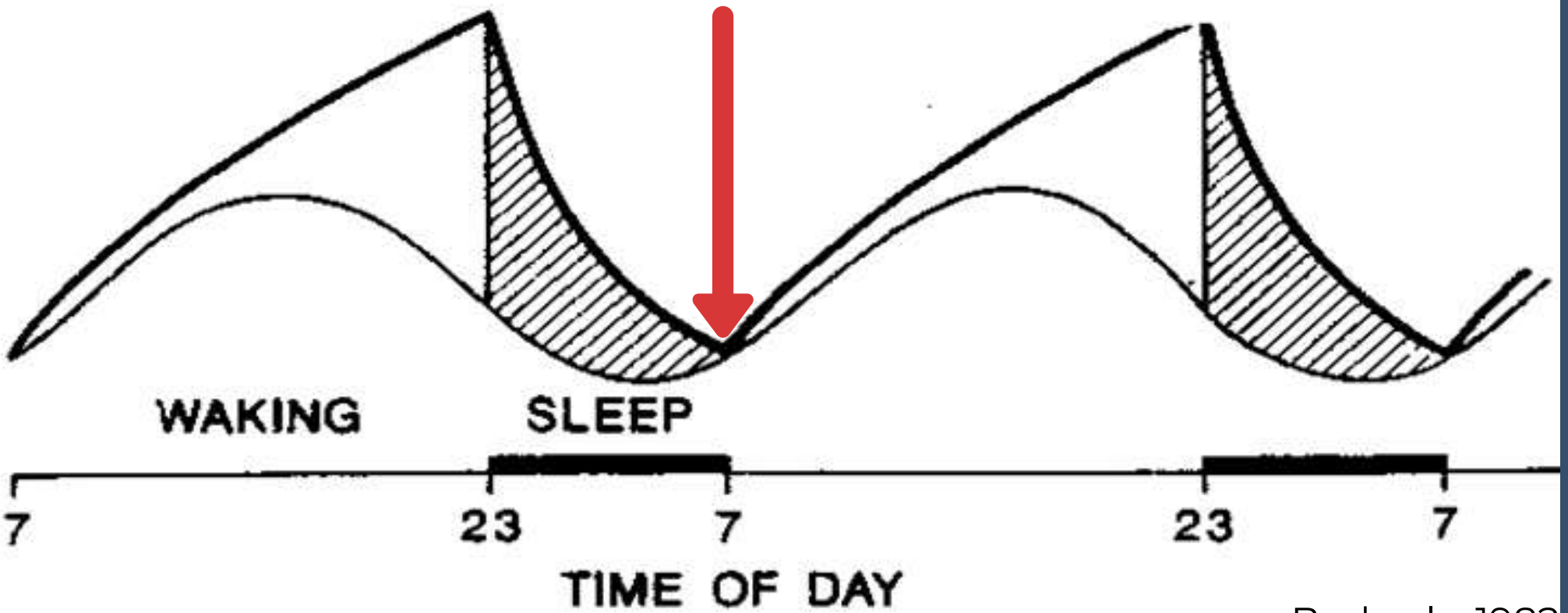

Borberly, 1982

The third process

"Immediately after getting up ...
one is not as one's best"

- N. Kleitman, 1939

What is sleep inertia?

- Grogginess
- Disorientation
- Tendency to fall back to sleep
- Impaired cognitive performance

CAUSES

What affects sleep inertia?

- Acute sleep loss
- Chronic sleep loss
- Circadian rhythm
- Sleep stage at wake
- Chronotype
- Genetics?

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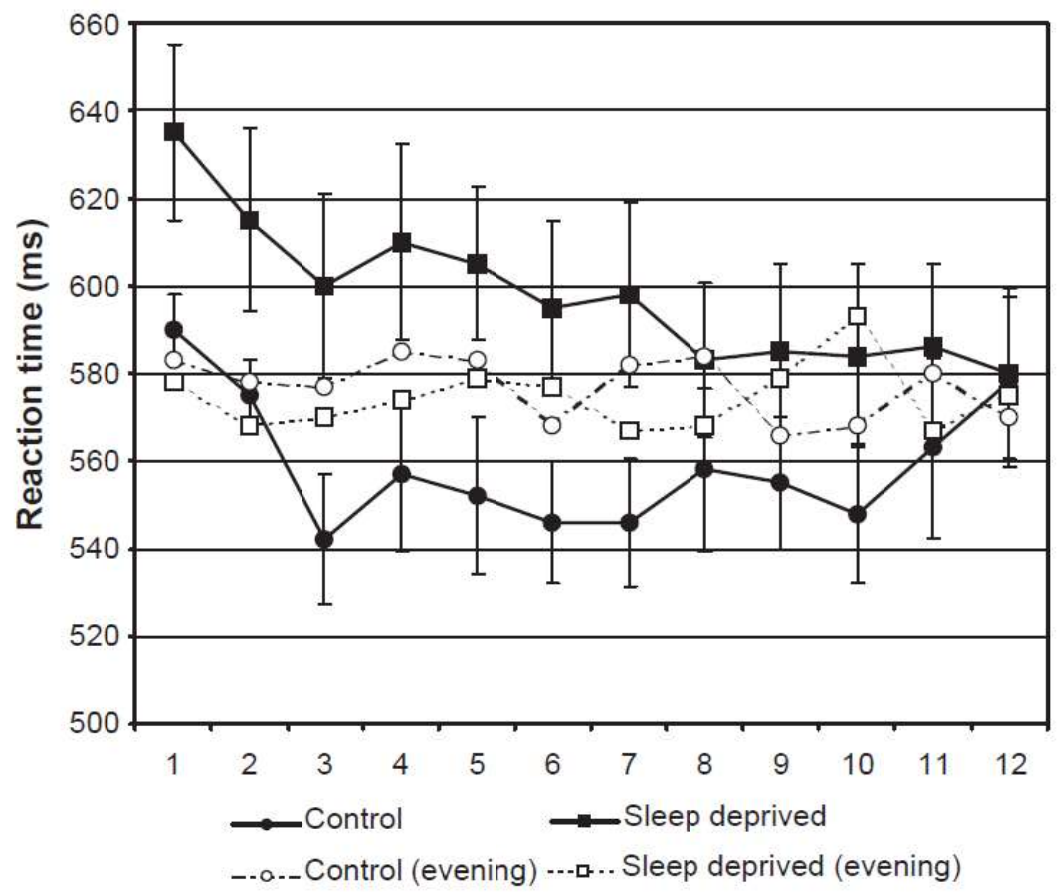

Tassi et al., 2006

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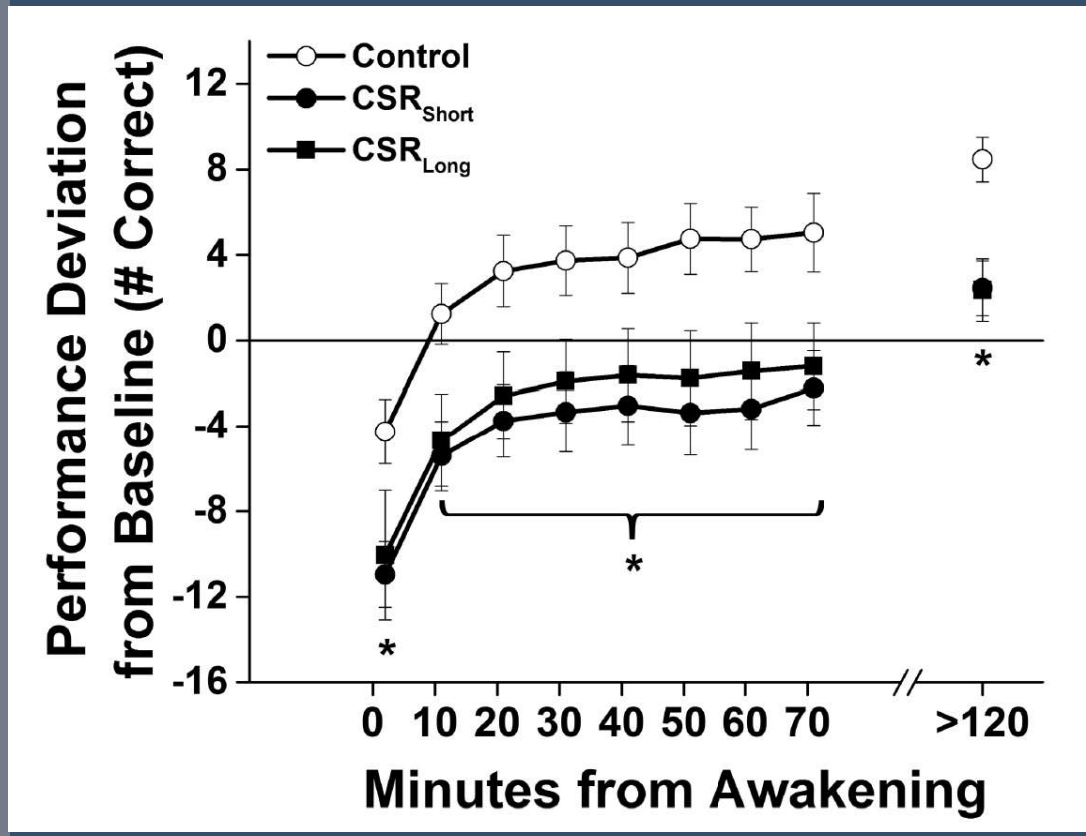

McHill et al., 2019

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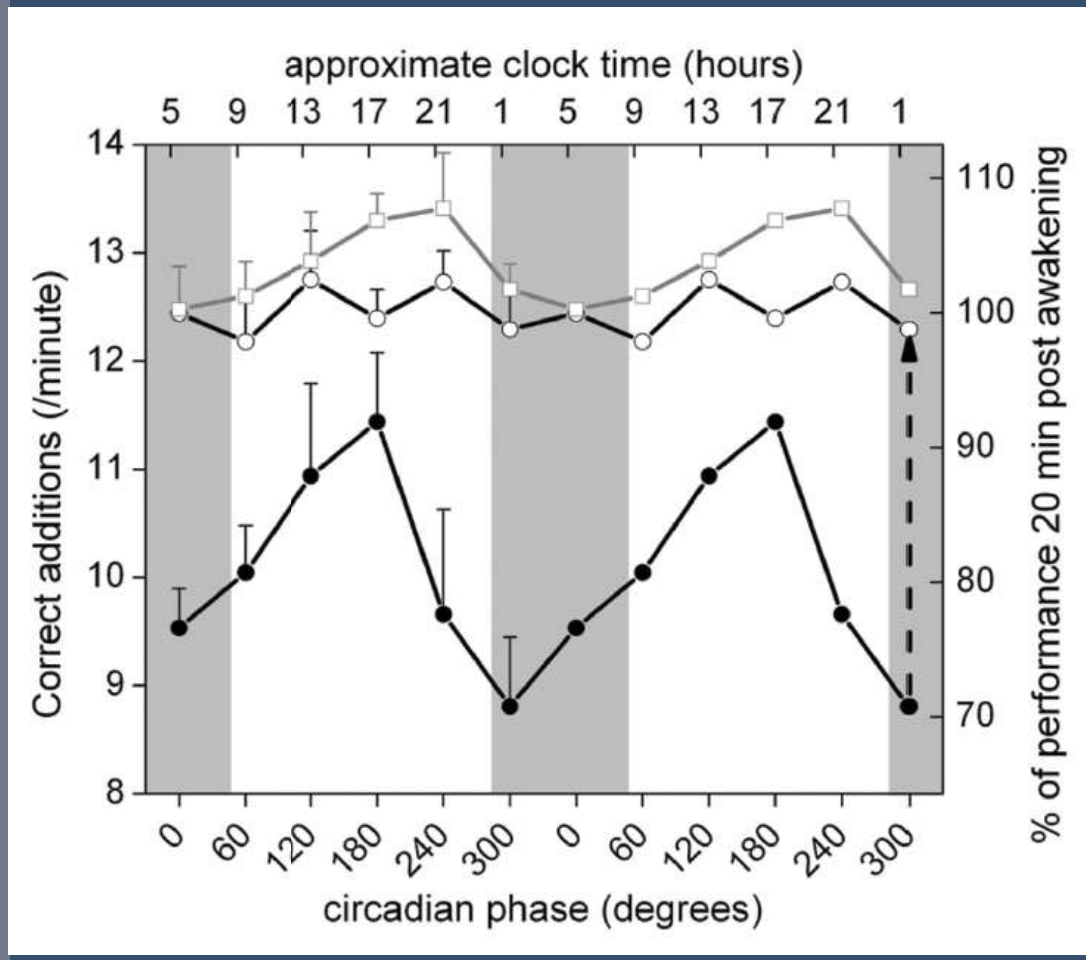

Scheer et al., 2008

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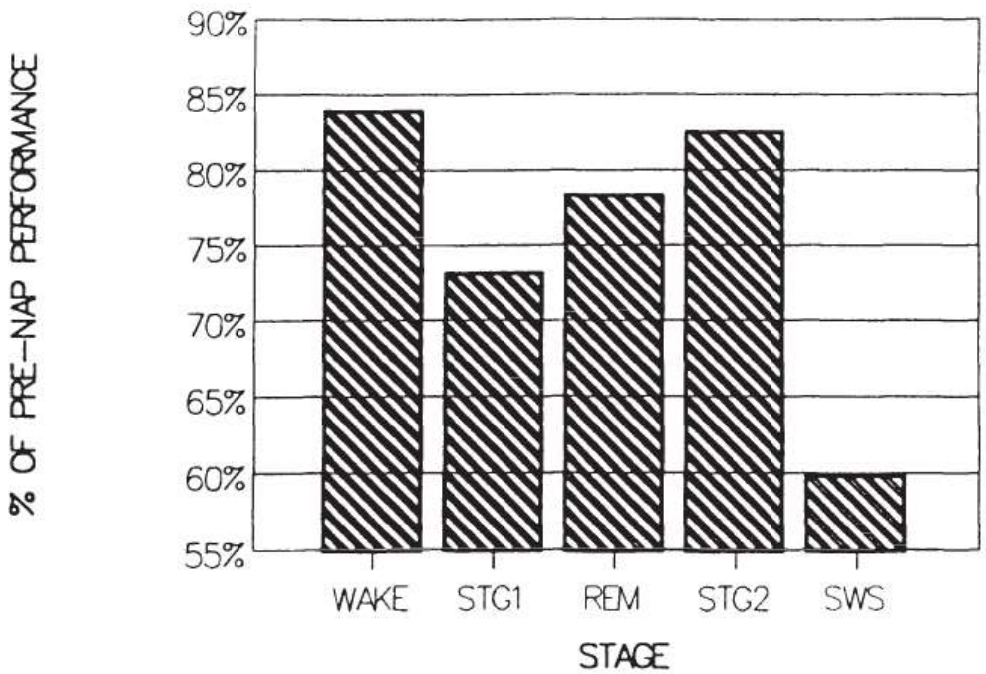

Stampi, 1992

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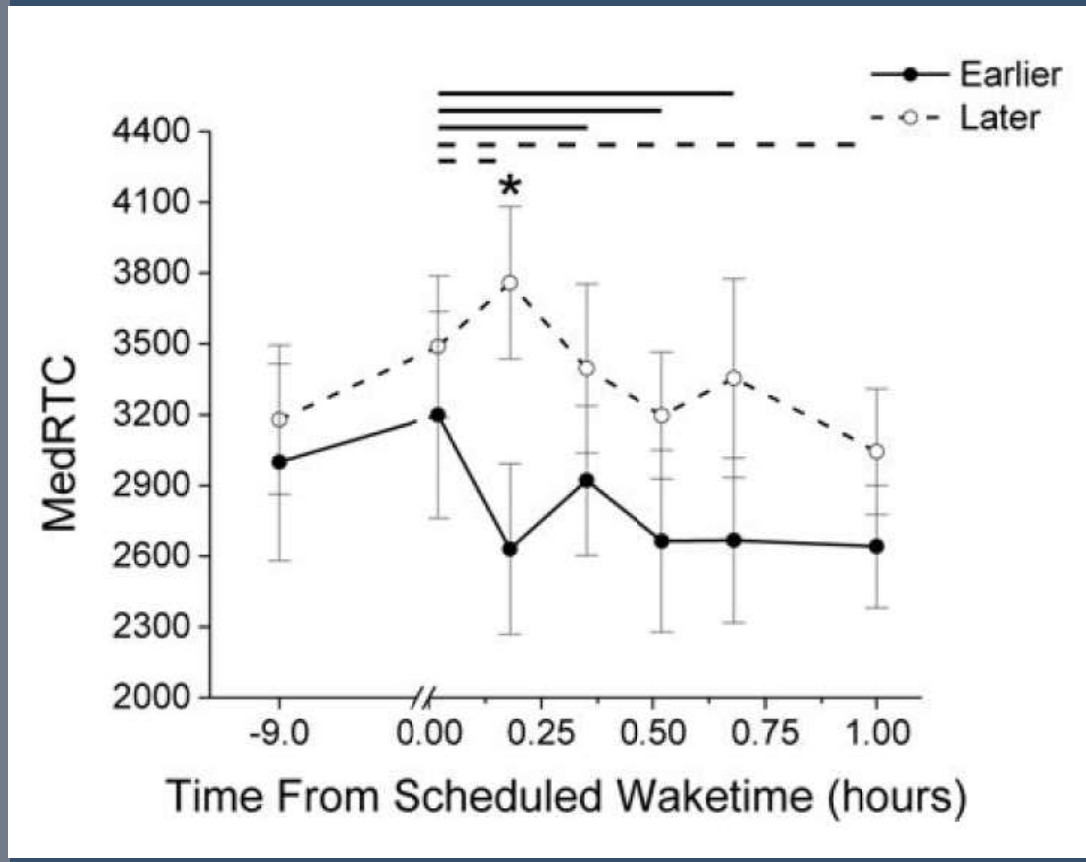
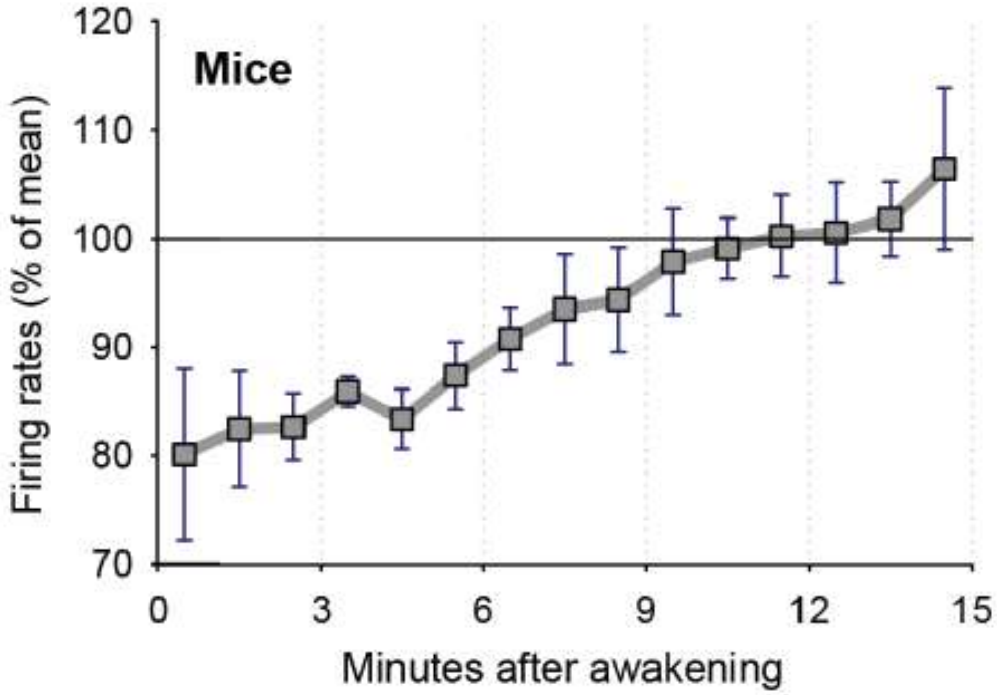


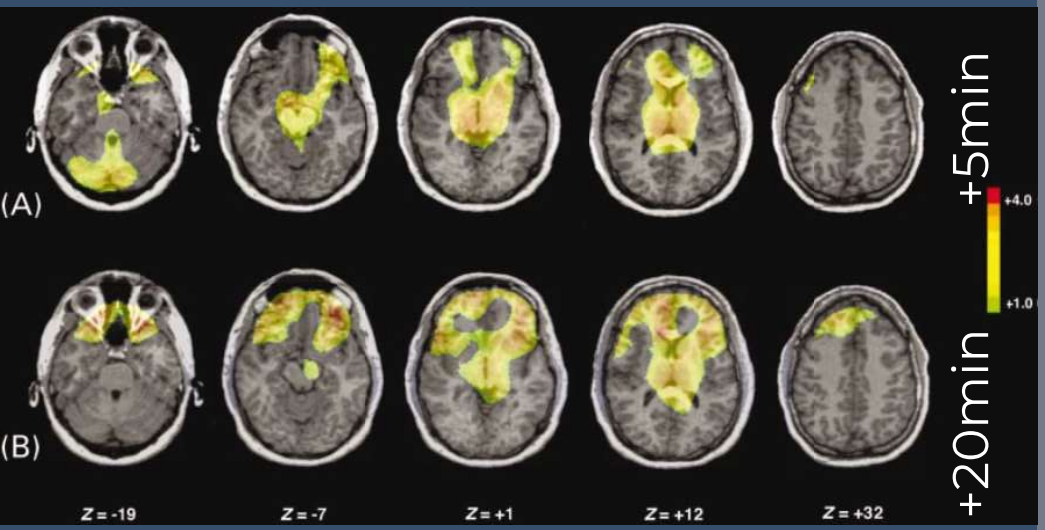
Ritchie et al., 2017



Vyazovskiy et al., 2014

Neural correlates

- **Neuronal firing rate**
- Cerebral blood flow
- Spectral power
- Functional connectivity
- Connectivity strength



Balkin et al., 2002

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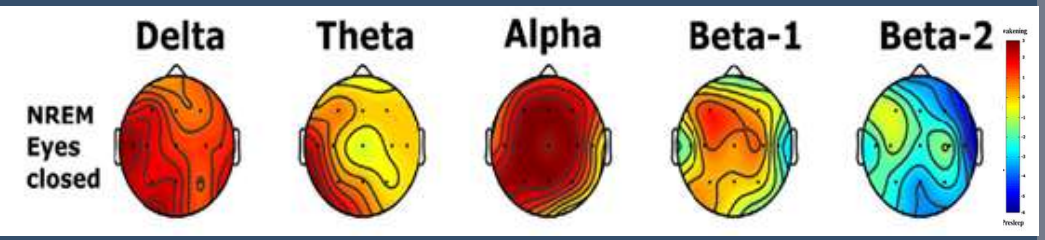
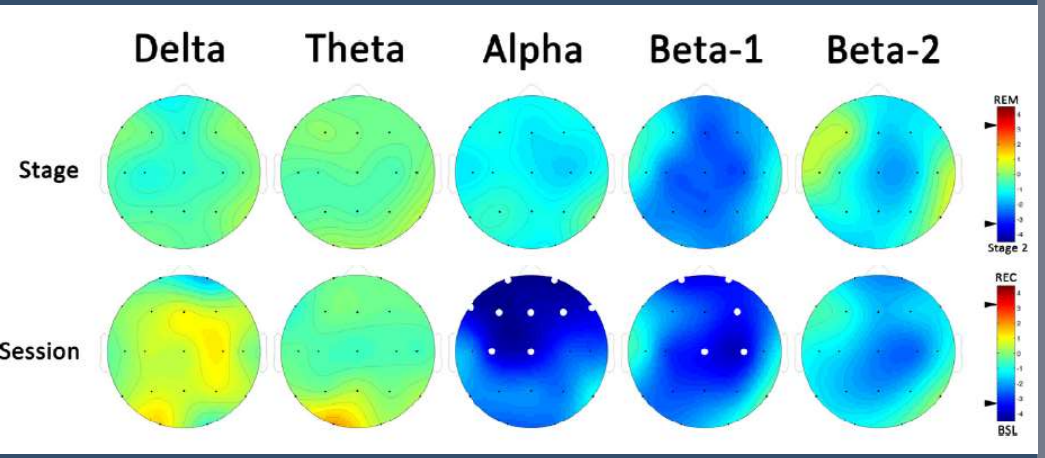


Marzano et al., 2011



Gorgoni et al., 2015

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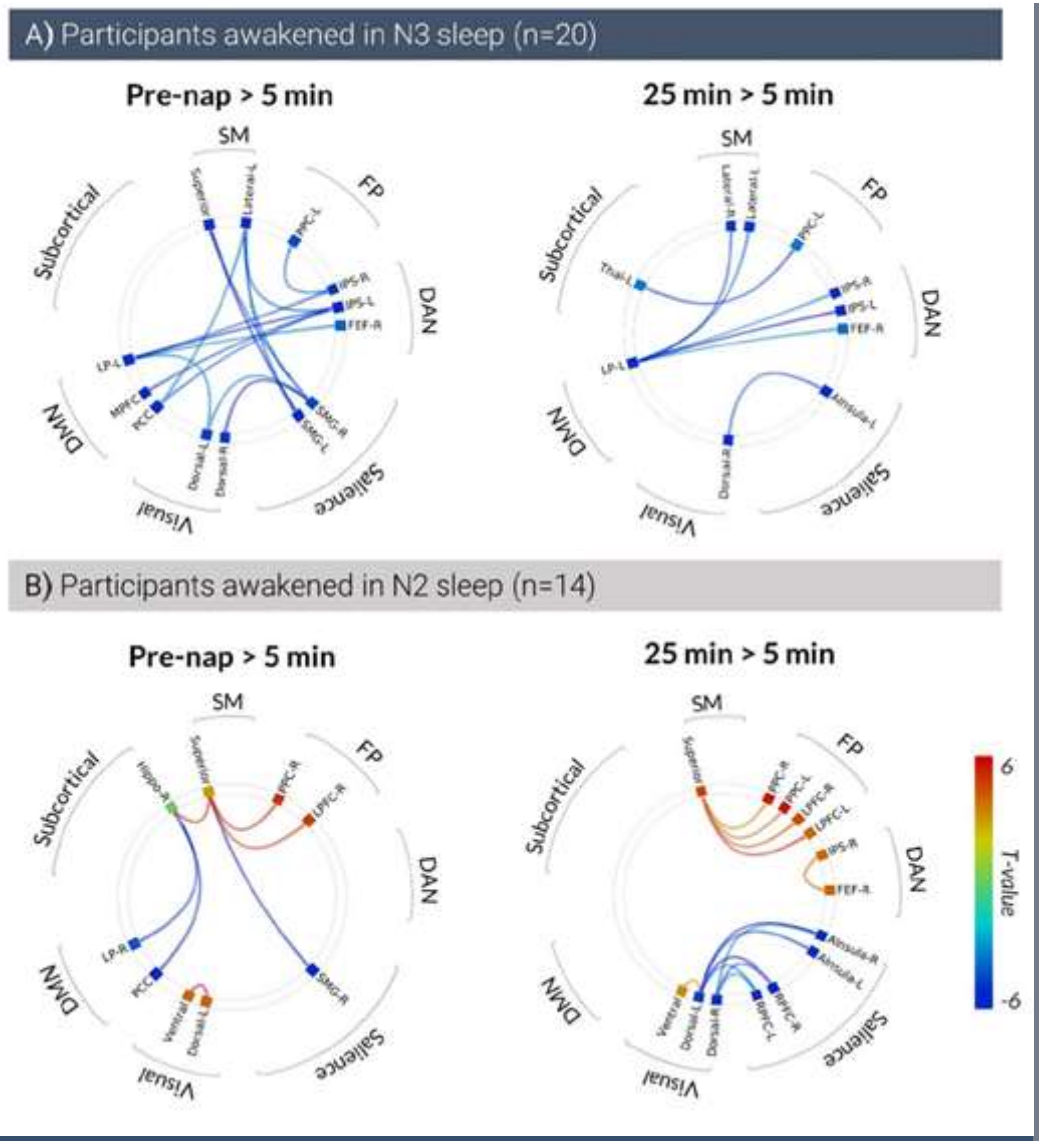

Vallat et al., 2019

Neural correlates

- Neuronal firing rate
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- **Functional connectivity**
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CONSEQUENCES

What does sleep inertia affect?

Reaction time

Memory

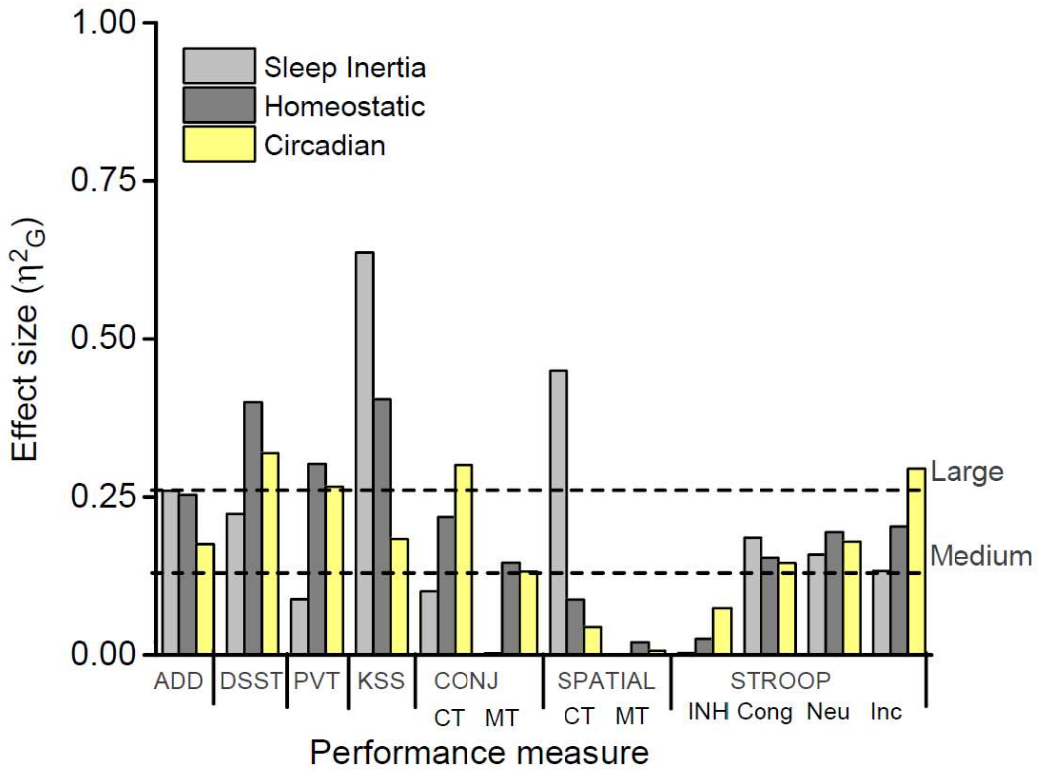
Cognitive processing

Arithmetic

Decision making

Tactical planning

Visual search



Burke et al., 2015

Reaction time

Memory

Cognitive processing

Arithmetic

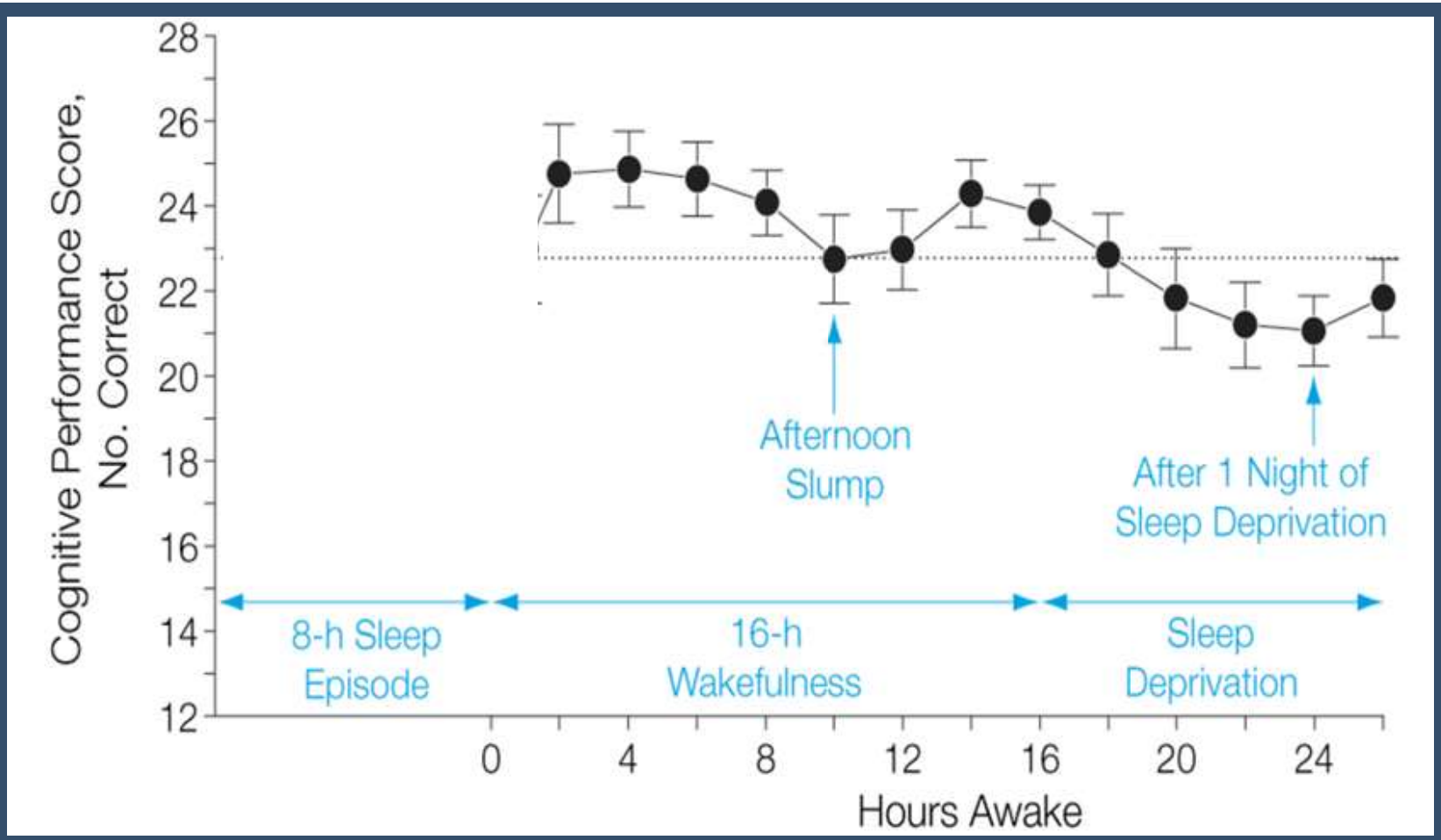
Decision making

Tactical planning

Visual search

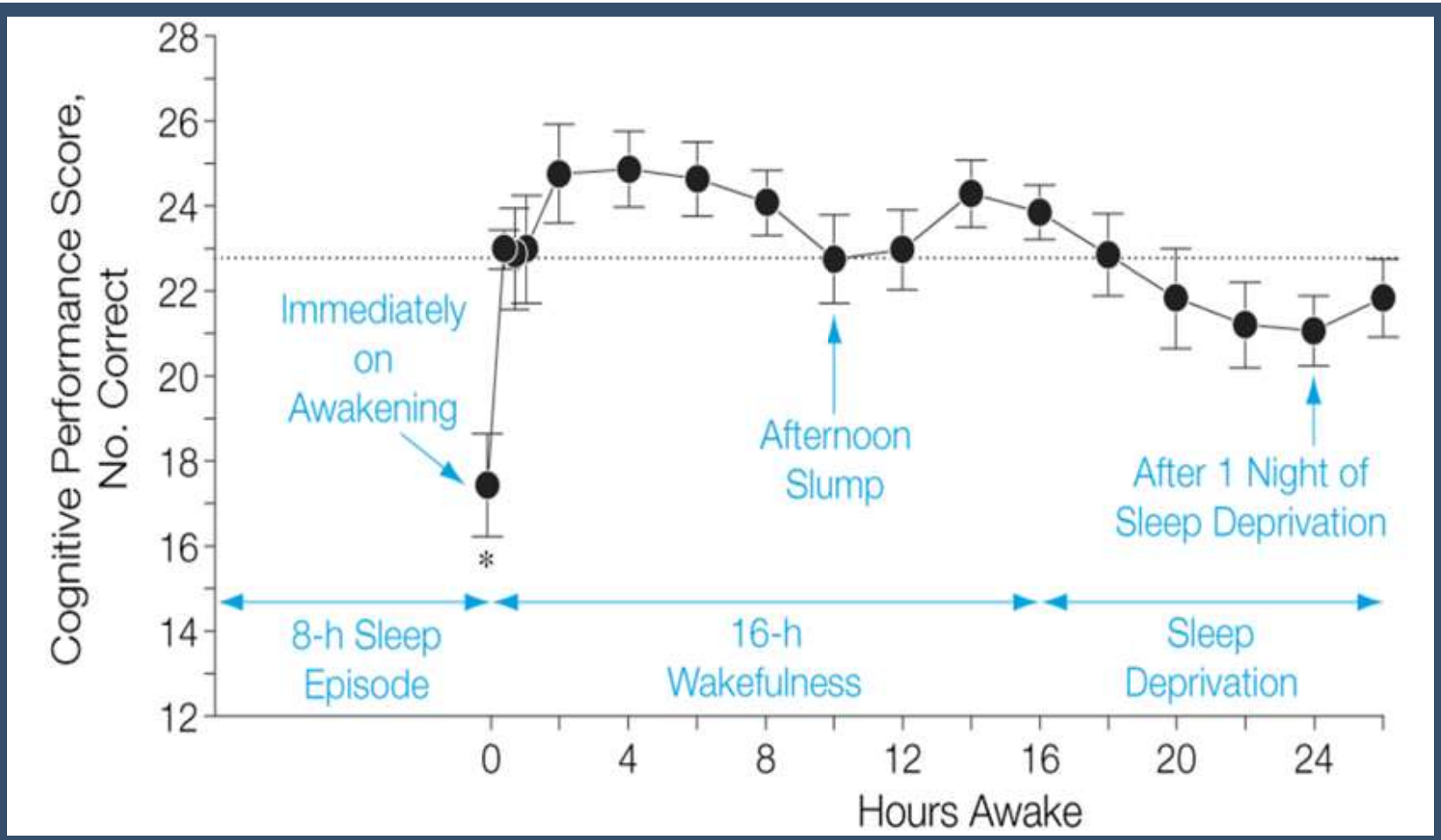
- On-call workers
- On-shift naps
- Safety-critical work

Who is at risk?



Wertz et al., 2006

Severity of impairment



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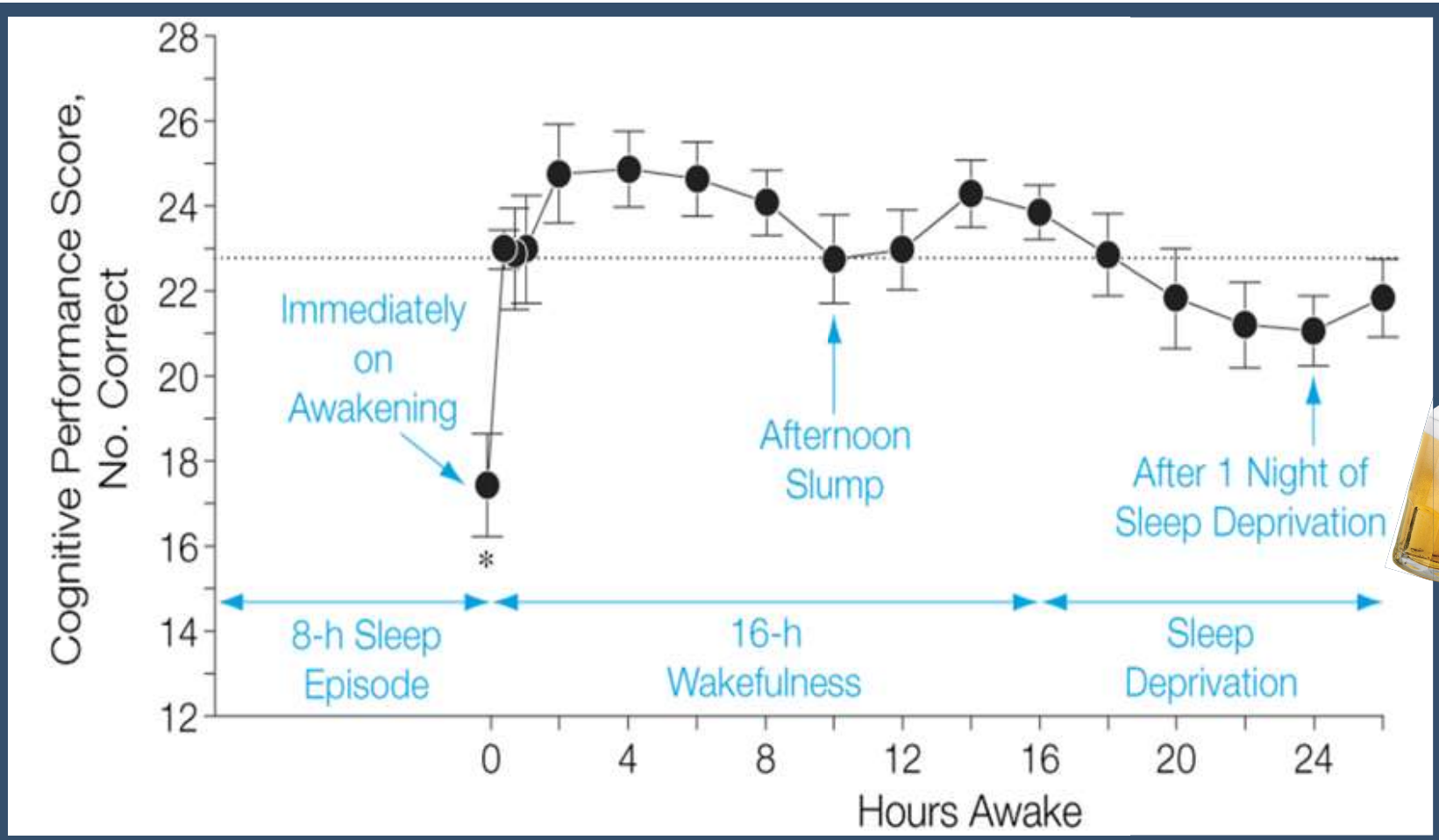

Wertz et al., 2006

Severity of impairment

COUNTERMEASURES

Exacerbating factors

- Acute sleep loss
- Chronic sleep loss
- Circadian rhythm
- Sleep stage at wake
- Chronotype
- Genetics?

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Proactive countermeasures

- Avoid prior sleep loss
- Avoid waking near circadian low
- Keep naps short

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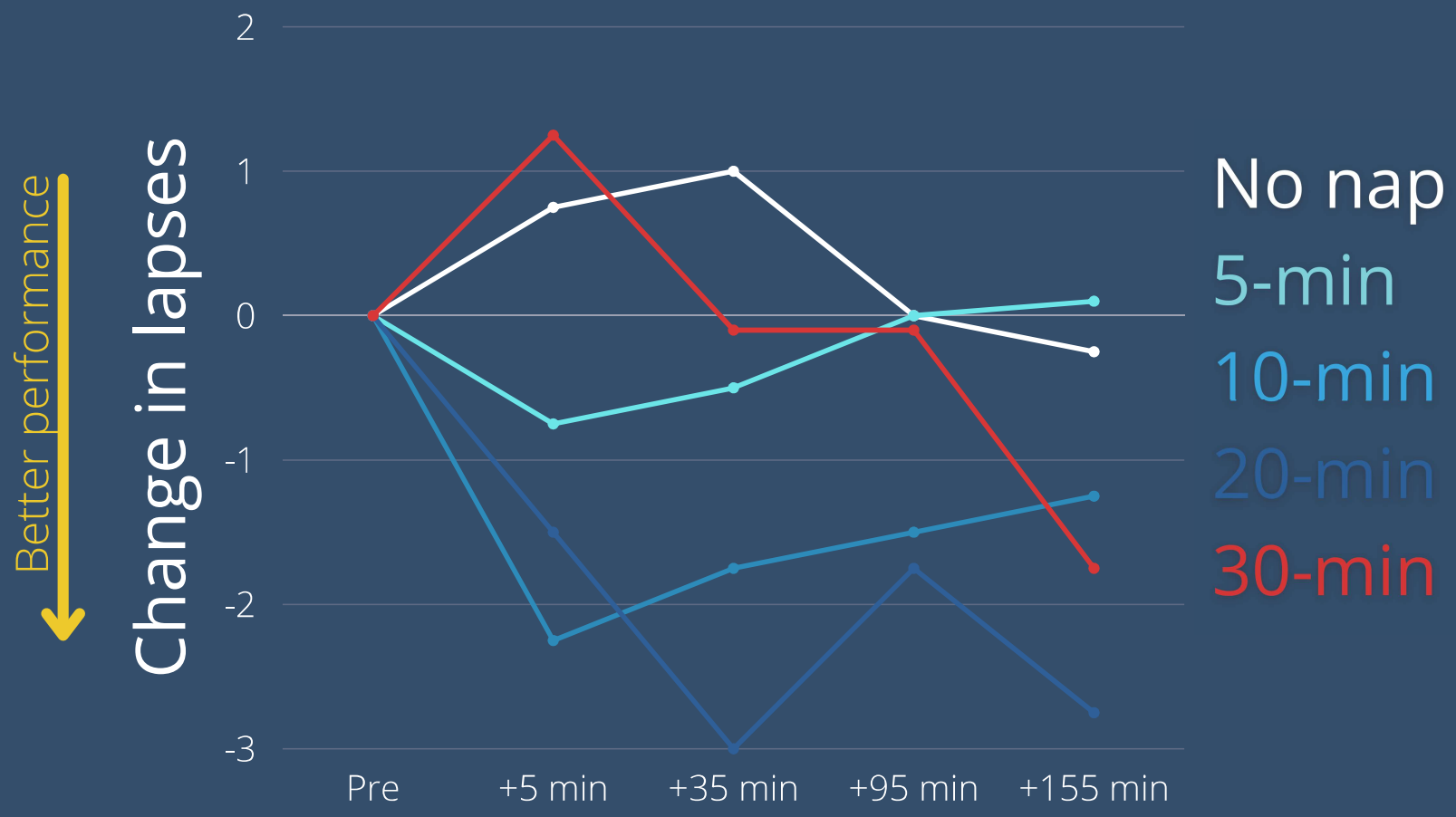


Adapted from Brooks & Lack, 2006

Short naps at night study

A 10-min daytime nap improves performance!

A 10-min daytime nap improves performance!

Can a 10-min nap at night improve performance?

Short nap during simulated night shift

Participants

- N = 31 (18F)
- Mean age = 24.3 y (SD 2.4)
- Non-shiftworkers

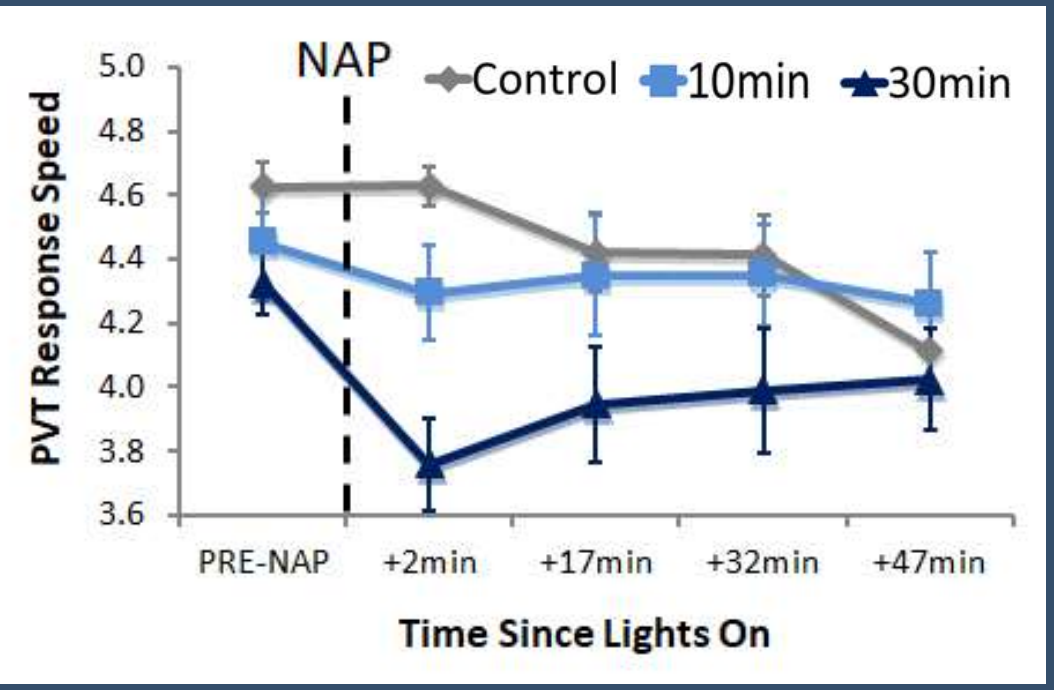
Conditions

- No nap
- 10-min nap (end @0400h)
- 30-min nap (end @0400h)

10-min nap at 0400h does not prevent SWS

- 30% entered SWS within 10 min TIB
- 100% entered SWS within 30 min TIB
- 50% of 30-min nap was SWS

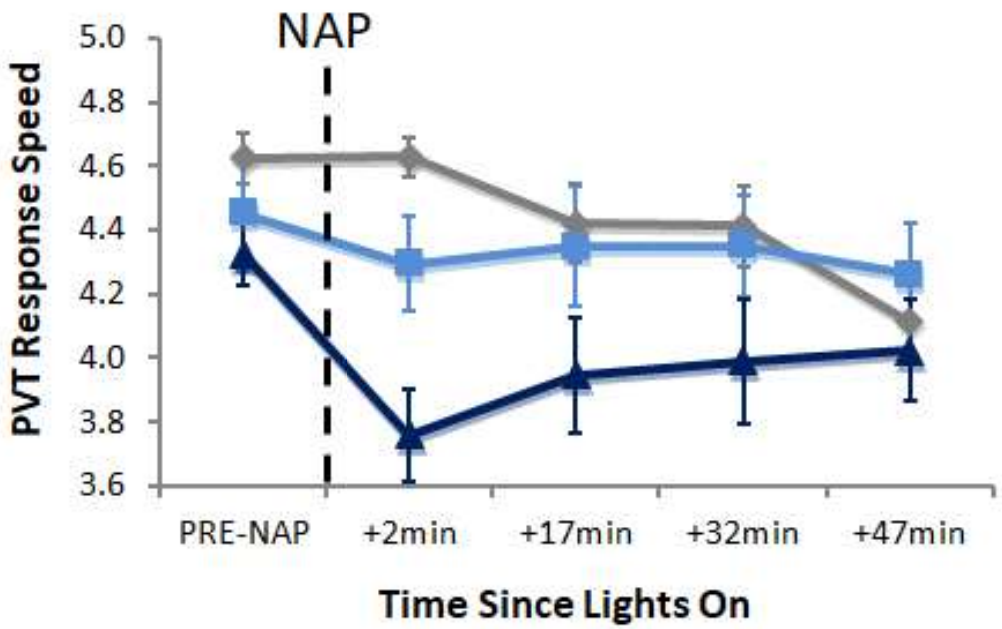
10-min nap at 0400h only stabilizes performance

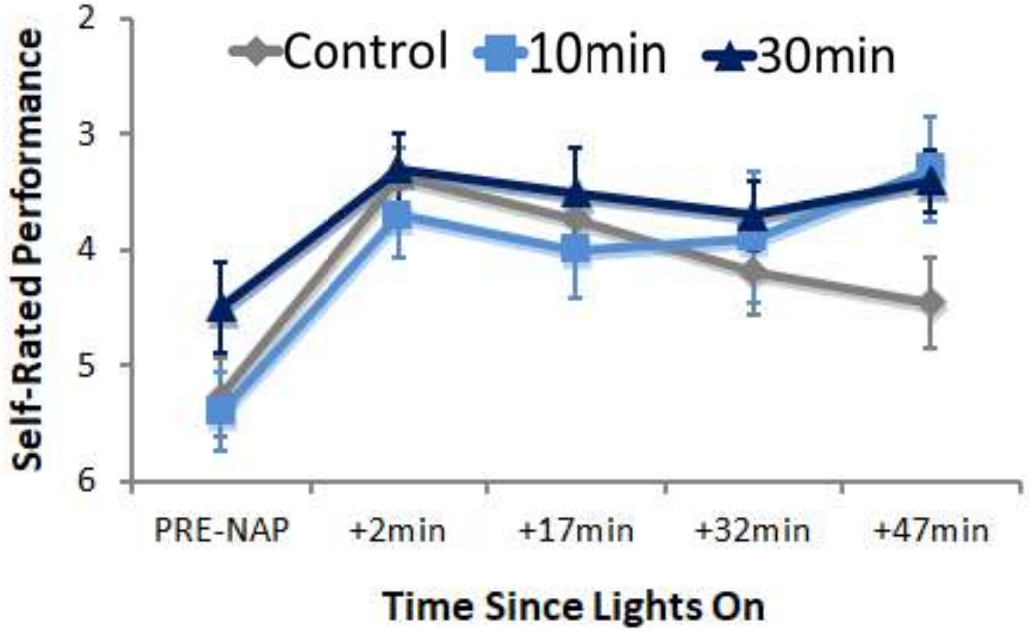


Better performance

Adapted from Hilditch et al., 2016

Subjective evaluation impaired





Driving home from night shift is associated with high accident risk.

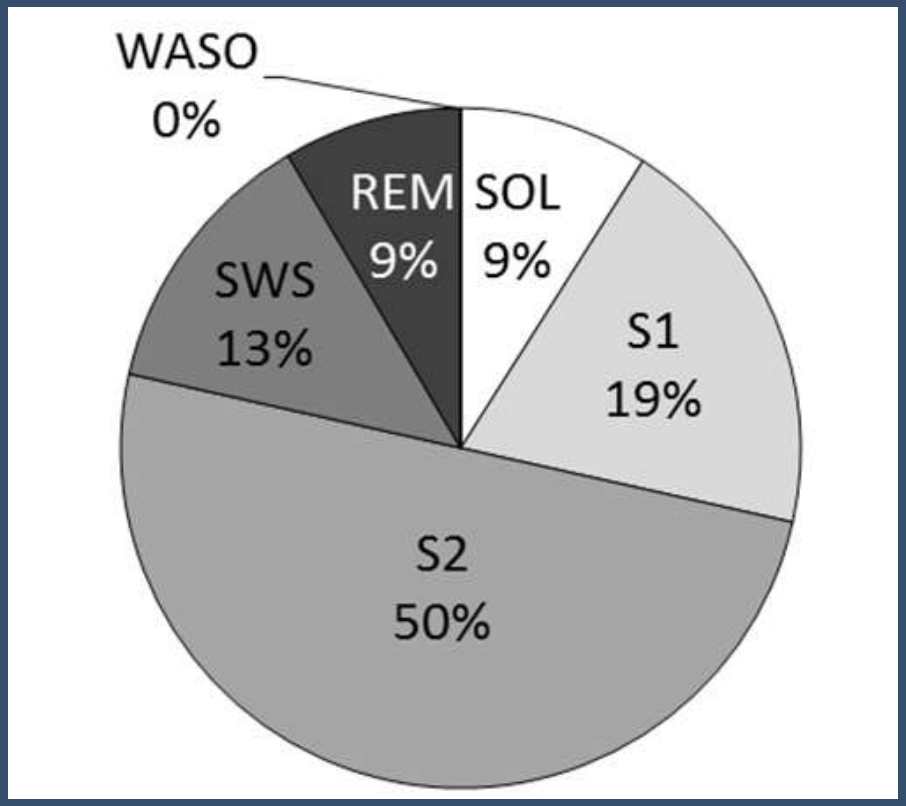
Can a short pre-commute nap improve driving and avoid sleep inertia?

Short nap before the commute home from a simulated night shift

Participants
- N = 21 (12F)
- Mean age = 24.1 y (SD 3.7)
- Non-shiftworkers

Conditions
- No nap
- 10-min nap (end @0700h)

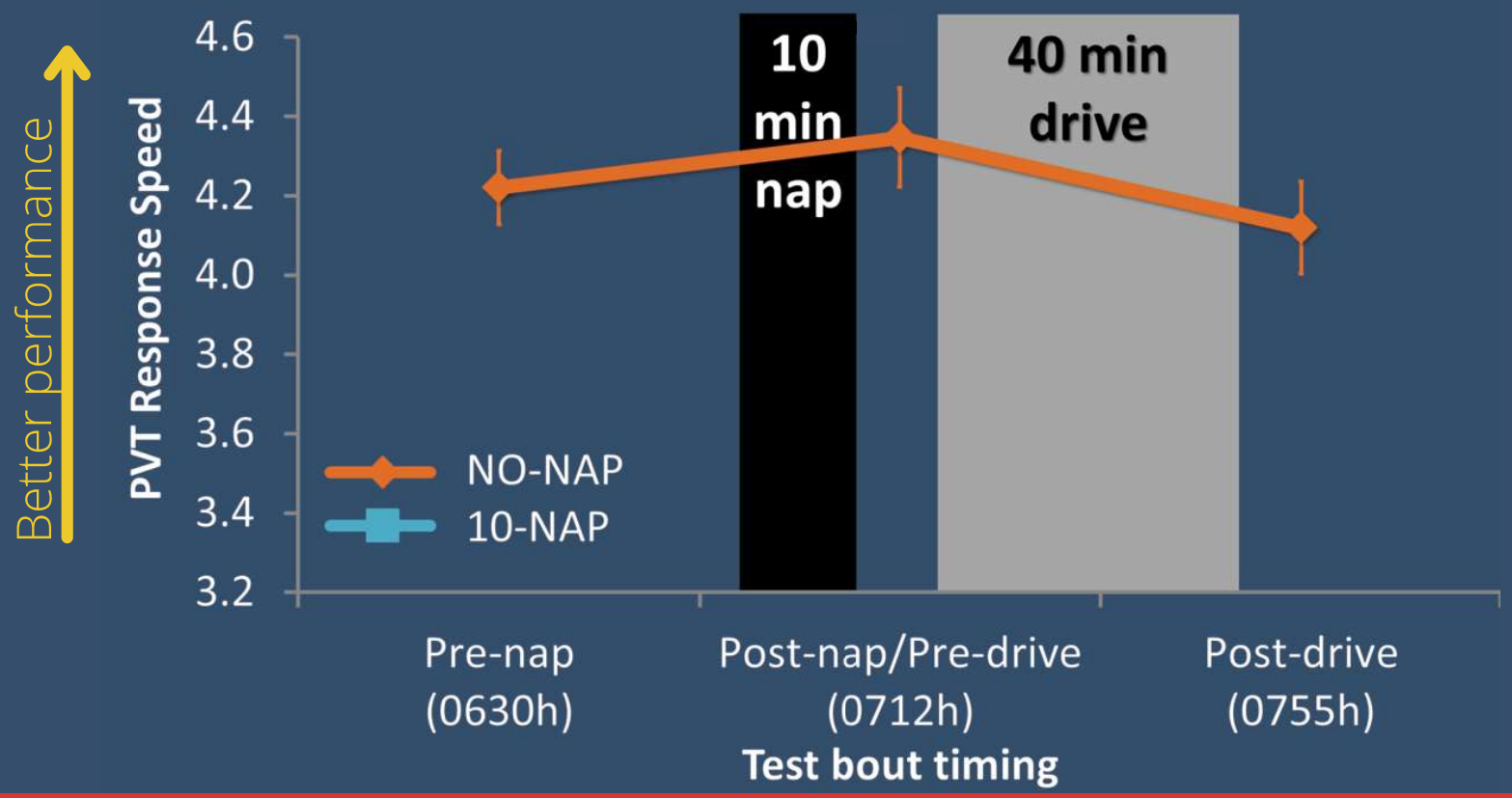
10-min nap at 0700h does not prevent SWS



Total sleep time

- 9.1 ± 1.2 min
- 40% entered SWS

Hilditch et al., 2015

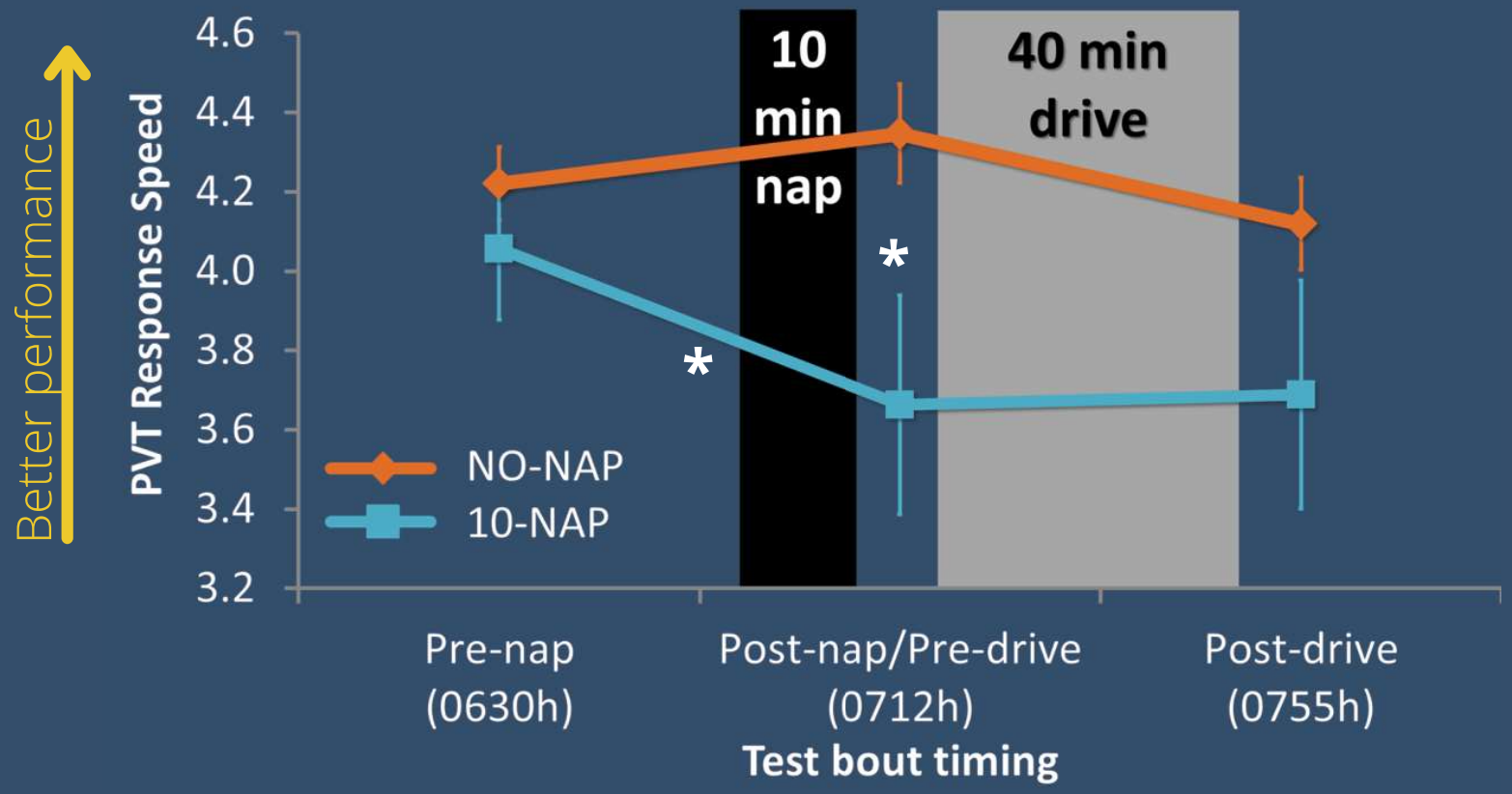


Adapted from Hilditch et al., 2015

Short nap before commute study

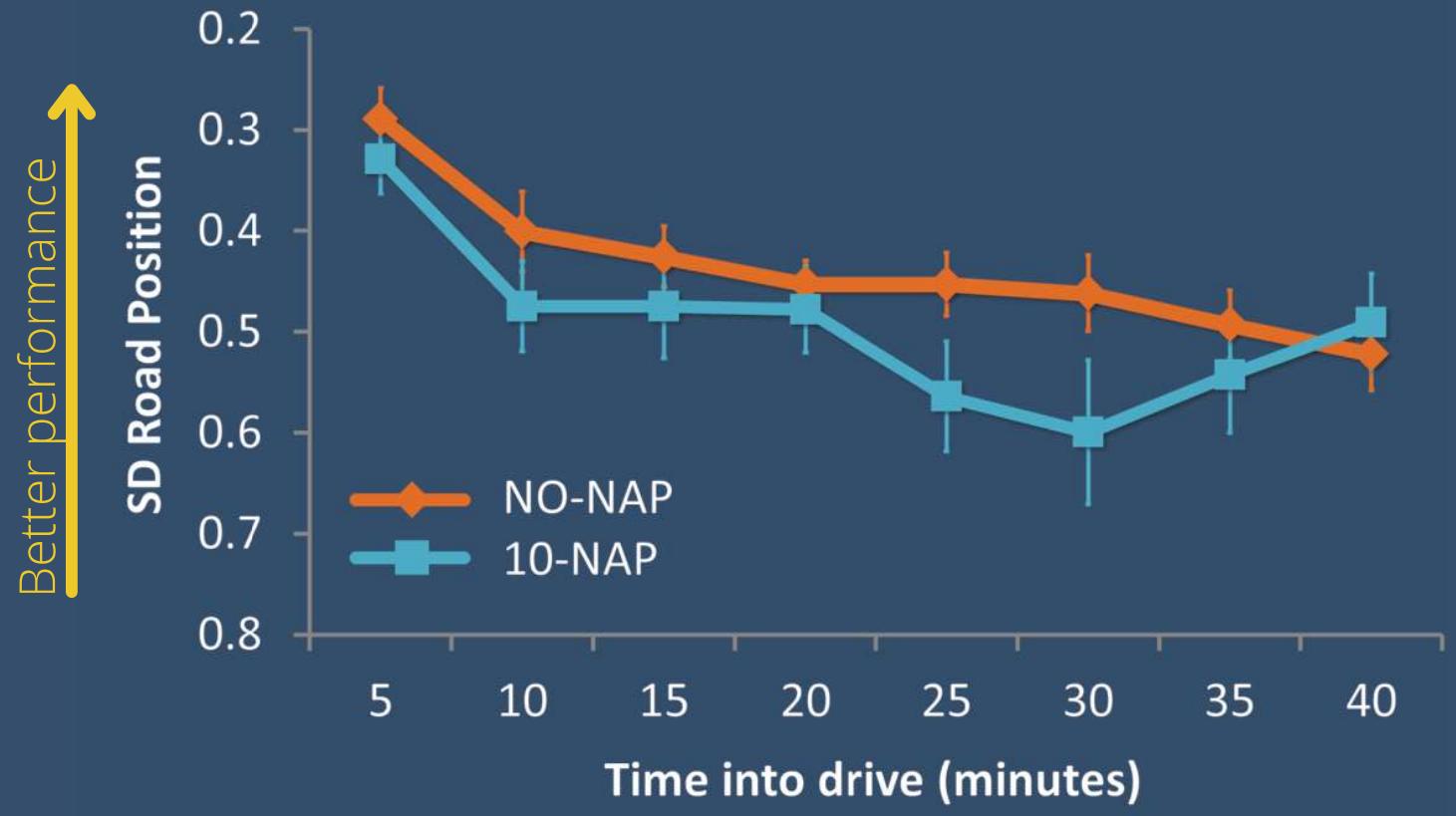
Background Methods Results Conclusions

10-min nap at 0700h impairs immediate performance



Adapted from Hilditch et al., 2015

10-min nap at 0700h does not impact driving



Adapted from Hilditch et al., 2015

Conclusions

POTENTIAL FOR SWS IN SHORT NAPS

SWS entered within 10 min of sleep opportunity

POTENTIAL FOR SLEEP INERTIA FOLLOWING SHORT NAPS

Impaired performance following 10-min nap after extended wakefulness

SUBJECTIVE EXPERIENCE NOT RELIABLE

Performance rated as improved despite impairment

Proactive countermeasures

- Avoid prior sleep loss
- Avoid waking near circadian low
- Keep naps short

Proactive countermeasures

- Avoid prior sleep loss
- Avoid waking near circadian low
- Keep naps short

Reactive countermeasures

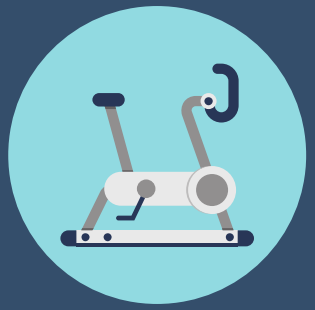
Field deployable

Caffeine

Delayed effects
Long half-life

Temperature

Only subjective, correlation
Distal-proximal gradient



Exercise

Intensity, duration
Multiple mechanisms

Sound

Intensity, frequency
Poorly controlled studies

Odor

Peppermint, smelling salts?
No studies published yet

Light

Intensity, wavelength
Time of administration

Adapted from Hilditch et al., 2016

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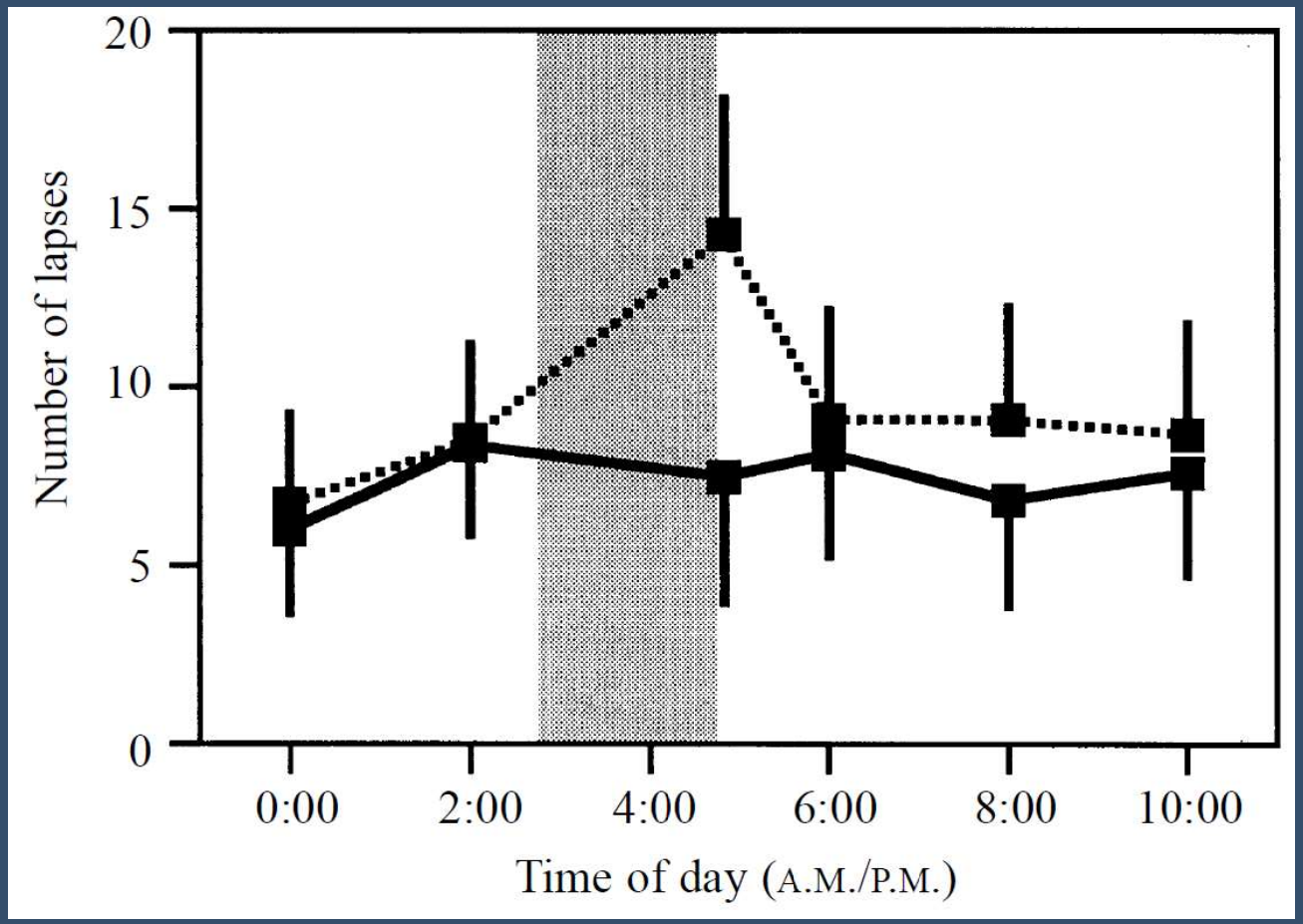
Delayed effects
Long half-life



Van Dongen et al., 2001

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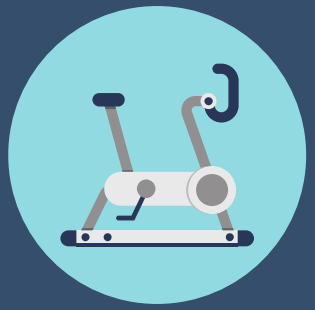

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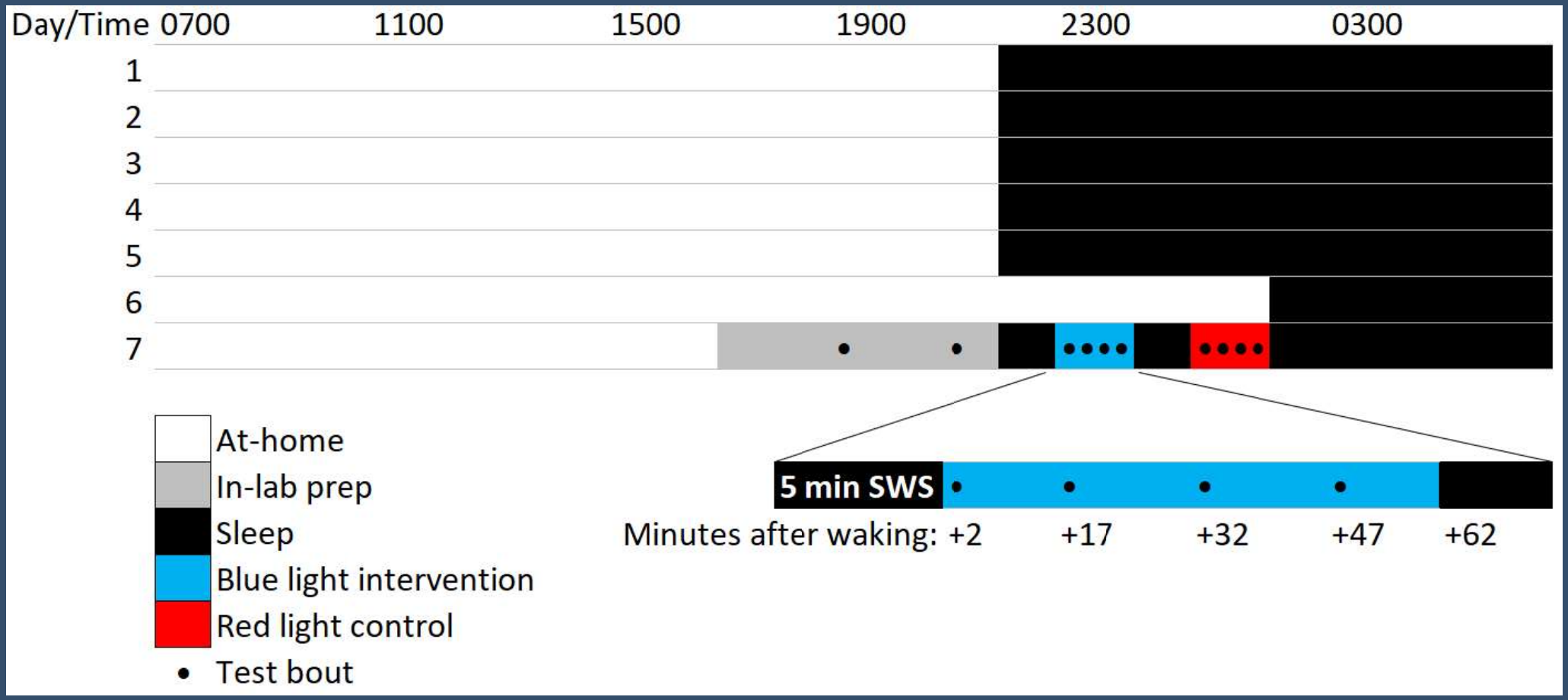
Light

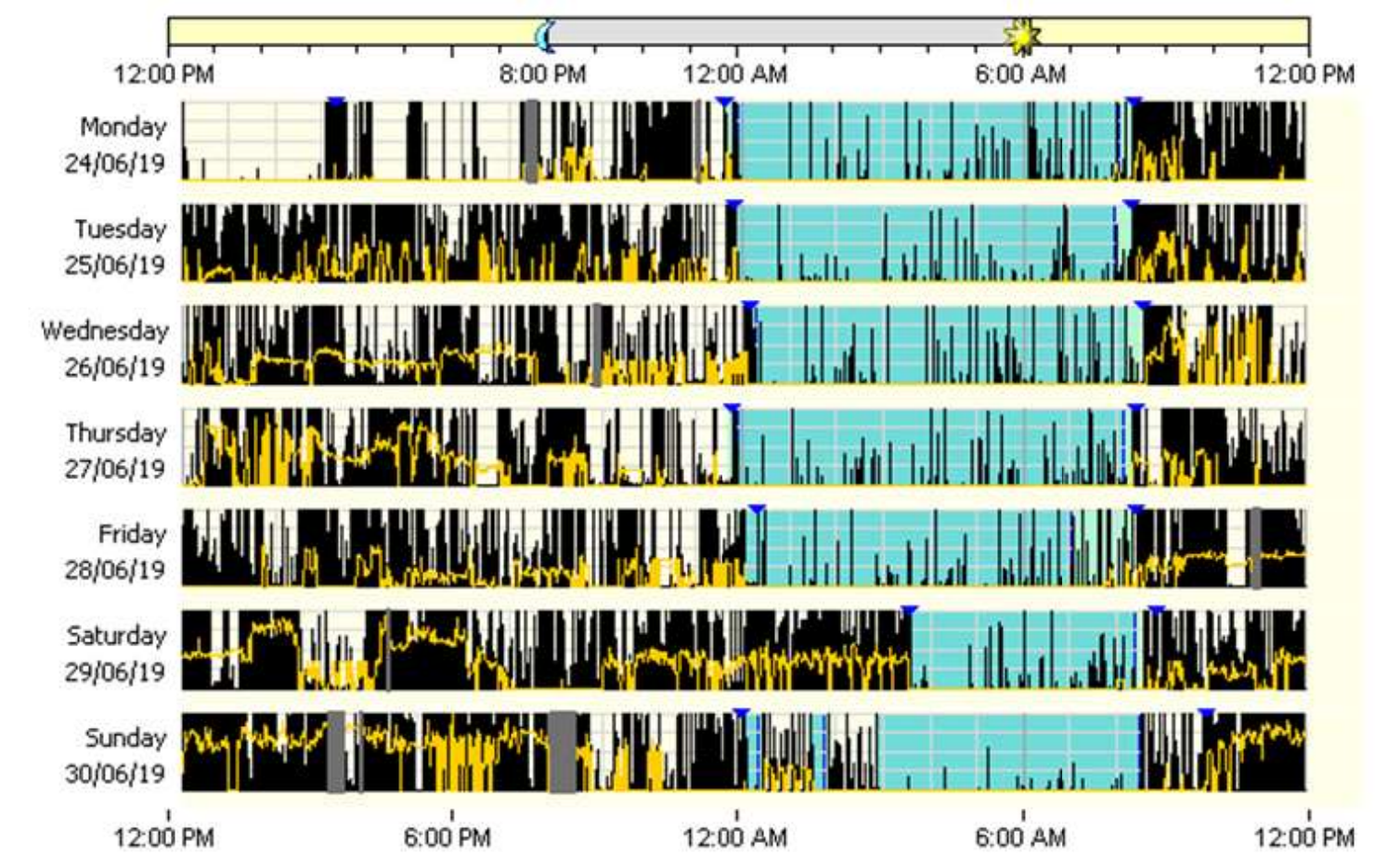
Intensity, wavelength
Time of administration

- Circadian phase shifting effects
- Acute alerting effects
- Sleep inertia countermeasure?



Light as a countermeasure study

Background Methods Results Conclusions



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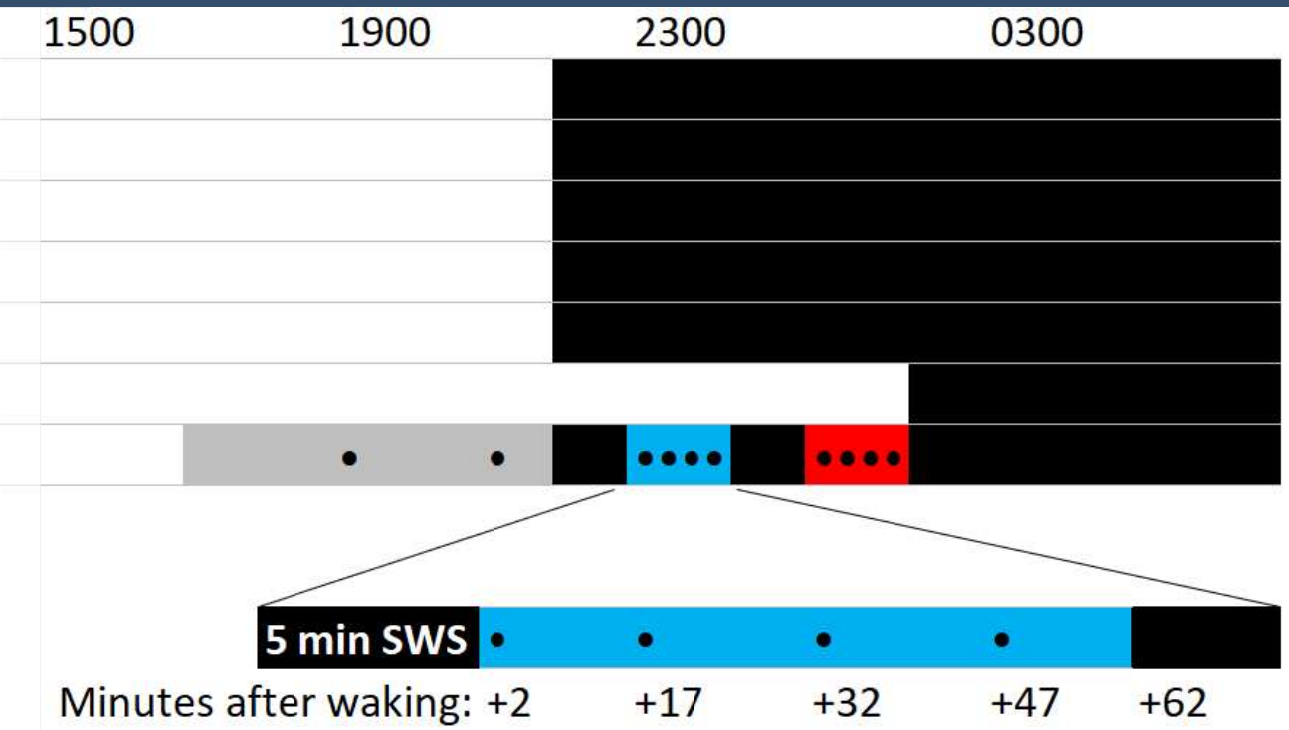

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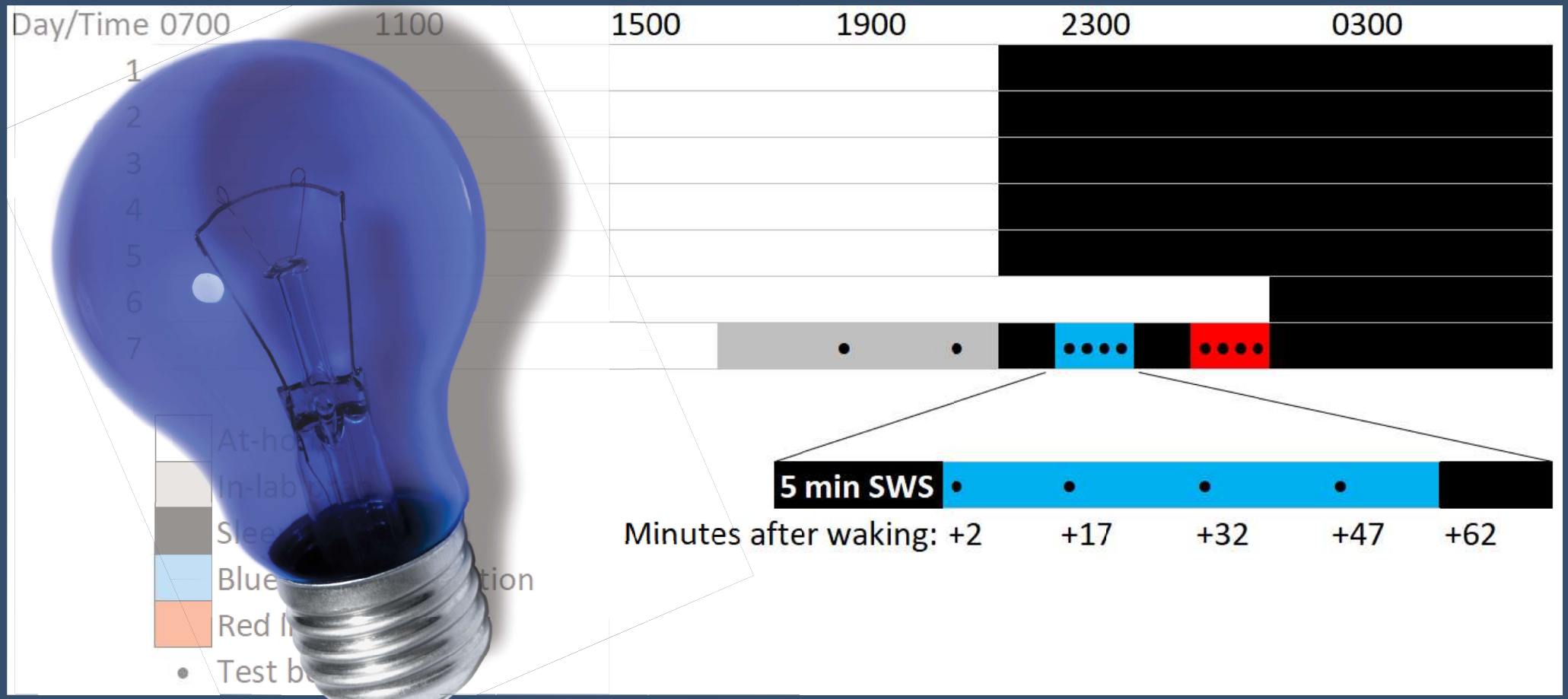
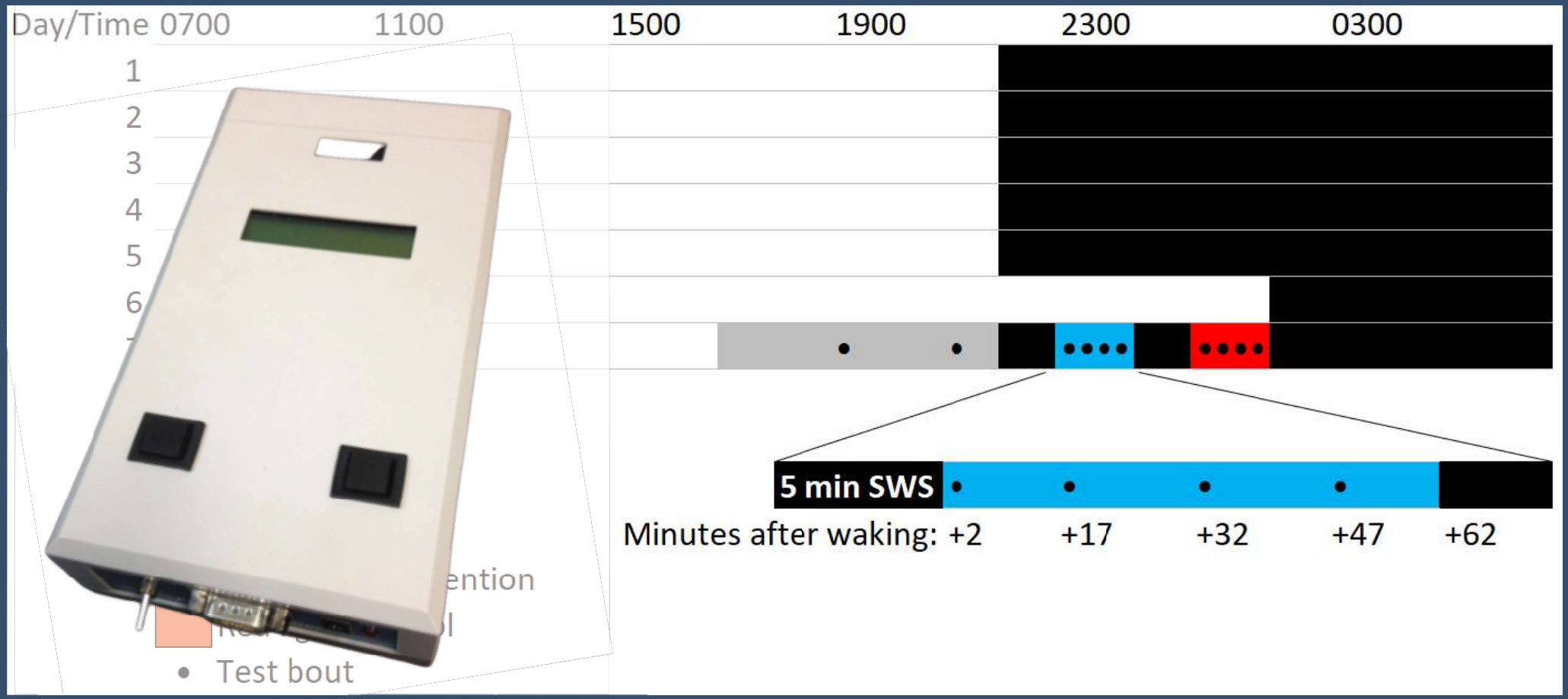


Light as a countermeasure study

Background Methods Results Conclusions

Blue light intervention

- 63.62 melanopic lux
- ~200 lux at angle-of-gaze
- Illuminated throughout test period (1 h)
- **Placebo**: ambient red light, 0.01 melanopic lux



Light as a countermeasure study

Background Methods Results Conclusions

Sleep inertia test battery

+1 min	Begin intervention/placebo
+2 min	PVT (5-min)
+7 min	KSS, Mood scales
+8 min	ANAM: Math, Go/No-Go
+13 min	Subjective performance rating
+14 min	Karolinska Drowsiness Task (3-min)

Participants

- N=12 (6F)
- Mean age 23.3 y (SD 4.2, range 19-35)
- 50% Asian, 42% White, 25% Hispanic
  (participants could identify as more than one ethnicity)

Conclusions

RISE AND SHINE!

Blue-enriched light exposure after waking improves performance, alertness, mood

HAVE A "NAPPUCCINO"

Caffeine before a short nap; proactive

JUMP OUT OF BED?

Exercise shows subjective improvements; strong mechanistic theory

WAKE UP AND SMELL THE... ?

Odor studies underway... watch this space!

CAUSES

Beginning to better understand the underlying neural physiology, potential targets

CONSEQUENCES

Brief but severe impairment, with real world consequences

COUNTERMEASURES

Exciting research underway, need to test field deployability

Time to wake up!

NASA & San Jose State University
Erin Flynn-Evans, PhD MPH
Lily Wong, MS
Nathan Feick, MS
Nick Bathurst, MA
Javier Garcia, PhD
Kanika Bansal, PhD
NASA System Wide Safety
Naval Postgraduate School

University of South Australia
Stephanie Centofanti, PhD
Jill Dorrian, PhD MS
Siobhan Banks, PhD
Australian Postgraduate Award
UniSA Postgraduate Scholarship

Thank you!

cassie.j.hilditch@nasa.gov