Advancing Fatigue Research at the Douglas Institute: Why does time matter?

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Fatigue and accidents

- Human errors: 80% of industrial accidents
- First cause: attention lapses and fatigue
- Reduced attention: 70% of railway incidents/accidents
- Fatigue: 31% of fatal to the driver truck accidents

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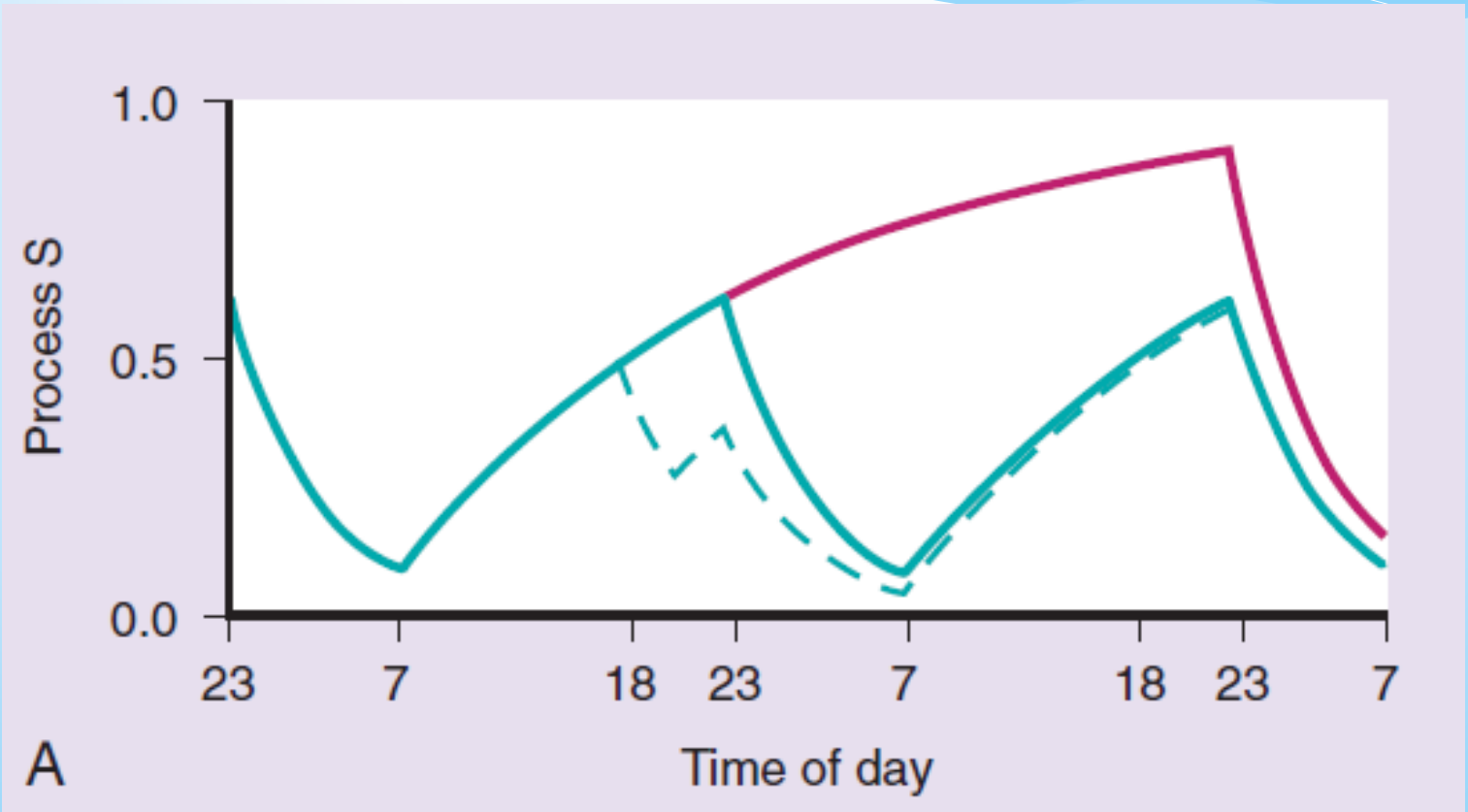
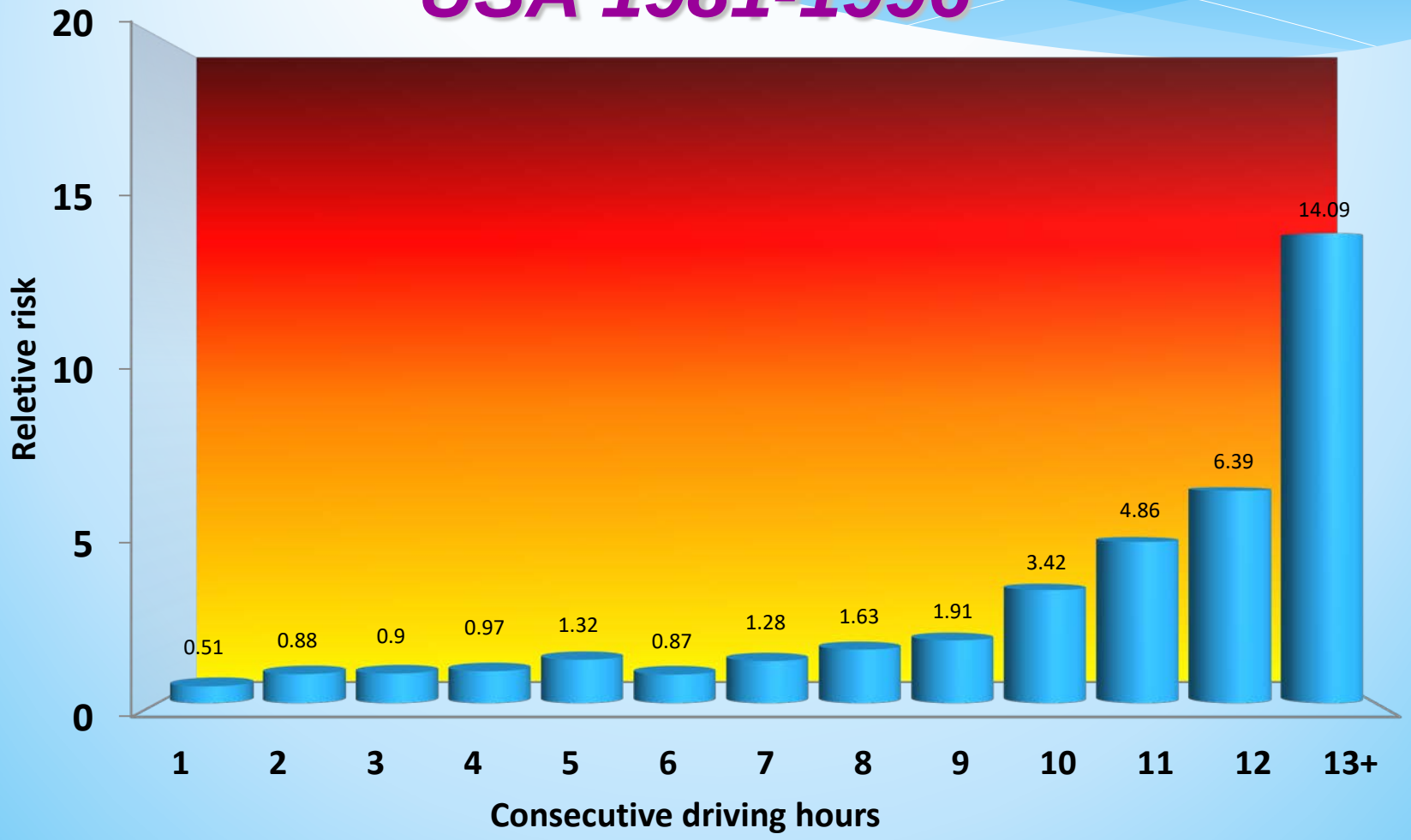
Wake duration affects vigilance



Achermann & Borbély, *Principles and Practice of Sleep Medicine,* 2011;Chap 37:439

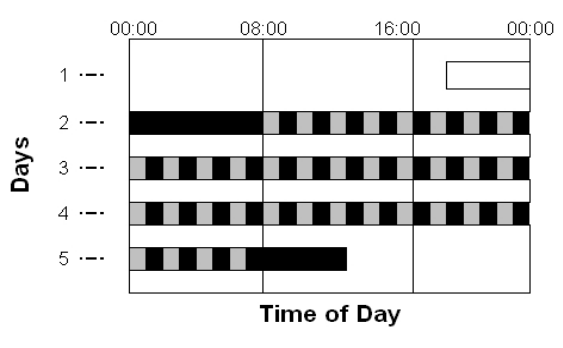
Accidents fatal to the CMV driver

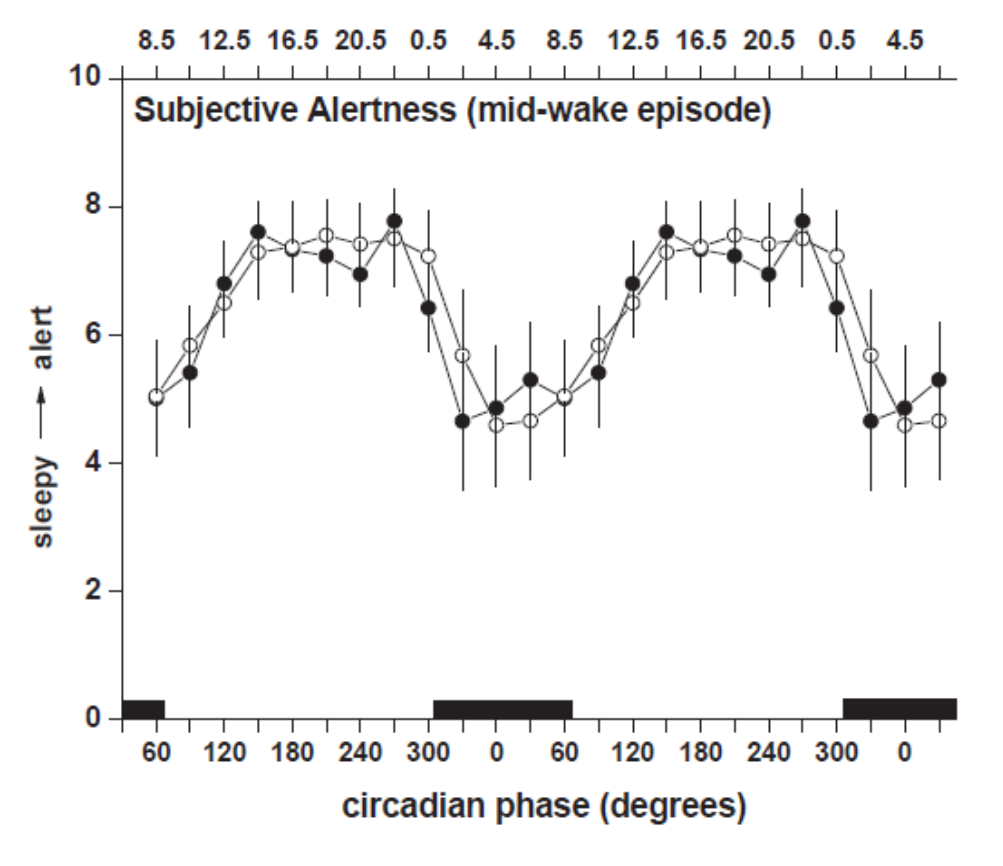
USA 1981-1996



Adapted from Campbell et Belzer 2000(*Fig. 59)*

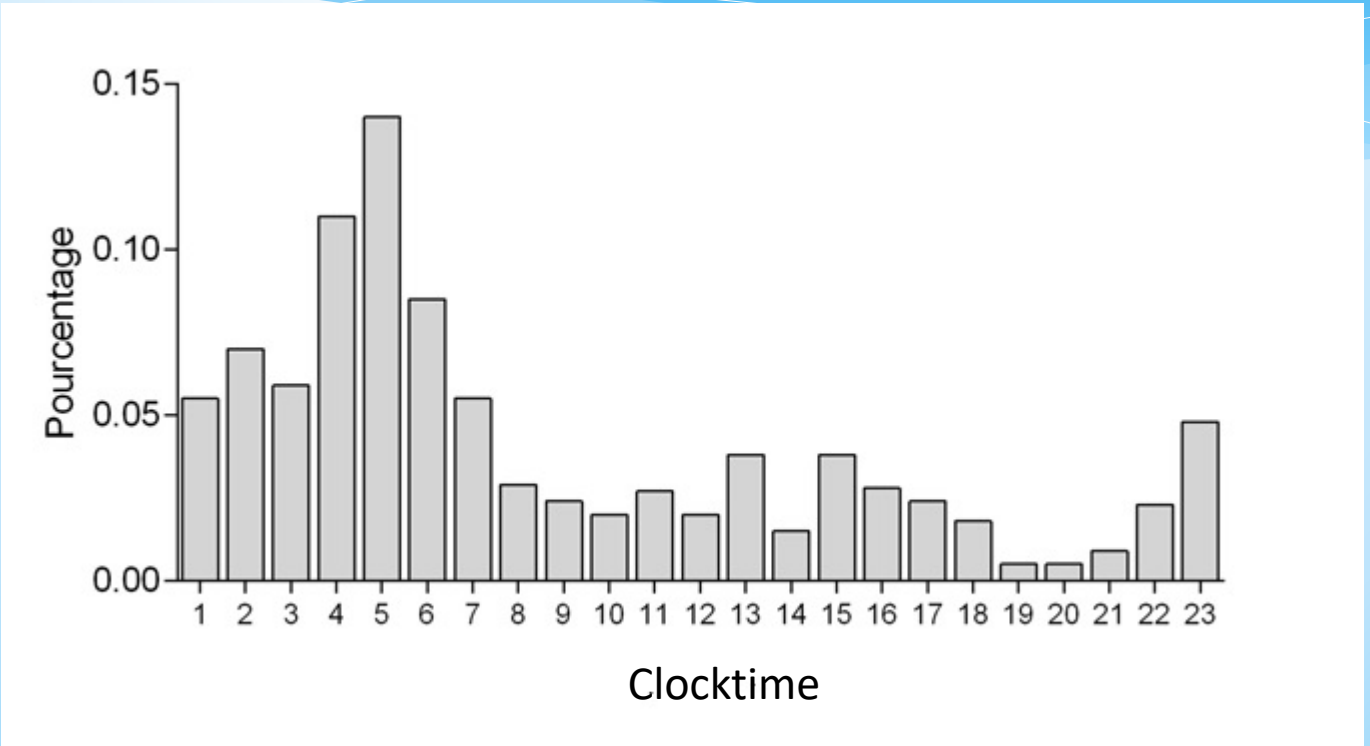
The circadian clock affects vigilance





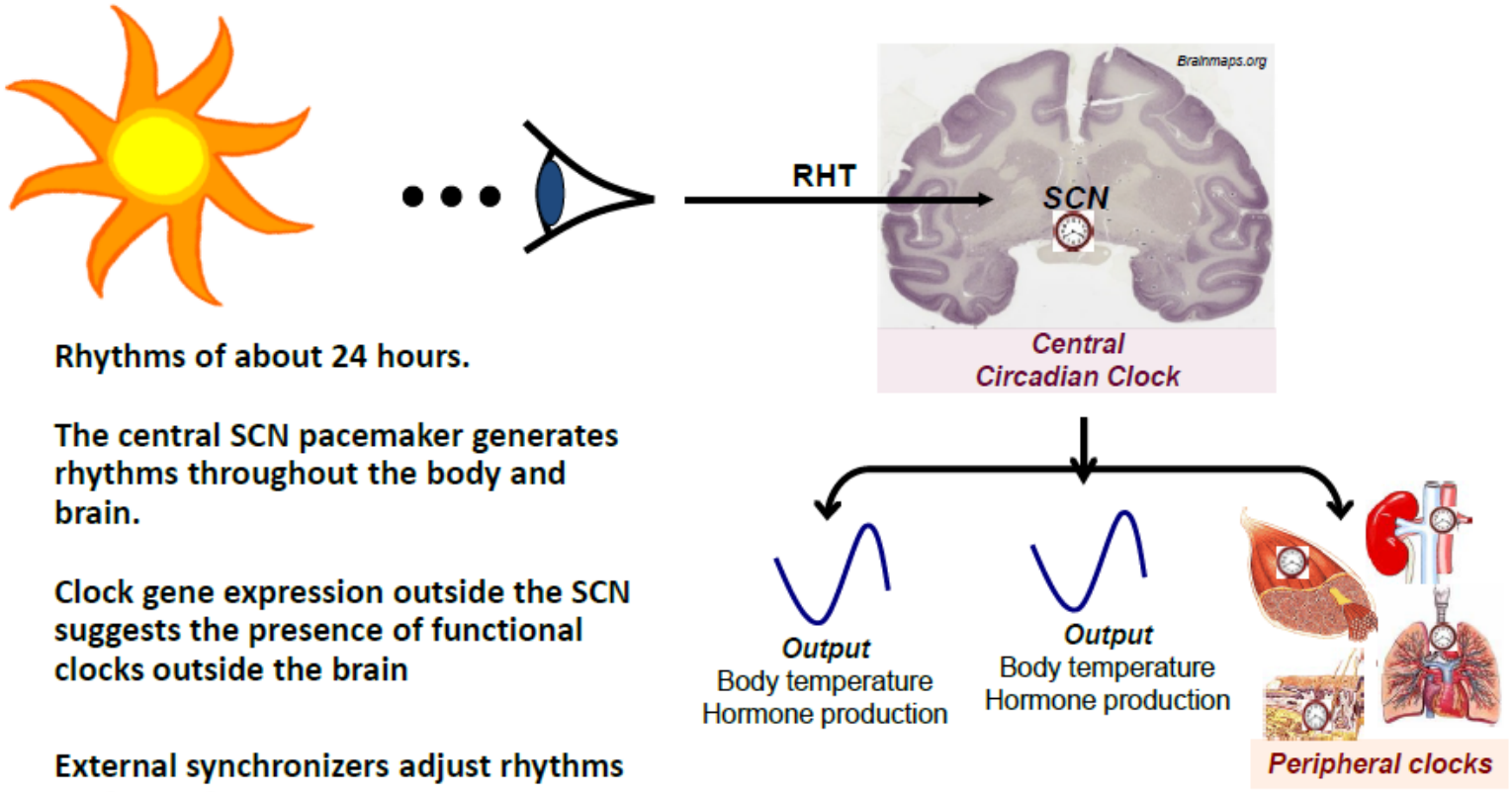
Shechter A et al. *Sleep* 2010

Accidents fatal to the CMV driver



Adapted from Campbell et Belzer 2000*(Fig. 89)*

The biological (*circadian*) clock



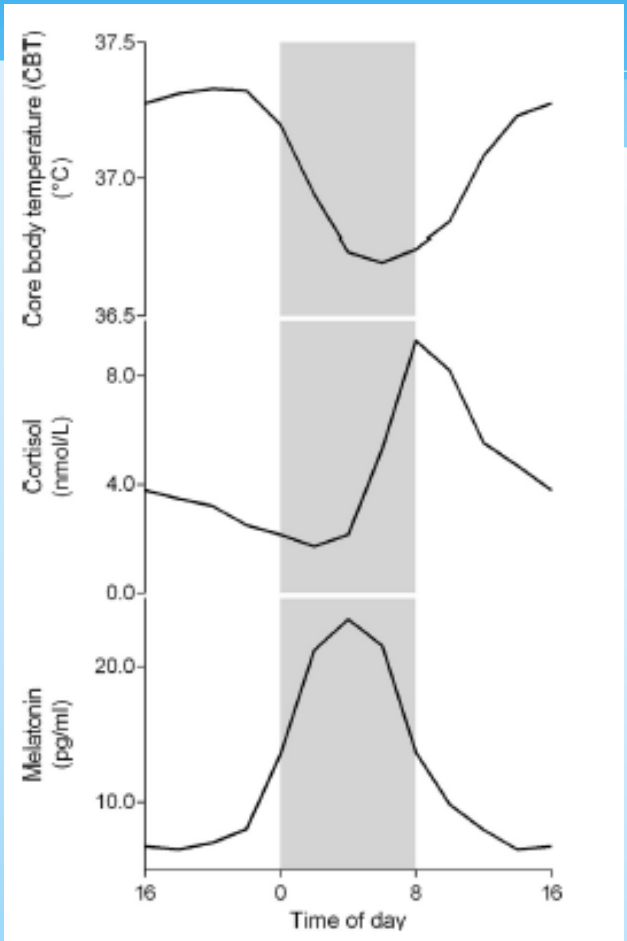
Rhythms of about 24 hours.

The central SCN pacemaker generates rhythms throughout the body and brain.

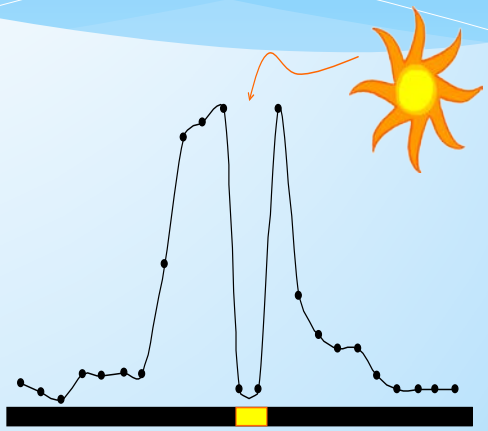
Clock gene expression outside the SCN suggests the presence of functional clocks outside the brain

External synchronizers adjust rhythms to the environment.

A few circadian rhythms

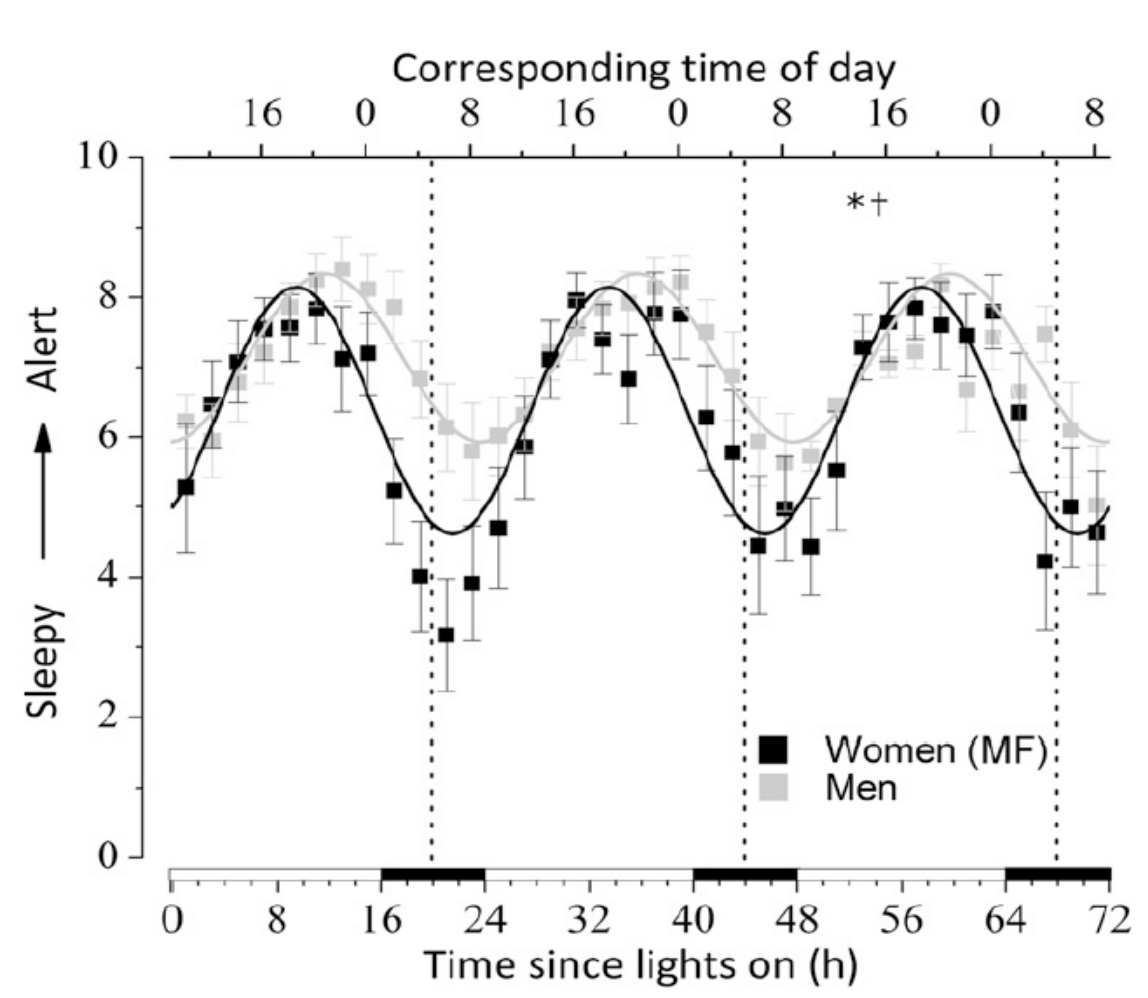


Boivin DB et al. *Pathologie Biologie* 2014



Boivin DB. Unpublished

Sex affects the circadian clock



Boivin DB et al. *PNAS* 2016

Atypical work schedules

Day shifts

- Early bedtimes and wake times

Night shifts

- Work when one would sleep
- Sleep when one would wake
- Abbreviated sleep
- Extended waking

Shift work associated risks

- Shift work is an individual risk factor for several medical conditions (cancer, gastrointestinal, metabolic, cardiovascular, psychiatric)

- Sleep-wake disruption in shift workers
  - Great individual variability in in sleep-wake disruption
  - About 5-10% of shift workers will develop SWSD
  - 2/3 of all attention failure during sleep deprivation accounted for by 25% of individuals (Czeisler CA 2009)
  - Individual factors affects severity of performance decrements to sleep deprivation (Van Dongen, H. P. Sleep 2005)

- Circadian factors in shift workers
  - Morning types have greater difficulties with night shifts and evening types with day shifts (Breithaupt, H. *et al* 1978; Hilliker, N.A. Et al 1992; Martin JS et al 2012))
  - Genetic predisposition (PER3$^{5/5}$)(Viola, A.U. *et al.* 2007, 2008)
  - Sex difference in the circadian variation of sleep (Boivin D.B. *et al* 2016)

Daytime sleep

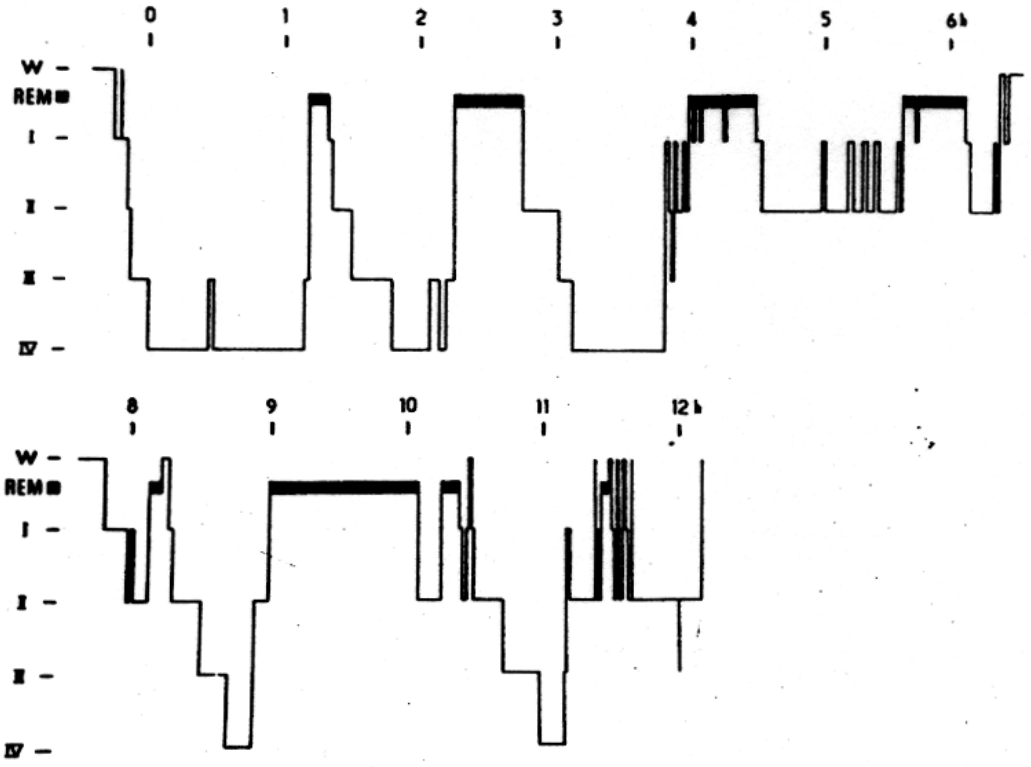
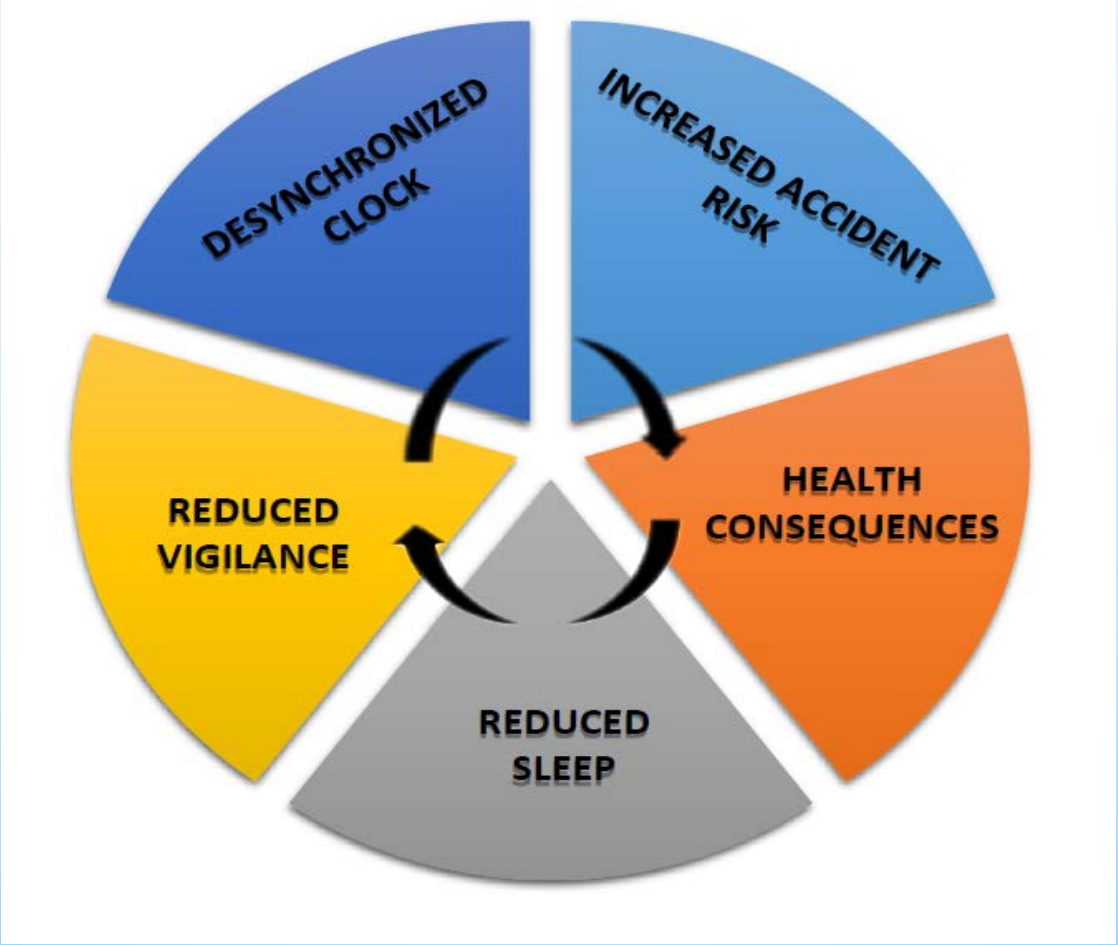


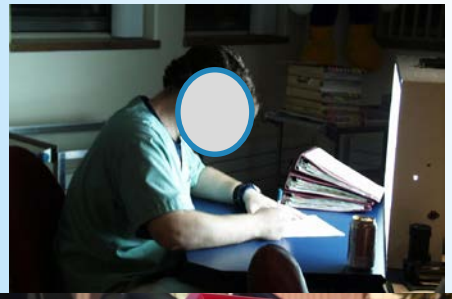
Fig. 1. Example of two "hypnograms": above a reference night. Below a day sleep of the same subject. As already reported in Table 2, the latency of the first PS period decreases and its duration increases (actually in this instance the second PS period increases)

Forêt et al *1986*

Workers on atypical schedules are at greater risk of fatigue-related accidents

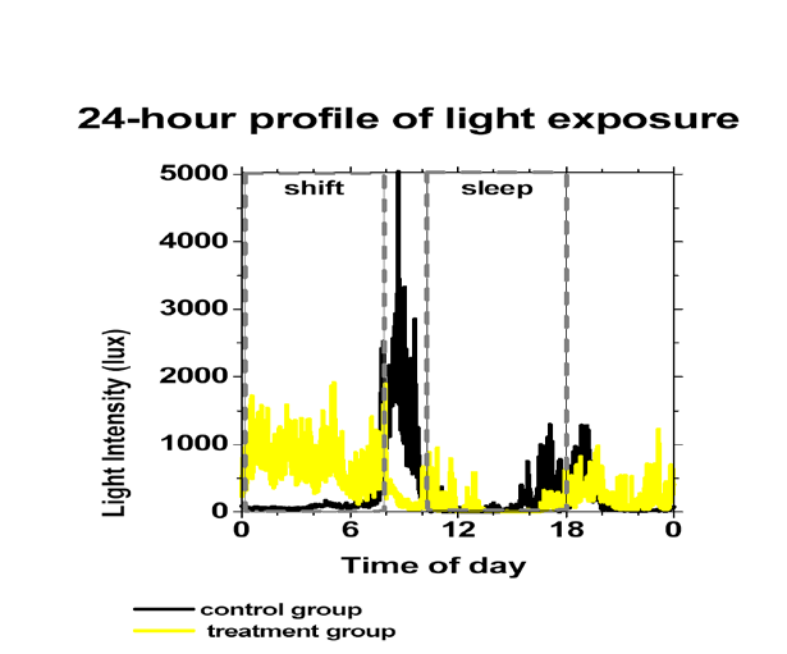


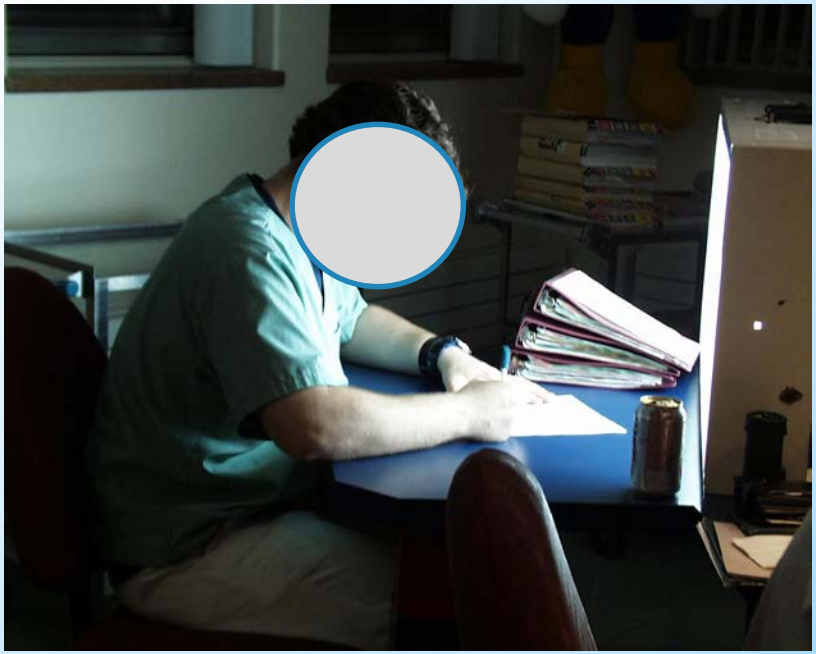
Field studies of shift workers



- Nurses on full time night schedule (≥8 nights/15 days)
- Police officers on rotating shifts
- Commercial ship pilots on irregular schedules

Hospital nurses study

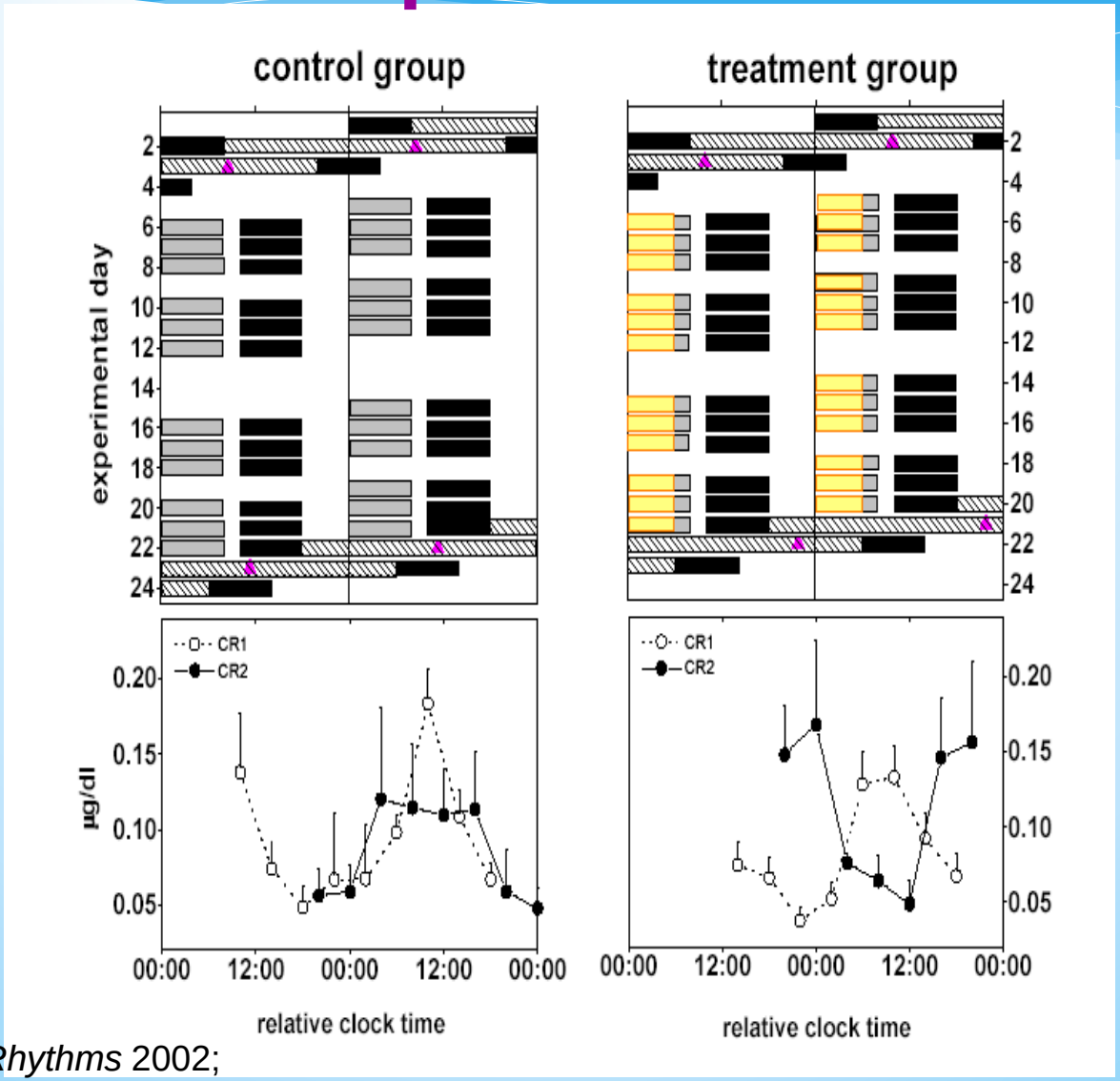




Boivin DB et al. *J Biol Rhythms* 2002

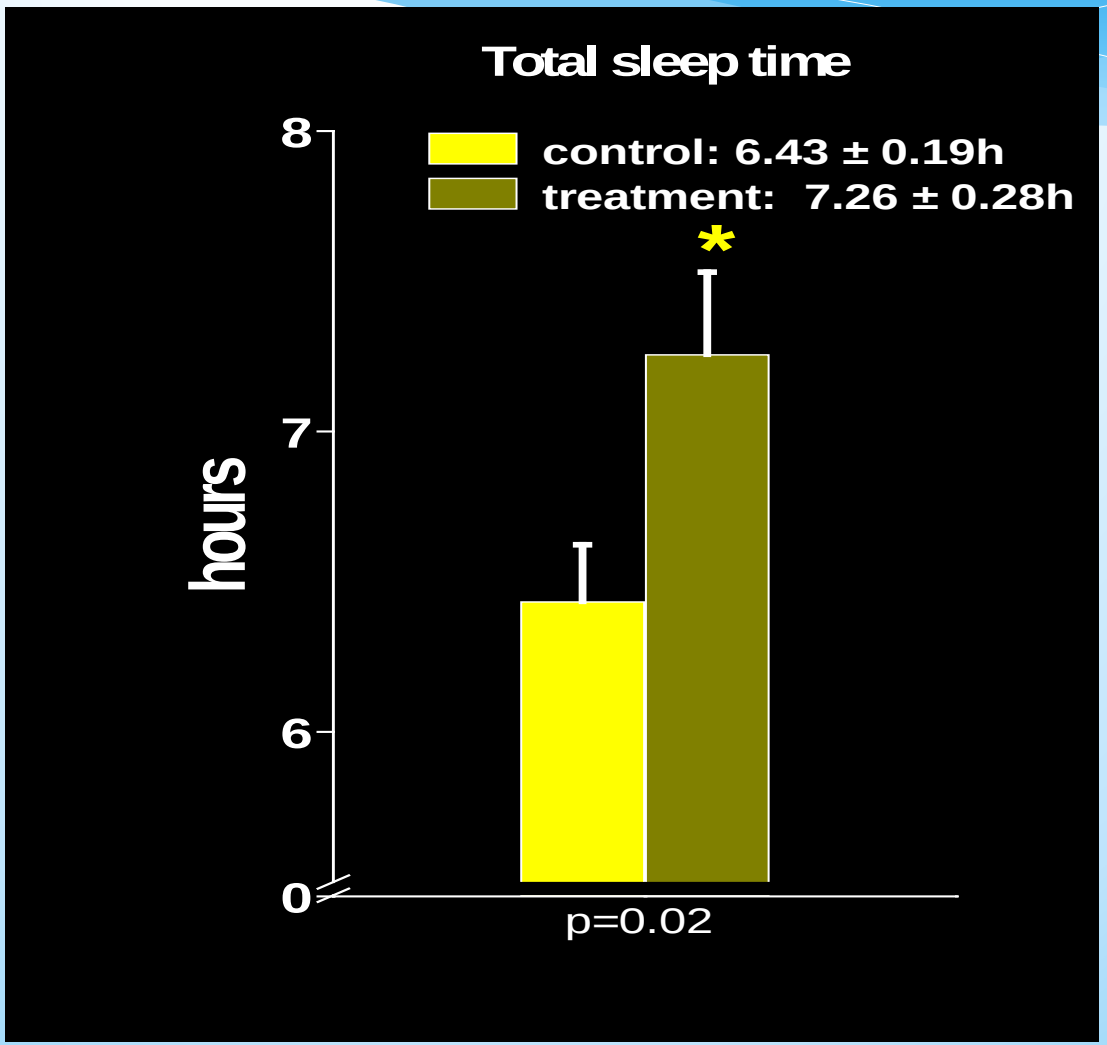
Control: 3 men, 6 women, 42.0 ± 7.2 y.o
Treatment: 4 men, 6 women, 41.7 ± 8.8 y.o

Hospital nurses



Boivin DB et al. *J Biol Rhythms* 2002;
James FO et al. *Chronobiol Int* 2004;
Boivin DB et al. *Chronobiol Int* 2012

Circadian adaptation affects sleep



Boivin DB et al *Chronobiol Int* 2012

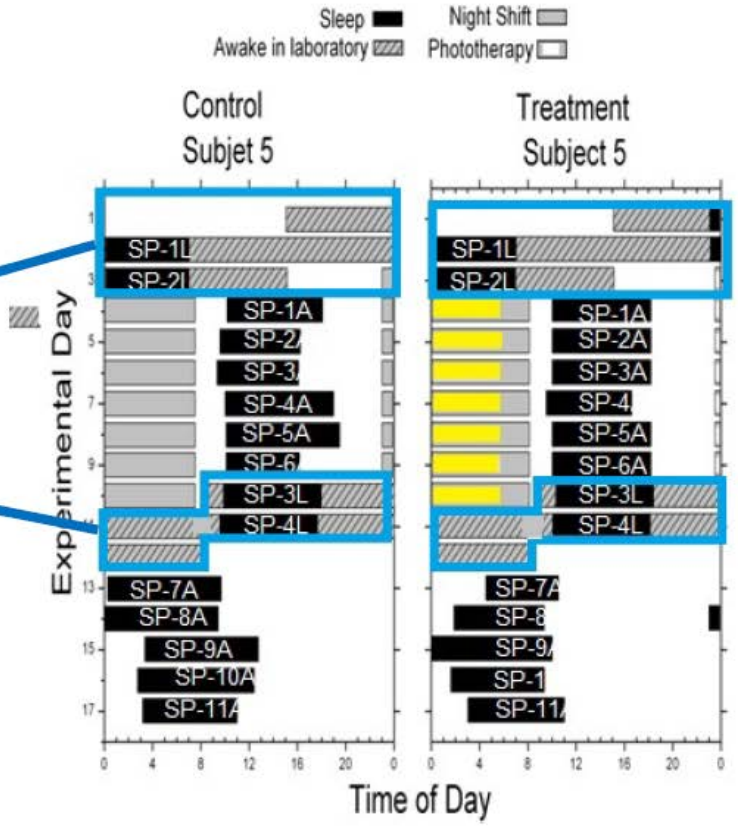
Police Officers' study

Control group: 4 women, 4 men, 29.8 ± 6.5 y.o.

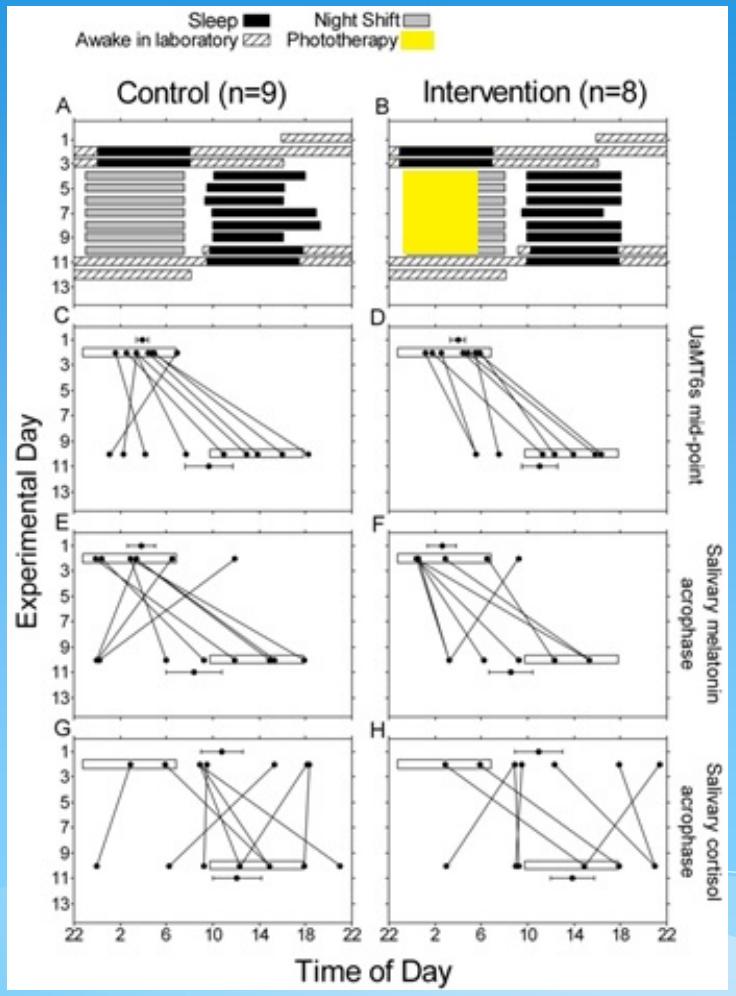
Intervention group: 4 women, 5 men, 30.3 ± 4.1 y.o.

D–Day shift
E–Evening shift
N–Night shift
O–Off

Dim	Lun	Mar	Mer	Jeu	Ven	Sam
O	E	E	E	O	O	D
D	D	D	O	O	N	N
N	N	N	N	N	O	O
O	O	O	O	E	E	E
E	O	O	D	D	D	O



Circadian adaptation of police officers



Boivin DB et al. *Chronobiol Int* 2012

	UaMT6s	Salivary Melatonin
Control group		
(n=9) **Average**	**-5.75**	**-4.52**
SE	**2.10**	**3.21**
Intervention group		
(n=8) **Average**	**-7.07**	**-5.93**
SE	**1.26**	**2.3**
p value Bilateral t test	***0.62***	***0.73***

Intervention vs control group

Greater, but n.s. phase delay

Circadian adaptation takes time

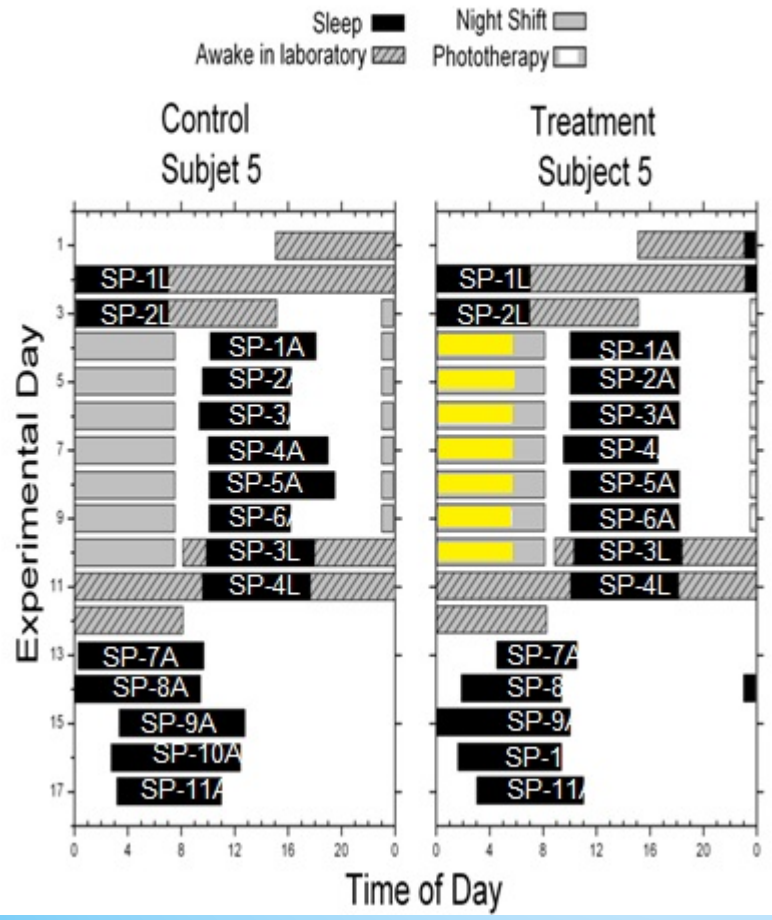
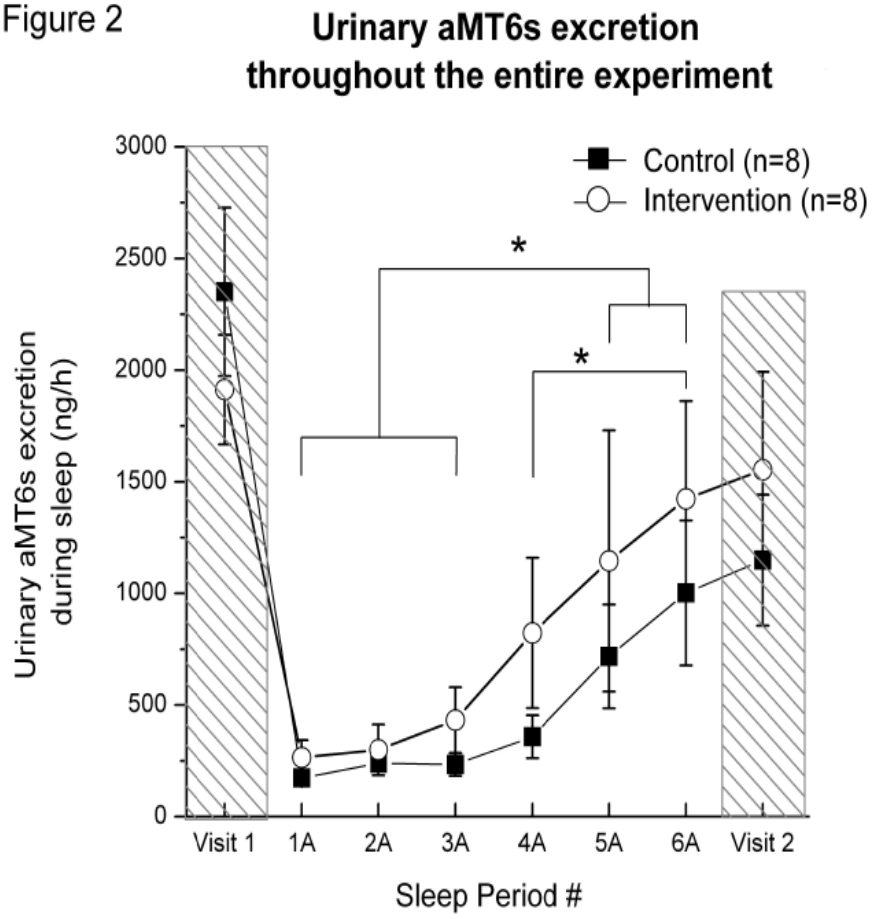
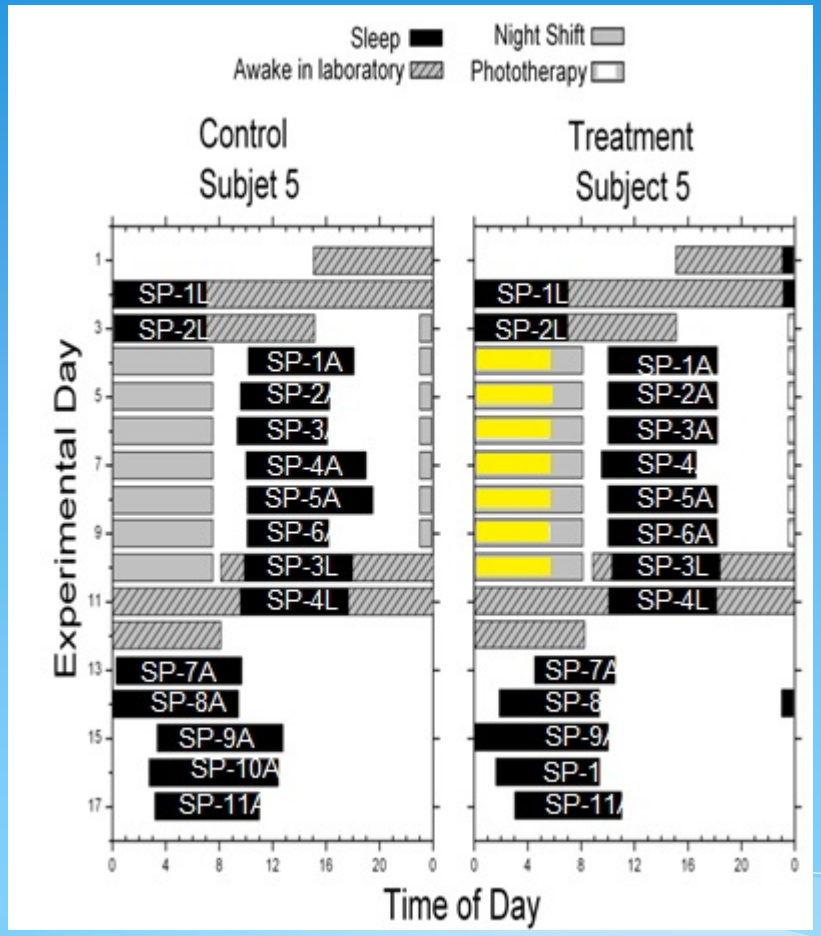


Figure 2

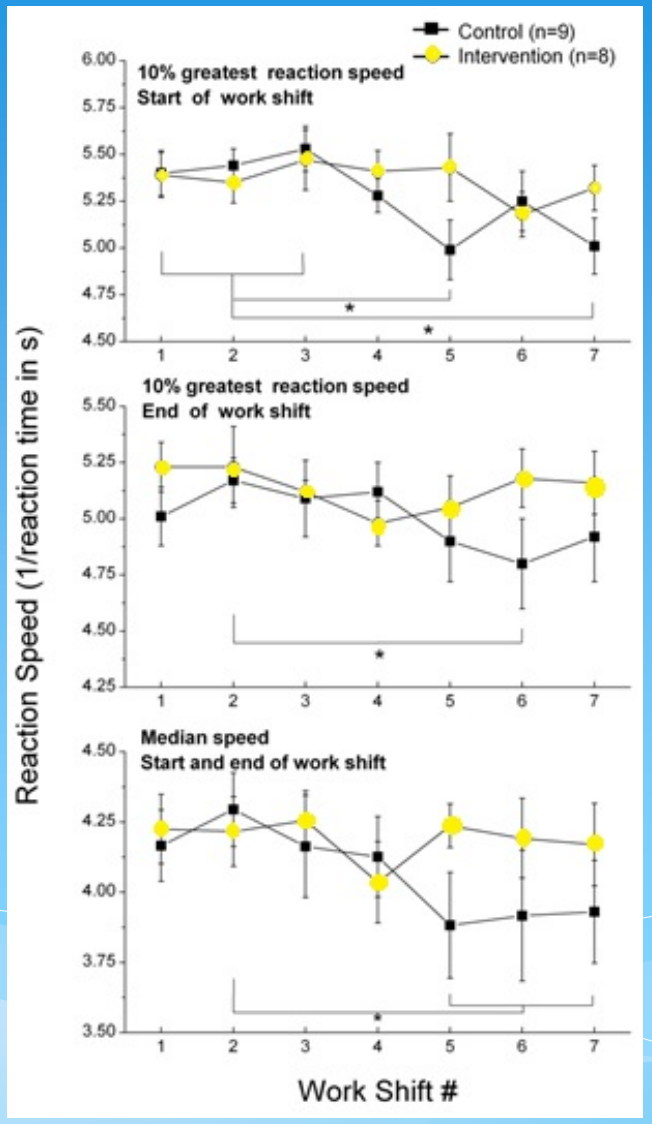


Boivin DB et al. *Chronobiol Int* 2012

Psychomotor performance across nights



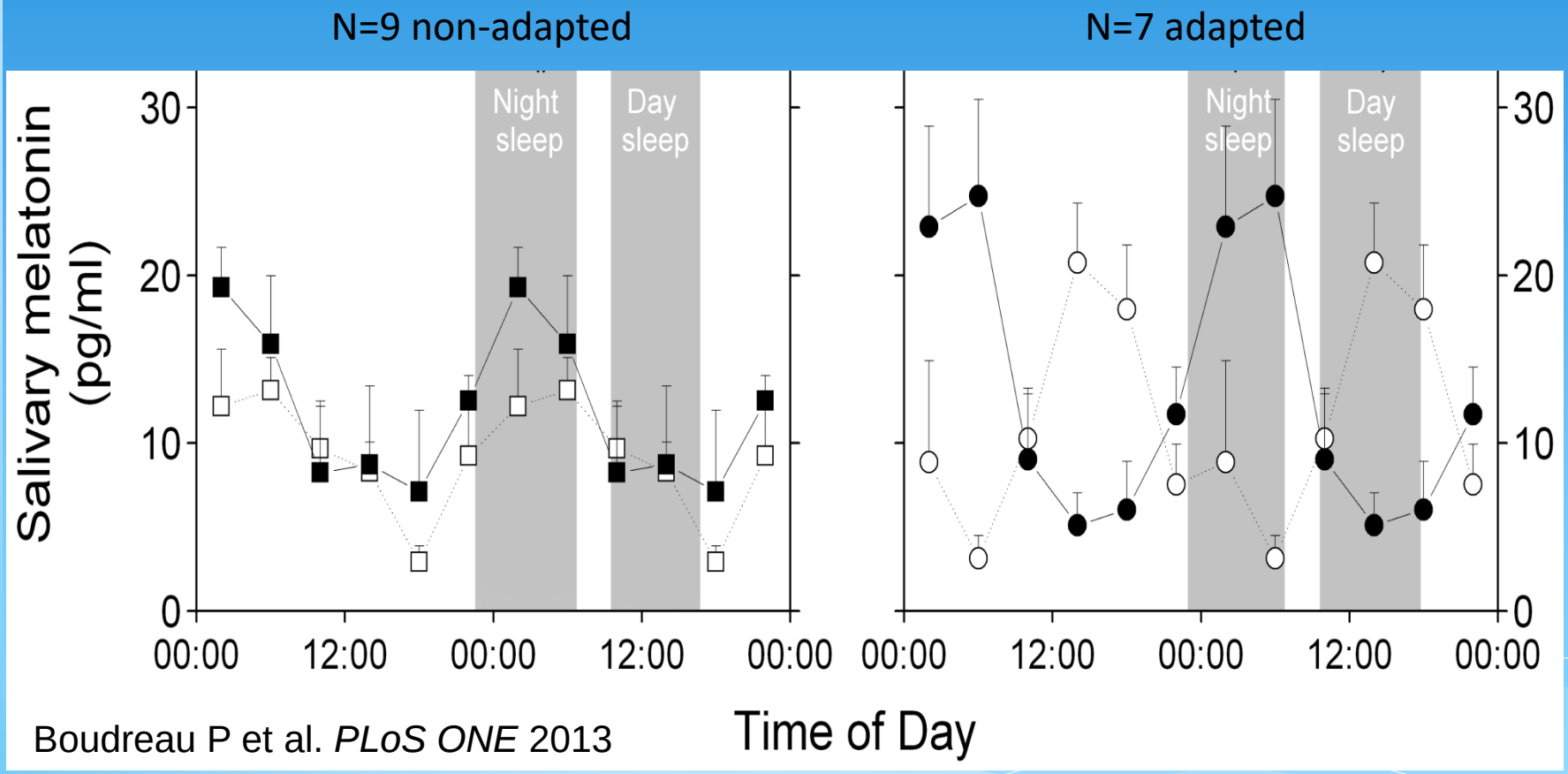
Boivin DB et al. *Chronobiol Int* 2012



Prevalence of circadian adaptation?

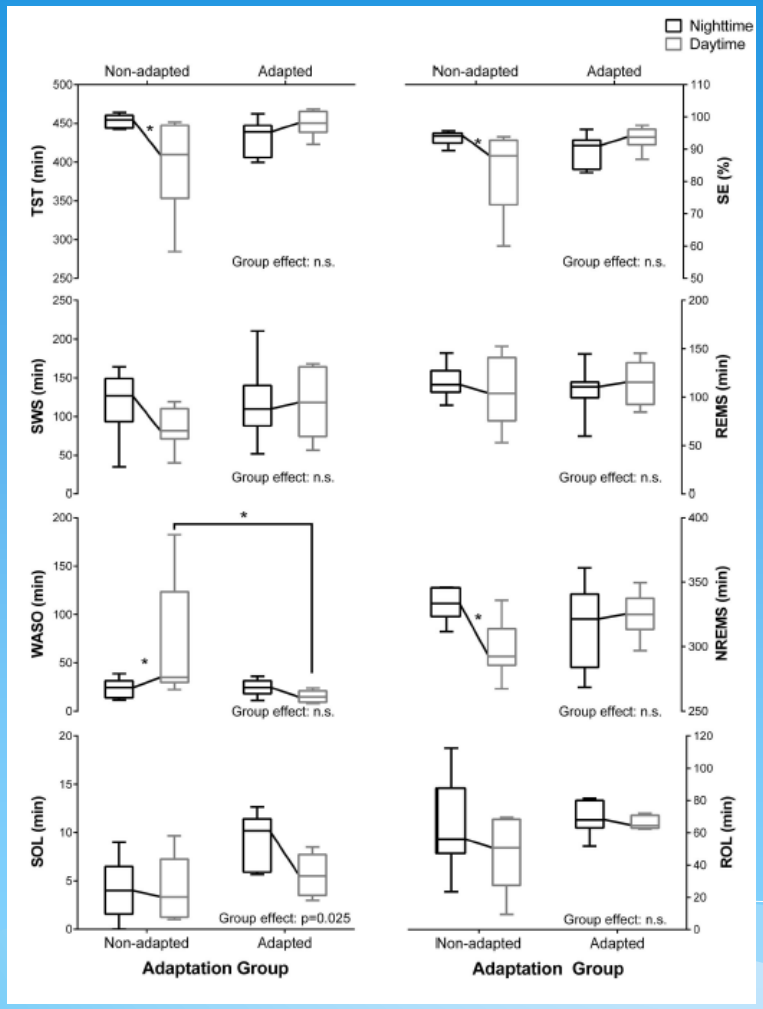
N=15, Aged: 30.1 ± 5.2 years

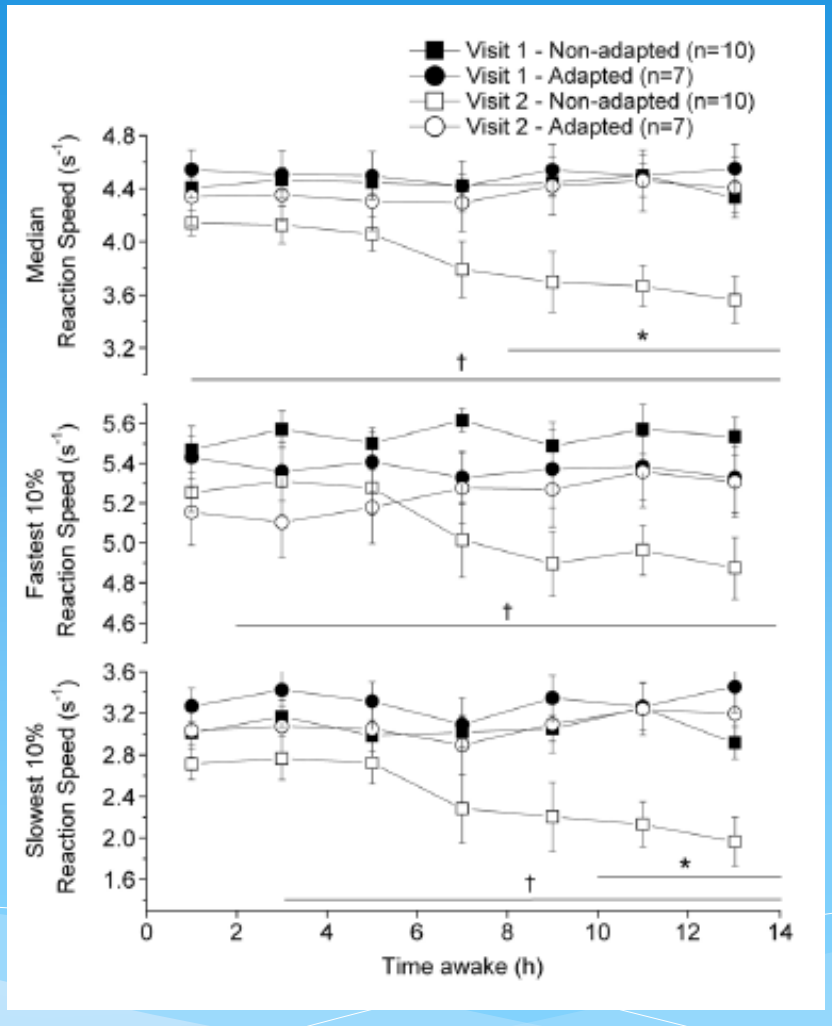
40% spontaneously adapted after 7 consecutive night shifts



Boudreau P et al. *PLoS ONE* 2013

Impact of circadian adaptation





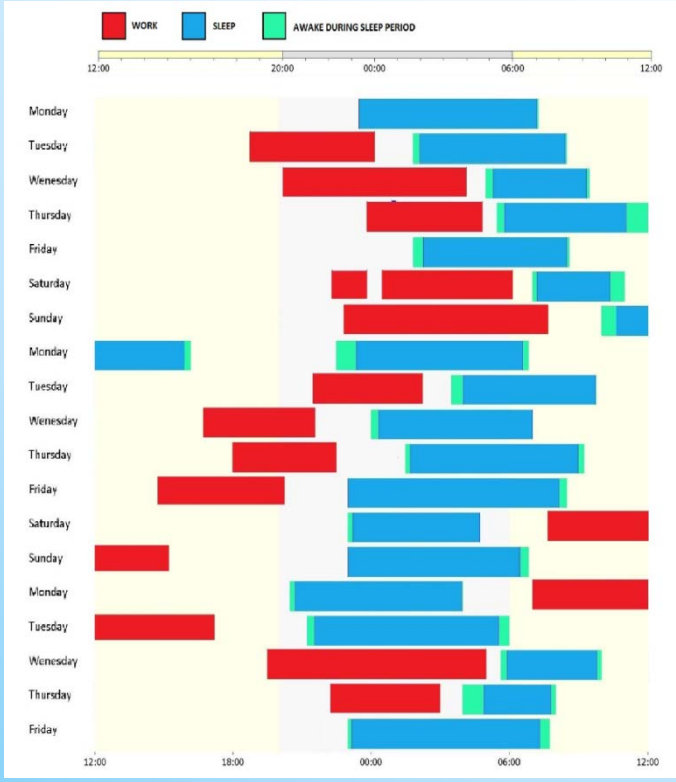
Boudreau P et al. *PLoS ONE* 2013

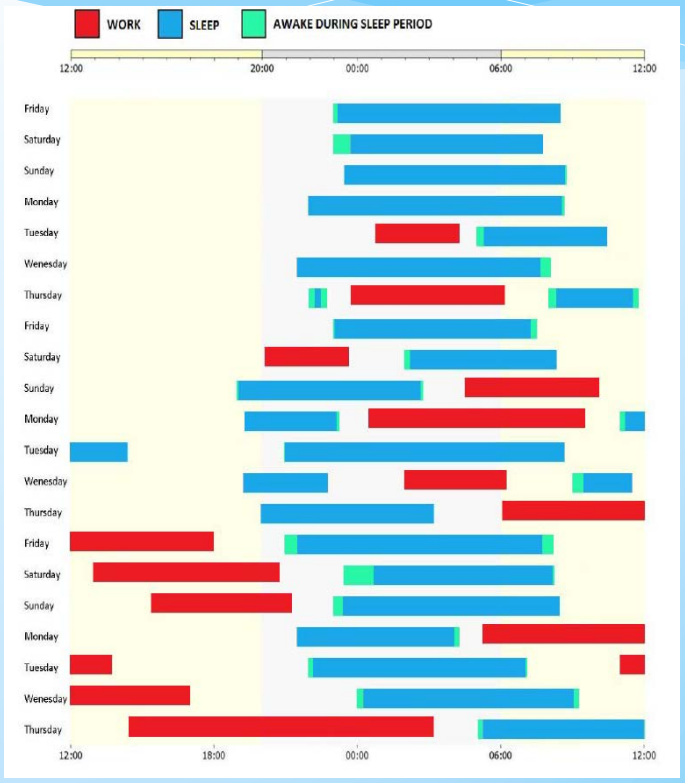
Work organisation of ship pilots

- Winter (January to March): double pilotage
- Summer: Single or double pilotage
- Work cycles of 16 to 19 consecutive days
- Followed by about 2 rest weeks
- About 10 to 14 trips per work cycle
- Around 207 available days and 128 trips per year
- « First in, first out » scheduling rule
- Mandatory 14 h rest (inc. 4 h notification time) period between ship transits
- Irregular and unpredictable work schedule

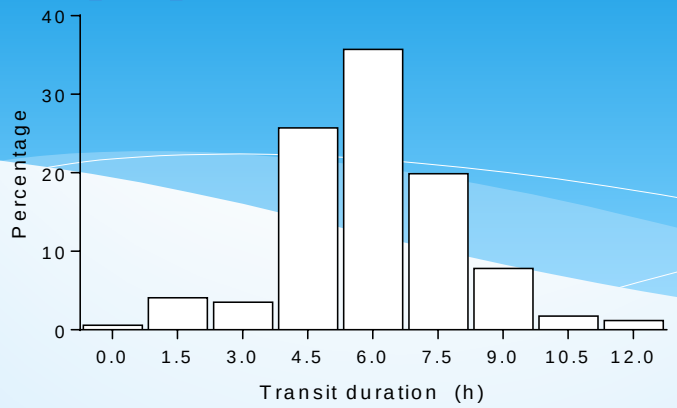
Work/sleep cycle of ship pilots

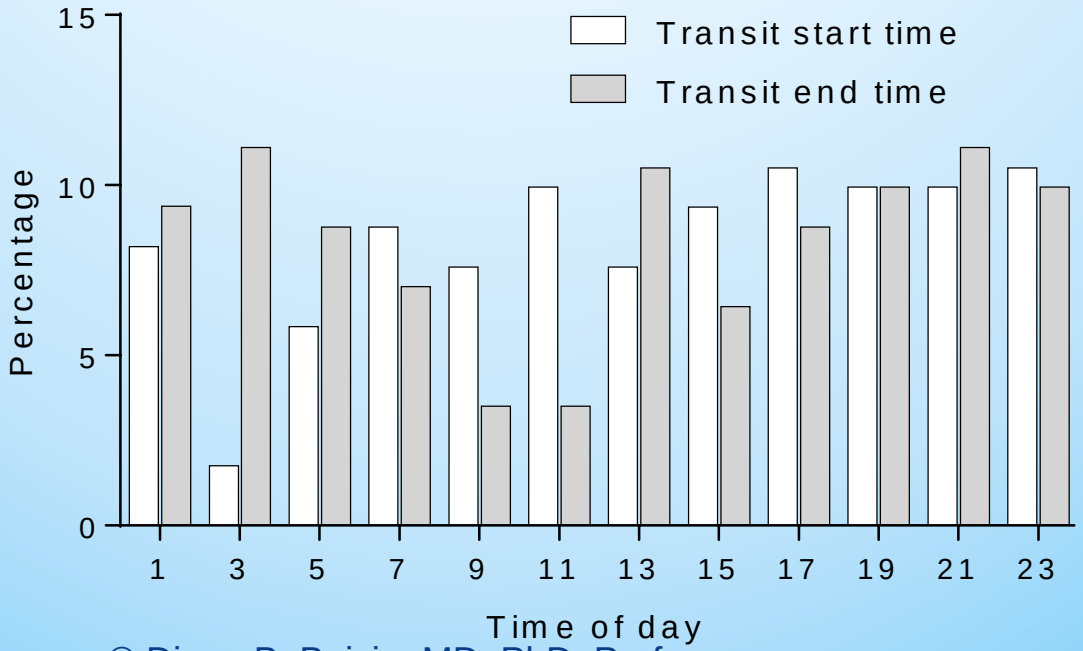
Example of work/sleep schedules of 2 pilots



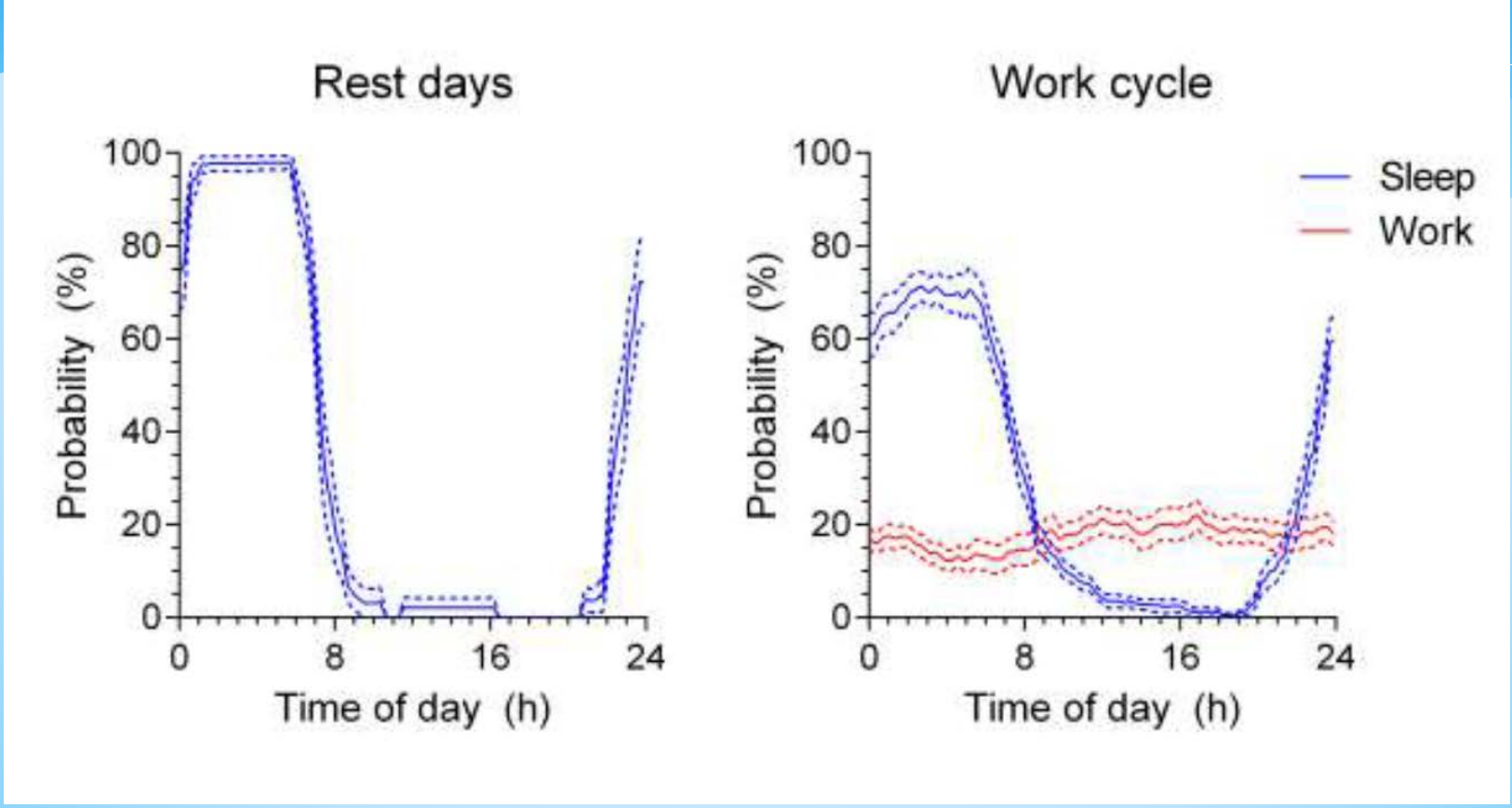


Ship pilots' transits





Sleep/wake cycle of marine pilots



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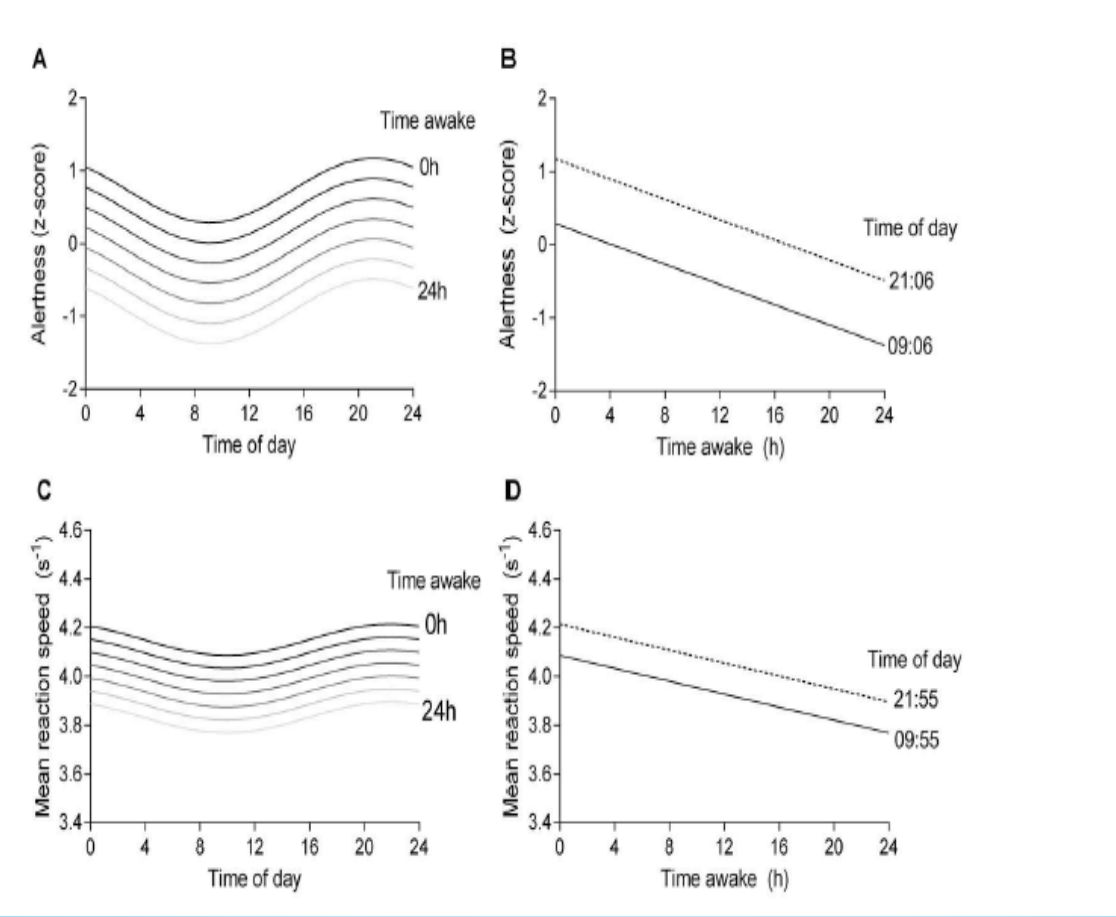
Modelled effect of time spent awake and time-of-day during marine pilot work cycle



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Conclusions

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- Time does matter and should be part of a comprehensive FRMS
- Today, we know very little about the rate of circadian adaptation to shift work
- We need more good, large scale studies
- We need easy, reliable circadian biomarkers Circadian-based interventions should be evidence based
- Not one-size fits all

Acknowledgements

Workplace organisations and workers

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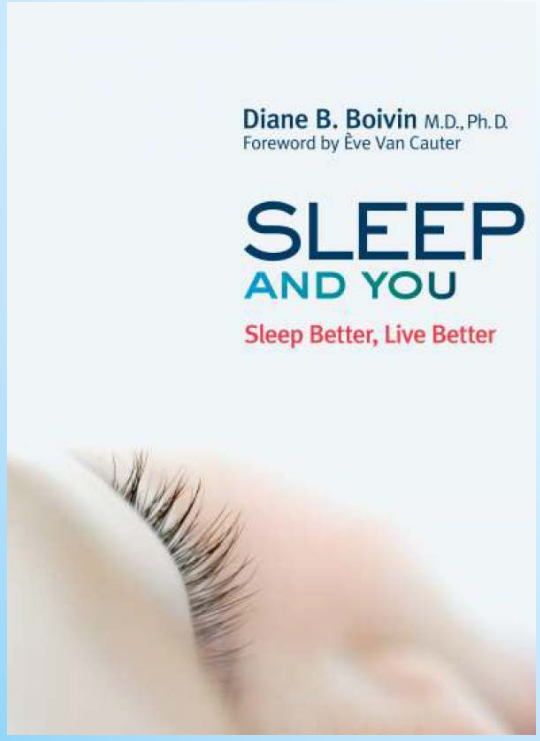
Corporation des Pilotes du Saint-Laurent Central
Laurentian Pilotage Authority

Research projects/consultations



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