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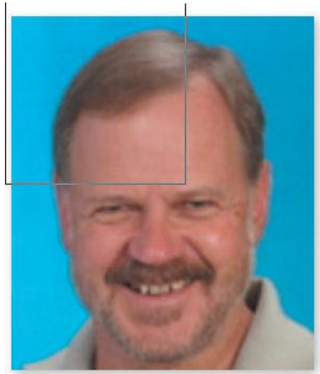

# Professor Richard Jones

Neuroscientist and Neuroengineer
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Christchurch

Saturday, August 10, 2019

(Room 5)

14:00 - 16:00 WS #105: Sleep 101 Forum (120mins, not repeated)

South GP CME – 3 Aug 2018, Christchurch

CHRISTCHURCH NEUROTECHNOLOGY
RESEARCH PROGRAMME
(www.neurotech.org.nz)

New Zealand
Brain Research
Institute

# Microsleeps:

## *Characteristics, dangers, and countermeasures*

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# Lapses of Responsiveness

**‘Lapse’** = *complete* and *transient* loss of responsiveness
during an active task

**Four main types**

1. Sleep events (> 15 s) = *Lapses of consciousness*
2. **Microsleeps** = *Lapses of consciousness*
   - Duration < 15 s
   - Loss of visuomotor responsiveness + transient eye closure
   - Clear behavioural indications of drowsiness
   - Distinction between sleep and microsleeps in terms of duration is arbitrary BUT are physiologically different due to recovery of responsiveness after a brief period in microsleeps
3. Attention lapses – Exogenous = *Externally diverted-attention lapses*
4. Attention lapses – Endogenous
   - Mind-wandering
   - Mind-blanks

# Are microsleeps dangerous? …

***Occupational***

- Drivers
  - Road:  trucks, buses, taxis, cars
  - Train drivers
  - Aircraft pilots
    - 56% of pilots surveyed had fallen asleep on flight deck  (Brit. Pilots' Assoc, 2013)
- Air-traffic controllers
- Medical:  Surgeons, Anaesthetists
- Armed forces:  Air Force, Navy, Army
  - Motor vehicle crashes account for ~⅓ of US military fatalities annually, making motor vehicle accidents *the* leading cause of fatalities among U.S. military personnel  (Krahl et al. *Amer J Prevent Med,* 2010)

  ➔“Microsleeps are the leading cause of fatalities in military personnel” (RJ)

# Are microsleeps dangerous? …

***Every-day life − Car drivers (~500 M)***

- Traffic accidents in Germany (Langwieder, et al., 1994)
  - 24% of fatal motorway accidents on German motorways due to falling asleep at the wheel

  +14% due to 'loss of attention'
  (lost & diverted attention lapses)

- Traffic accidents in US (Mitler et al., *Sleep*, 1999)
  - 15-30% traffic accidents caused by fatigue or dozing off

- Traffic accidents in US (Tefft. AAA Foundation Report, 2014)
  - Imputation of ~14,000 motor vehicle crashes
  - 21% of fatal crashes involved a drowsy driver

# Are microsleeps dangerous? …

***Consensus statement*** (Akerstedt, *Aviat Space Environ Med*, 2000)

- Sleepiness is the largest “preventable cause of accidents (15-20% of all accidents), surpassing alcohol, drugs, etc., in all modes of transport”

# Microsleeps *versus* Drowsiness/Fatigue

- Drowsiness/Fatigue
  - Feeling tired/sleepy
  - But can still do your job while drowsy
  - ***Mildly dangerous***

- Microsleeps
  - Short, but complete, shutdowns in responsiveness
  - Can happen when NOT drowsy!
  - ***Extremely dangerous***

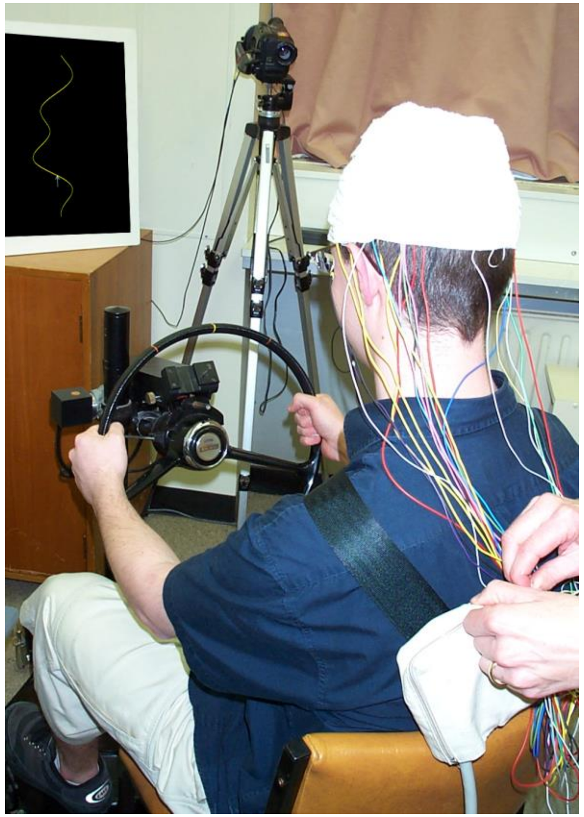
# NeuroTech's Lapse Research Programme

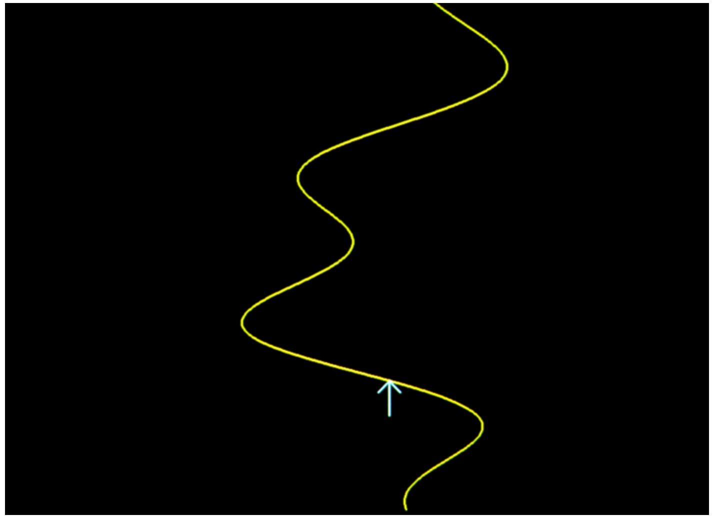
- **Behavioural**
  - Characteristics
    - How often do microsleeps occur? Duration? Within-subject differences? Between-subject differences?
  - Factors
    - Usual sleep duration? Sleep deprivation? Sleep propensity? Sleep apnoea?
- **Countermeasures**
  - Prevent/reduce likelihood of microsleeps
    - (naps, caffeine)
  - Neurotechnology for detection & prediction
    - EEG
    - Computer vision
- **Mechanisms**
  - What happens in the brain during, before, and coming out of microsleeps?
    - EEG
    - fMRI

# Study 1 − Lapses

**Subjects**

- 15x healthy male volunteers
- Age 18–36 years
- Not sleep-deprived



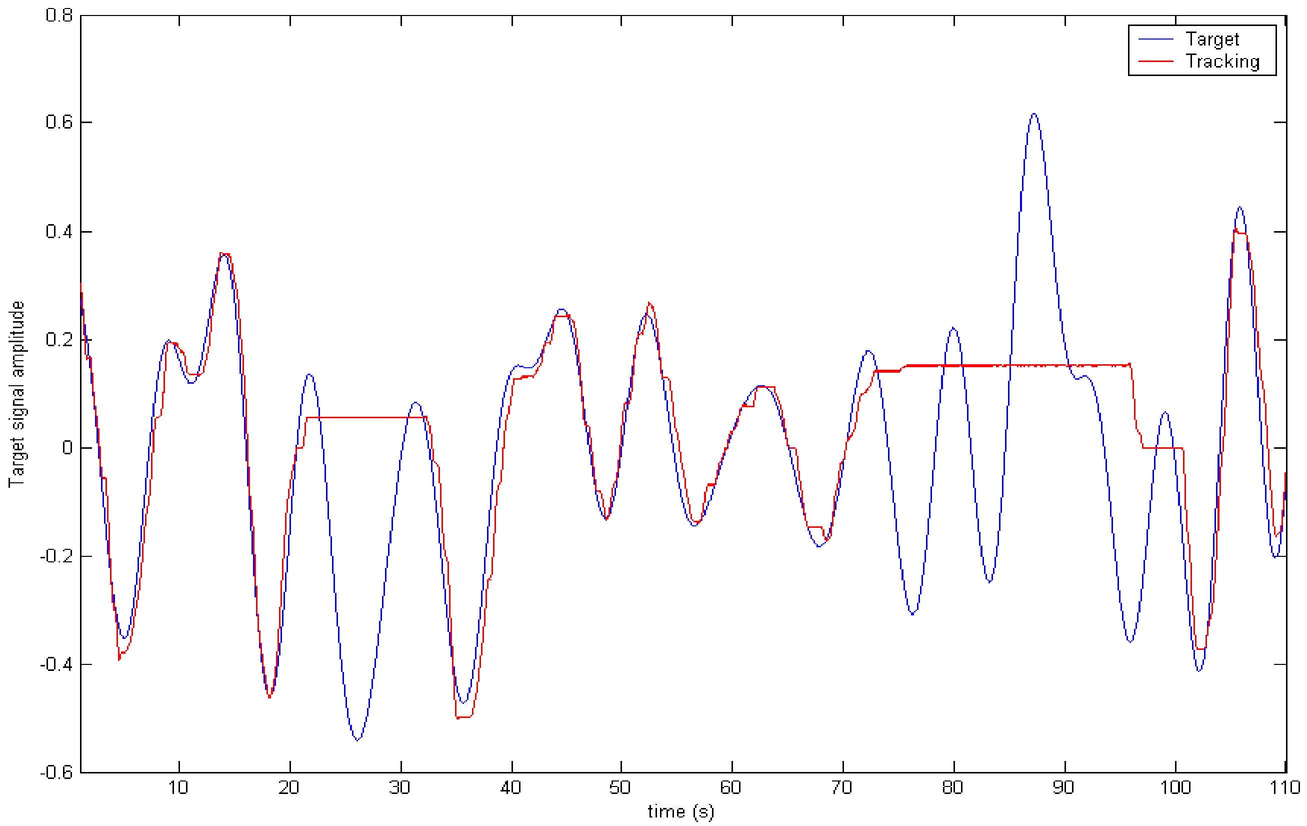


**Procedure**

- Preview tracking for 1 hour

# Results (Peiris et al. *J Sleep Res*, 2006)

- 14 of 15 subjects lapsed at least once
- Average 39 lapses/h (0 – 141) ~ mostly microsleeps
- Mean duration = 3.4 s (1.0 – 8.3 s)



# Preliminary Conclusions

- Microsleeps can occur in young healthy adults to a *much* greater extent than previously recognized
- Major implications for occupations that require sustained alertness over long periods of time, particularly in transport and military sectors
- Need: To counter microsleeps through early detection

  ➔ Lapse detector/predictor
- Need: To understand mechanisms underlying lapses

# Study 2 − Lapse Mechanisms

## Simultaneous fMRI + EEG

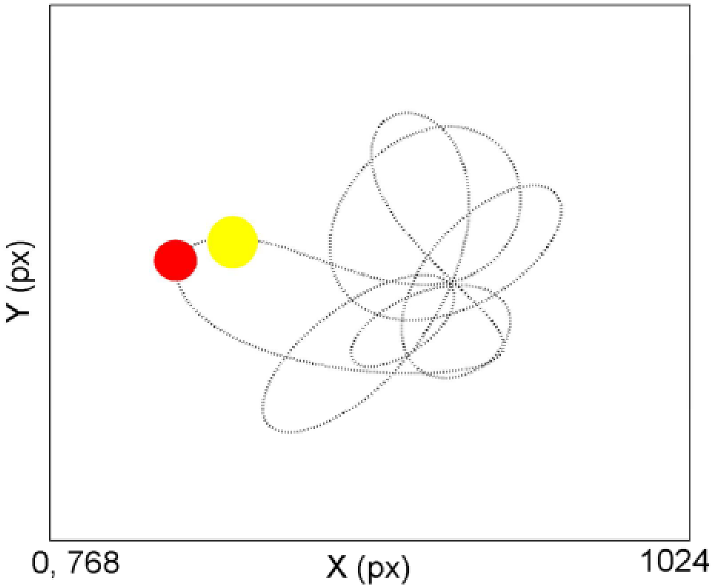
# fMRI + EEG + Tracking + EyeVideo

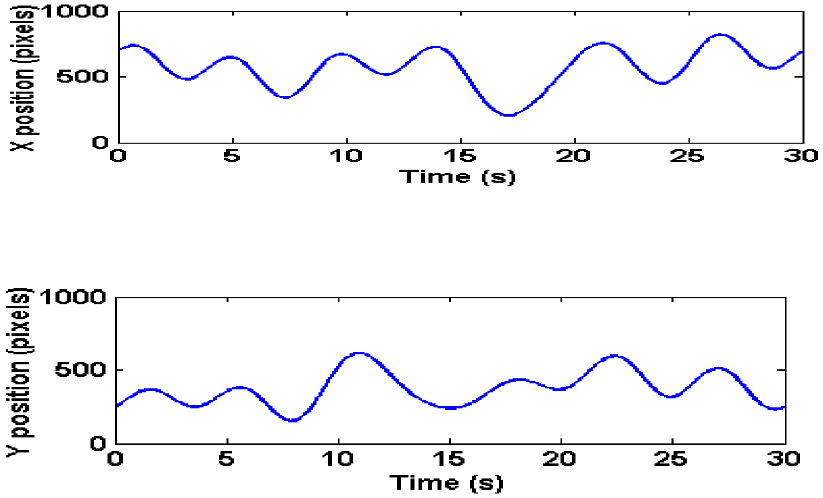
# Participants

- 20 young healthy right-handed volunteers
  - 10 males, and 10 females
  - 21–45 years (mean 29.3)
  - no neurological, psychiatric, or sleep disorder
  - usual time to bed 10–12 pm
  - reported time in bed of ~7.0–8.5 hours
  - no stimulants or depressants (e.g., alcohol, caffeine) on the day of the session
- Sessions conducted between 1:00-4:30 pm
- Questionnaire assessed general health, sleep quality, morningness-eveningness, and daytime sleepiness
- Sleep diary, actiwatch measures for previous 6 days and 5 nights
- All normally rested (not sleep deprived)

# Continuous visuomotor tracking task (50 min)

- Participants performed a 2-D tracking task with a target trajectory defined as sum of sines in both directions:

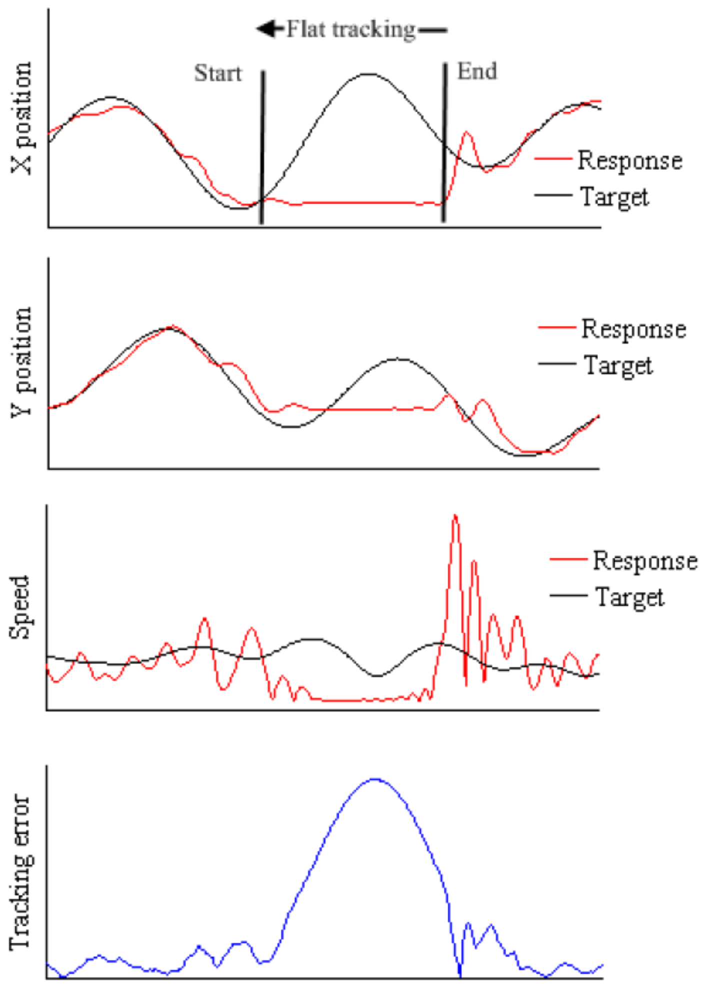


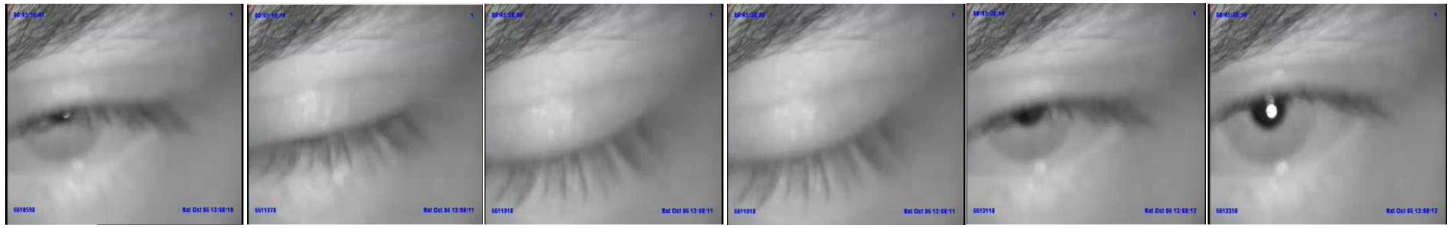




- Sum of 7 sine-waves = 0.033 — 0.231 Hz
- Horizontal and vertical phase shift $\varphi_n$ ➔ pseudo-random ➔ not predictable
- Minimum speed = 63 px/s ➔ no target flat spots
- Period = 30 s

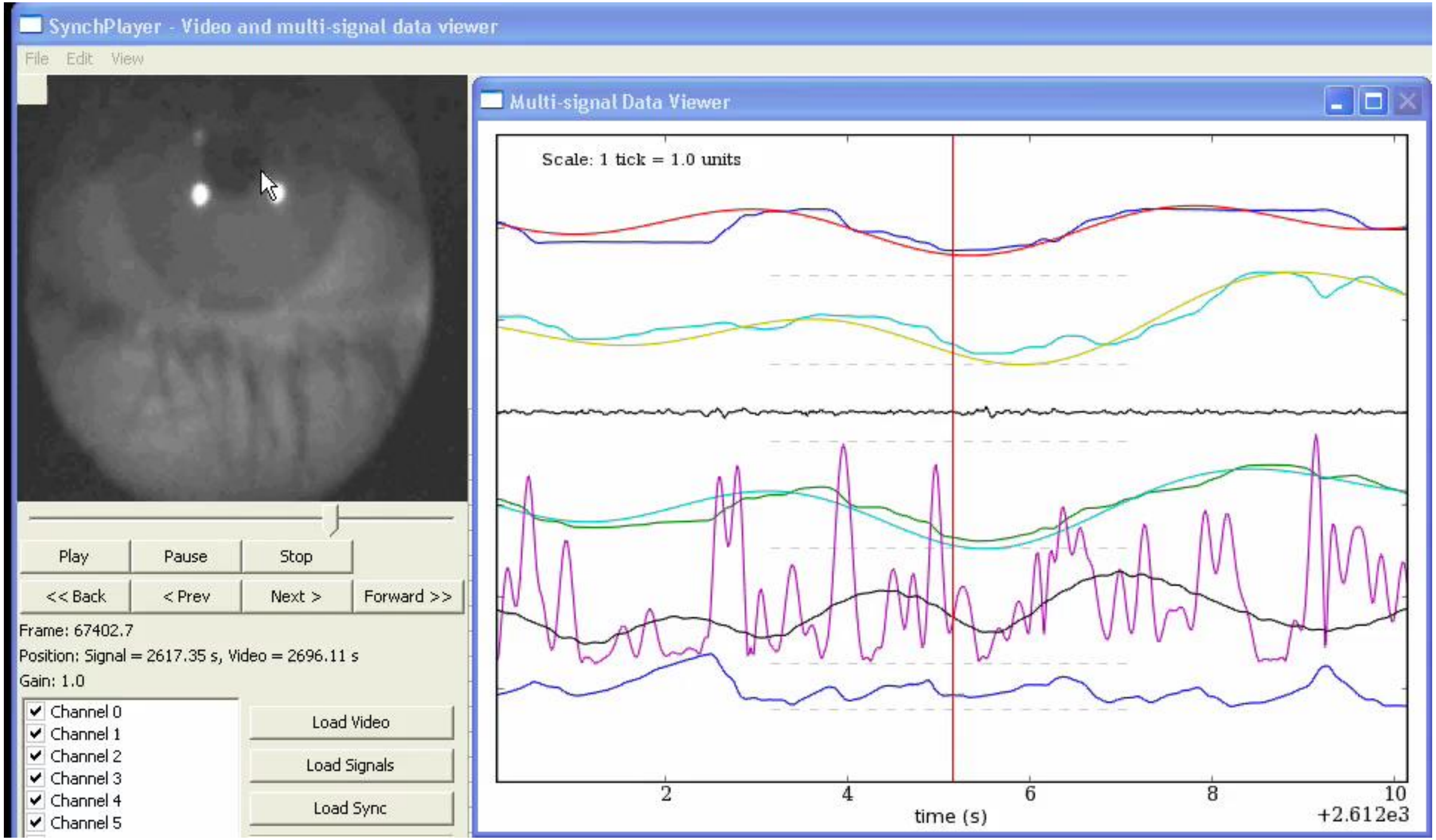
# Rating microsleeps

- Microsleeps defined as:
  1. Flat tracking for 0.5 – 15 s
  2. Phasic/transient eye-closure
  3. Drowsy behaviour

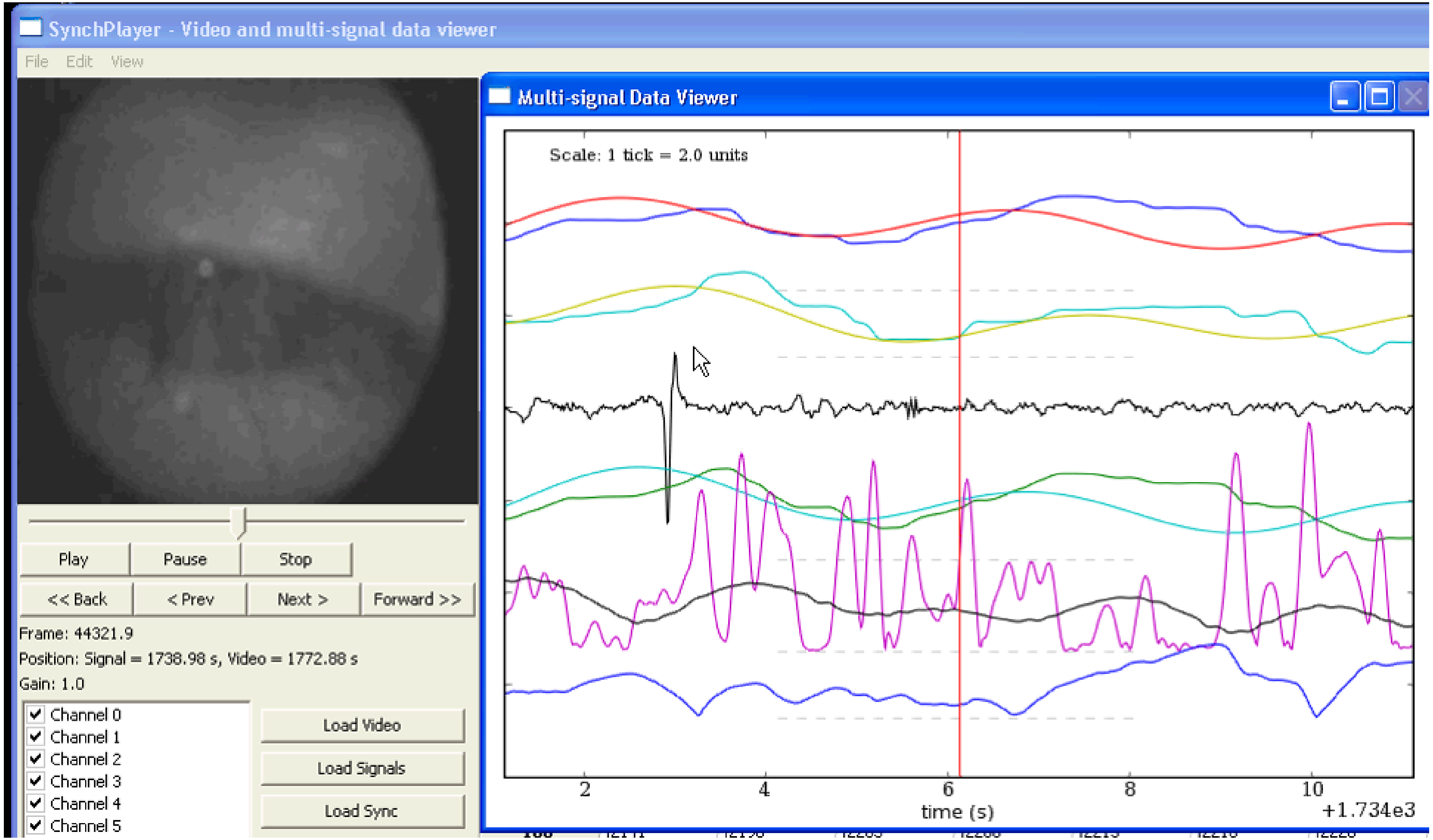


# 1x microsleep (5 s) in MR scanner

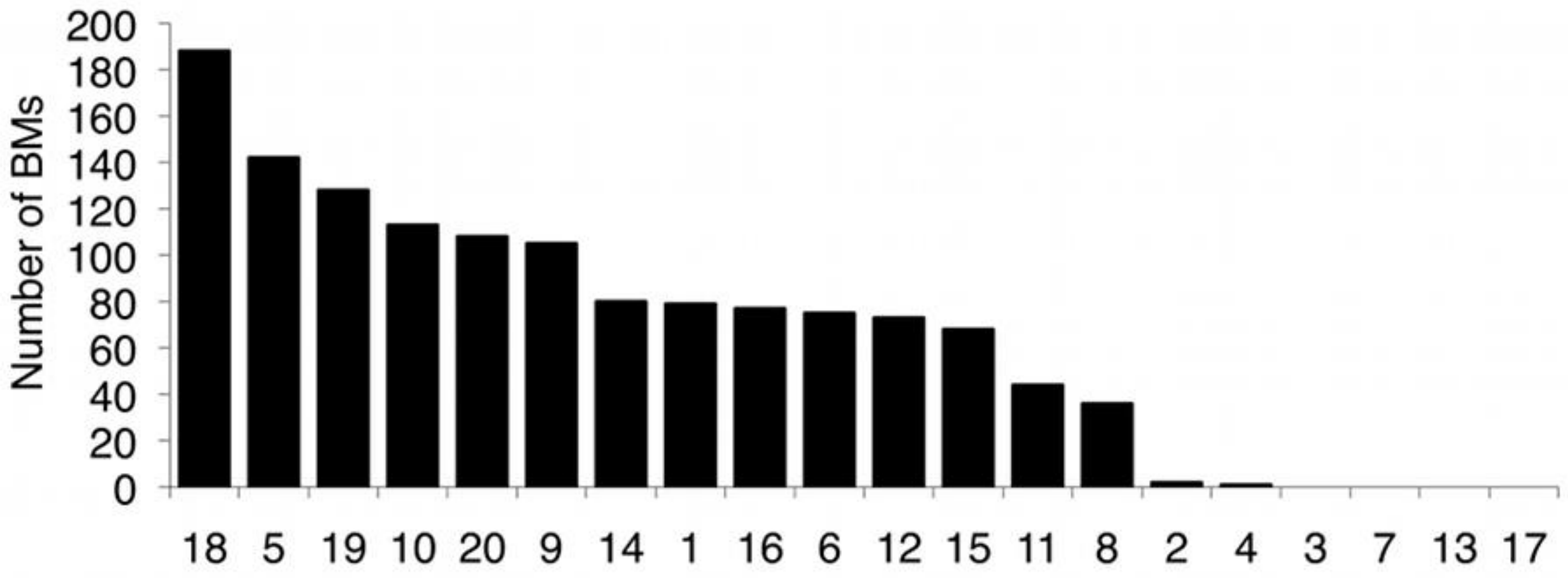


# *Coming out of microsleep (5 s) + 4x short (0.5-2 s) + 1x long (9 s)*



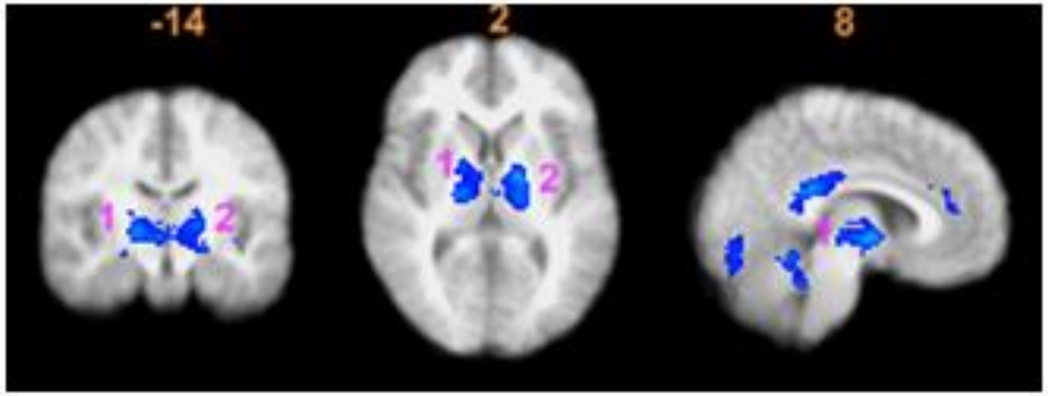
# Behavioural results - *Microsleeps*

- 16 of 20 subjects had microsleeps
- 14 over 43 /h
- Event rates = 79 /h (0–225)
- Event durations = 3.3 s (0.5–15 s)

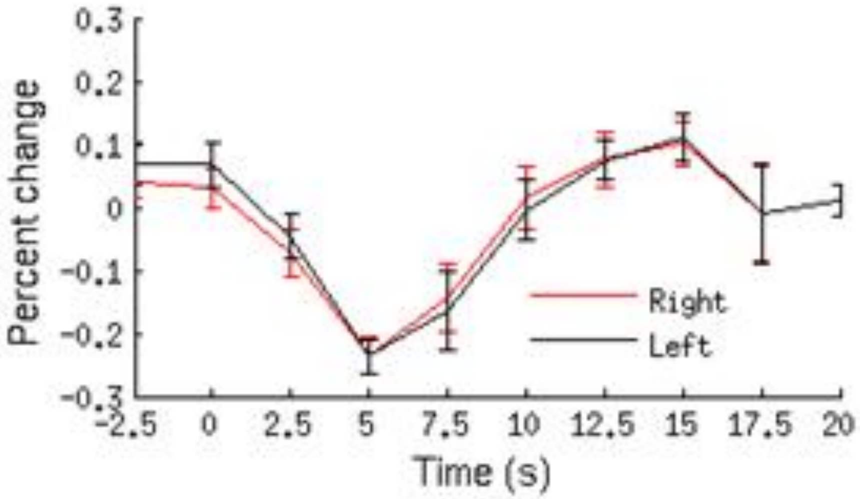


# fMRI results

## *Decreased activity during behavioural microsleeps*








**Thalamus**

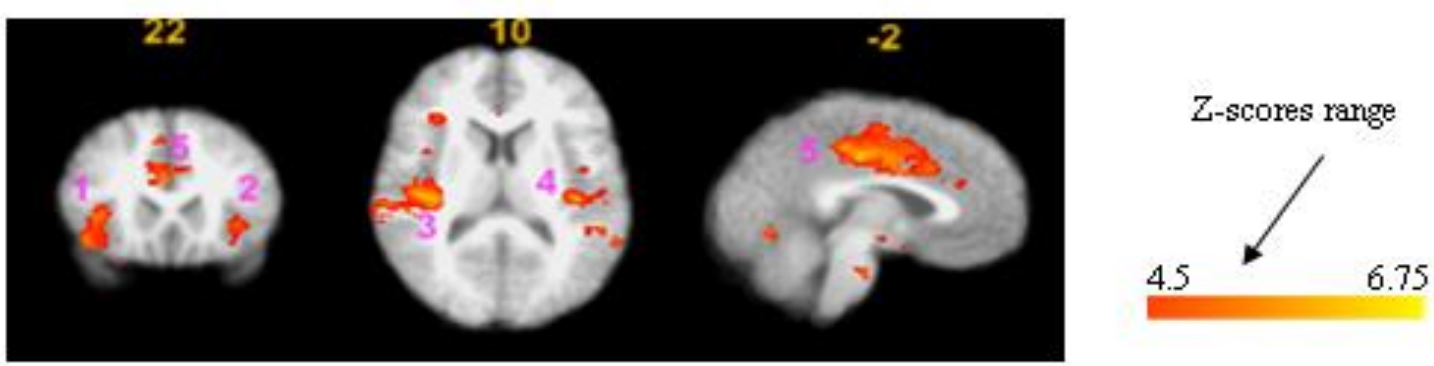
Right = 14, -12, 2 (1)

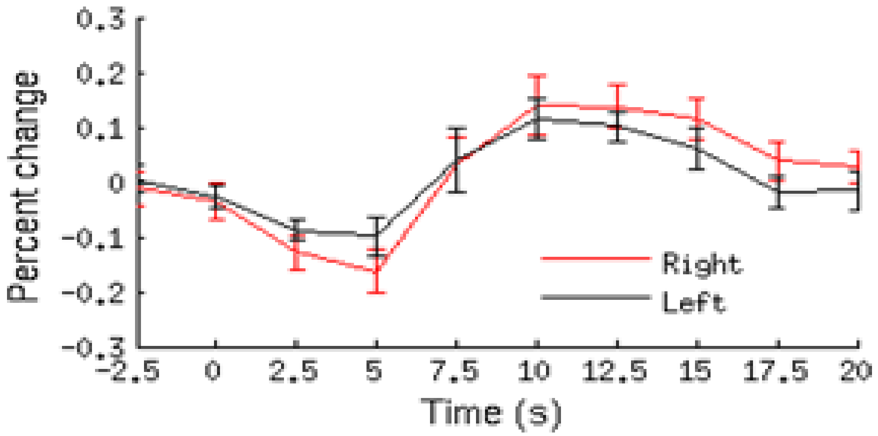
Left = -12, -16, 2 (2)

(Poudel et al. *Hum Brain Mapp*, 2014

# fMRI results

*Increased activity during behavioural microsleeps*



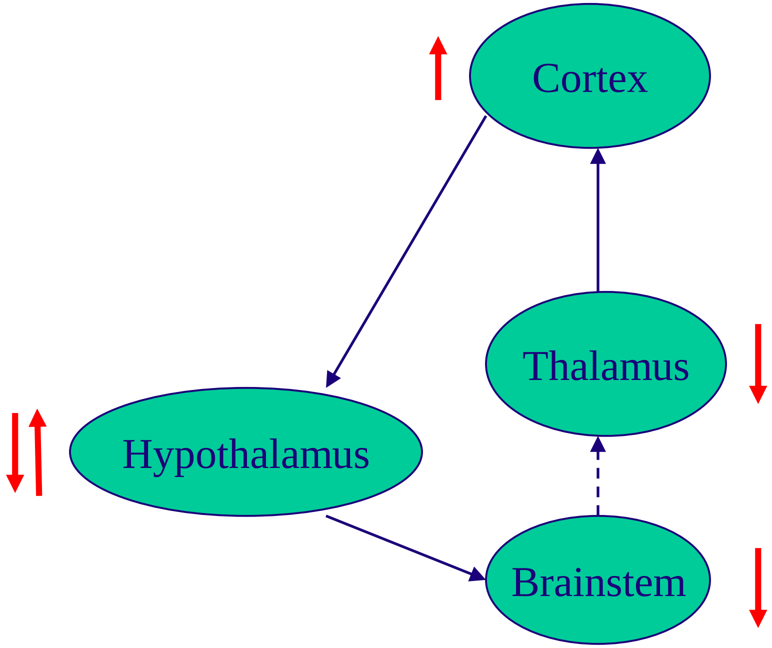

**Cingulate gyrus**

Right = 6, 18, 30 (5)

Left = -4, 22, 40 (5)

# Mechanisms – *Microsleeps*

- Decreased activity in - subcortical arousal network (reticular activating system)
  - hypothalamus (wake-promoting orexin neurons)
- Increased activity in - visuomotor and attentional networks
  - hypothalamus (sleep-promoting VLPO + MnPn)
- Mechanisms?
  - Decreased thalamic activity likely due to disruption in tonic input from other parts of the ascending arousal network due to increased sleep drive
  - Short-term increase in activity in cortical areas reflects a top-down effort by cortical areas to reactivate subcortical wake-promoting processes (orexin & histamine neurons)



# Study 3 - Normally-rested vs sleep-restricted

## Methods

- Recruited 20 healthy volunteers
  - 10 males, 10 females
  - 20–37 years (mean 24.9)
  - reported time in bed ~7.0–8.5 hours

- Same basic methodology as Study 2 except for two experimental sessions (counter-balanced)
  - Following a ‘normal’ night of sleep
  - Following a night where time-in-bed is restricted to 4 hours

- Length of tracking task reduced from 50 min to 20 min.

# Propensity for microsleeps

*Normally rested* ➔ *Sleep-restricted*

**Normally rested**

- Microsleeps
  - Subjects = 8
  - Mean rate = 34.2 /h
  - Mean duration = 2.7 s

**Sleep-restricted**

- Microsleeps
  - Subjects = 12
  - Mean rate = 83.7 /h
  - Mean durations = 2.8 s

## Conclusions

- Microsleeps even when not sleep-deprived
  - Due to *passive fatigue* – Exertion due to effort required to maintain attention/responsiveness/vigilance in a monotonous task
- High variability between individuals
- Higher propensity with partial sleep deprivation

# Take-home messages: *Microsleeps*

- Most of us have microsleeps.
- Propensity varies greatly in healthy subjects.
- Can occur even when not sleep-deprived.
- Propensity increases with excessive sleepiness:
  - Sleep deprivation
  - Poor/fragmented sleep (e.g., due to OSA)
  - High on sleepiness trait (Epworth Sleepiness scale).
- Big killer on the road:
  - ~20% of fatal accidents on the road (more than alcohol & drugs)
- Countermeasures:
  - A good night's sleep
  - Nap (30 min)
  - Stimulant:  Caffeine, Modafinil, amphetamine, methylphenidate, …
  - Strong coffee + nap
  - CPAP (if severe OSA)
  - *Awareness*