Does Rapid Eye Movement (REM) sleep prepare the brain for wakefulness?

John Axelsson[1 2 3], Göran Kecklund[3], Matthias Gloel[1], Lars Tigerström[1]
[1] Department of Clinical Neuroscience, Karolinska Institutet, [2] Osher Center for Integrative Medicine, Karolinska Institutet,
[3] Stress Research Institute, Stockholm University, Stockholm, Sweden

Objective
To study whether REM sleep prepares the brain for wakefulness.

Conclusions
We found no scientific support for REM preparing the brain for wakefulness.

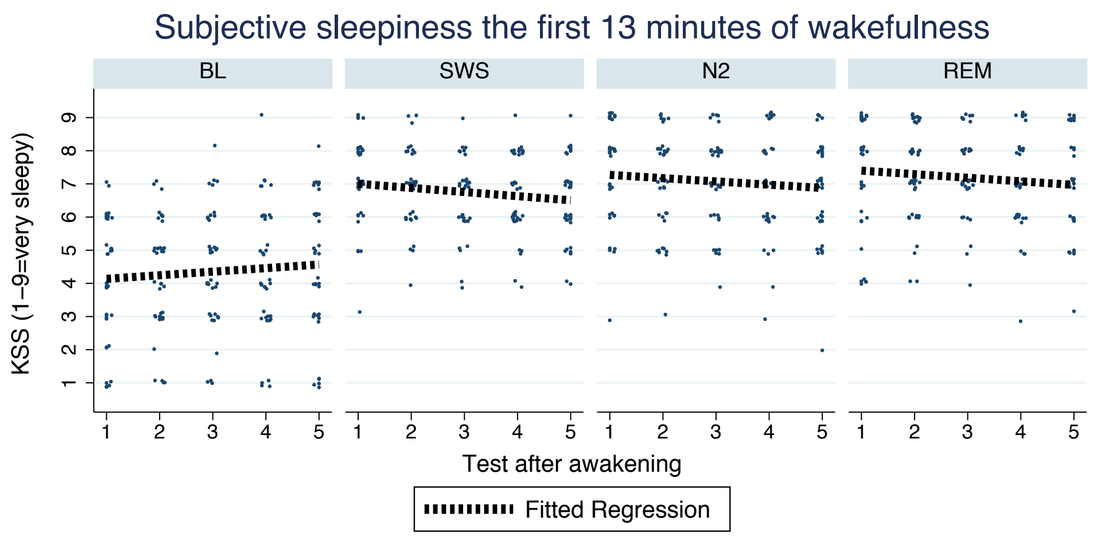
Introduction
It has been proposed that rapid eye movement (REM) sleep prepares the brain for wakefulness (1) and that it is easier to wake up from REM-sleep than from non-REM (NREM) sleep. To address this question, we investigated how waking up from different sleep stages affected cognitive functions and subjective sleepiness.

Methods
31 healthy participants (mean age 25±4SD yr, 10 women) went through the study protocol twice.

During each participation night, the participants carried out a test battery (*the Karolinska WakeApp*): during baseline (+1h prior to lights out), and directly upon awakening from slow wave sleep (SWS), NREM stage-2 sleep (N2) and rapid eye movement sleep (REM). Each awakening occurred after at least 10min of sleep in that particular sleep stage. Awakenings from N2 and REM were balanced.

The test battery included five cognitive tests that were presented in a randomized order. The tests were mathematical skill (addition task), working memory (spatial), short-term memory (words), episodic memory and a probabalistic inference task (jumping to conclusions). Each test was 2-2.5min long and followed by ratings of sleepiness.

References
(1) Horne, J., Why REM sleep? Clues beyond the laboratory in a more challenging world (2013). Biological Psychology, 92, 152-168



Test	Worse performance: Cognitive speed	Worse performance: Mistakes
Mathematical skill	SWS, REM, N2	SWS
Short-term memory	n.a.	SWS, REM
Working memory	n.a.	SWS, REM
Episodic memory	SWS, REM, N2	SWS
Decisions making	SWS, REM, N2	-

Decision making was made on a probabalistic inference tank (Jumping to conclusions),
SWS = Slow wave sleep, REM = Rapid eye movement sleep, N2 = non-REM stage 2 sleep

Results
- Mathematical performance was significantly worse after waking up from all sleep stages (SWS -2.6±.6, REM -2.0±.6, N2 -2.1±.6, p's<.01) as compared to baseline (intercept 15±.6). With respect to sleep stages, SWS was worse than N2 and REM (p's<.05).
- Both short-term memory and working memory was significantly worse after waking up from SWS and REM as compared to baseline (p's<.05), but not for N2. There were no significant differences between sleep stages with respect to working memory, but short-term memory was worse after waking up from SWS as compared to the other stages (p's<.05).
- Episodic memory was worse after all sleep stages as compared to baseline (intercept 11.0±1.0, SWS -2.0±0.6, REM -1.1±.6, N2 -1.4±.6, p's <.05). There were no significant differences between the sleep stages.
- Probabalistic inference performance had deteriorated after all sleep stages as compared to baseline (p's<.05), although no differences between the stages were found.
- Subjective sleepiness was higher after all sleep stages as compared to baseline (p's <.01), but less after SWS as compared to the other stages (p's<.01).

Results
Separate analyses for cognitive speed and mistakes showed that cognitive speed was reduced after all sleep stages for tests measuring speed. Mistakes were increased after SWS for all but one test, while REM increased the mistakes for two tests, and N2 for no tests.

Discussion
Being in REM sleep prior to awakening did not improve sleepiness or performance for any of the five cognitive tests as compared to N2. In fact, performance after awakenings from N2 was surprisingly good with no increases of mistakes. Performance was worst after SWS, supporting the notion that waking from deep sleep has adverse effects on cognitive performance, although this was not supported by worse subjective sleepiness.

It is likely that circadian aspects and amount of sleep pressure influenced the results, but this will not have affected the differences between REM and N2 since the awakenings from these two sleep stages were balanced.

In conclusion, there was no support for REM preparing the brain more than N2 for any aspect of wakefulness. **Although REM sleep is likely has multiple functions, our findings do not provide evidence for REM having a role in preparing the brain for wakefulness.**

John Axelsson, Dept of Neuroscience, Karolinska Institutet, Nobels väg 9,171 77 Stockholm, Sweden
John.Axelsson@ki.se