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How fast do cognitive functions return to normal in the awakening brain?

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Objective

To study how fast cognitive functions, particularly mistakes, return to normal after being awakened from sleep

Conclusions

Almost all cognitive functions were back to normal, within 12-13 minutes.

Introduction

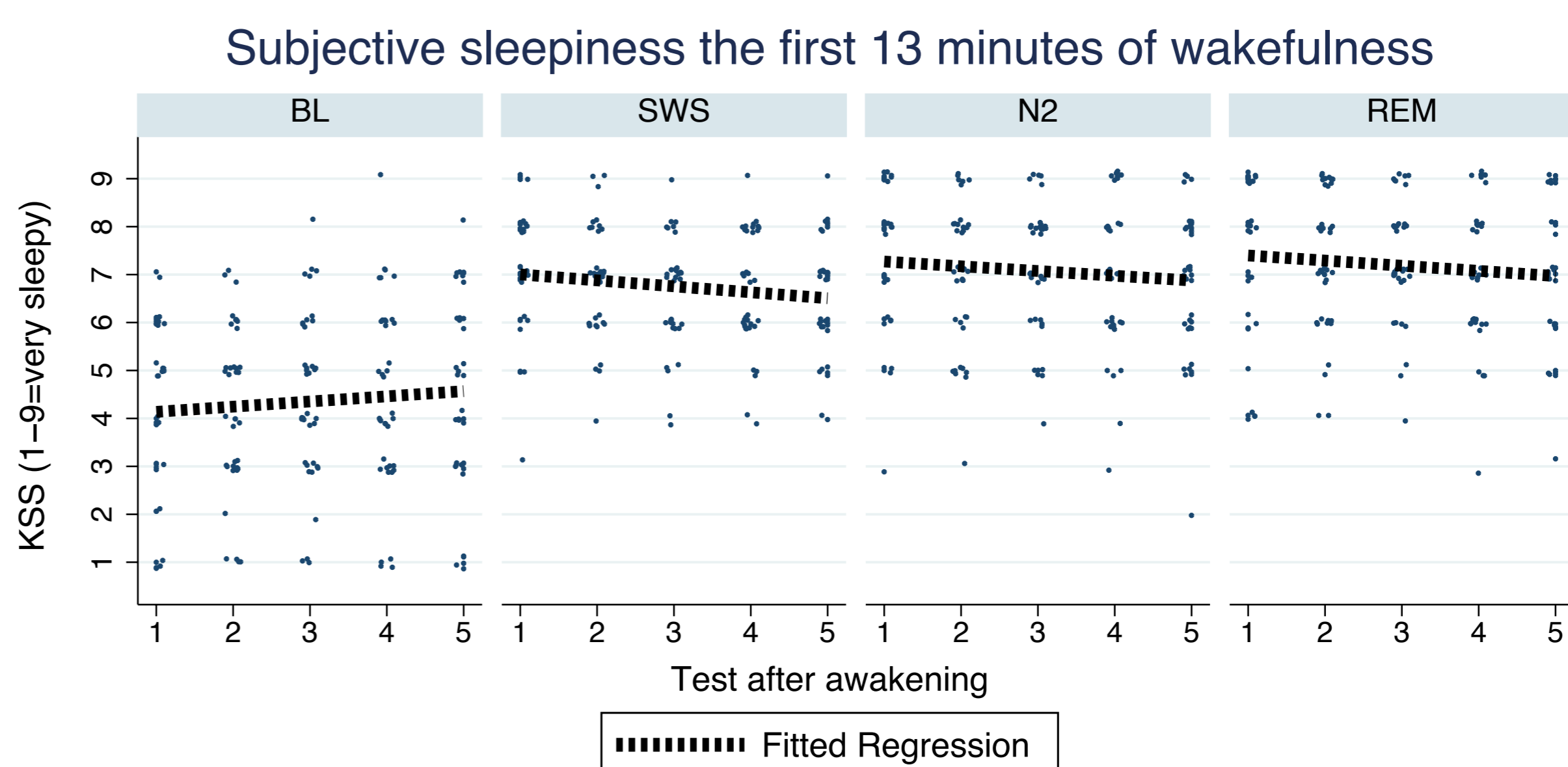
It is largely unknown of how fast the brain goes from sleep to being fully awake and whether sleep stage affects this process. It has for example, been proposed that rapid eye movement sleep (REM) prepares the brain for wakefulness. To address these questions, we investigated how fast cognitive functioning and subjective sleepiness returned to normal after awakenings from different sleep stages.

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 probabilistic inference task (jumping to conclusions). Each test was 2-2.5min long and followed by ratings of sleepiness.



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

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

Results

Cognitive speed was significantly slower (for all tests measuring speed) after awakening from all sleep stages as compared to baseline ($p < .05$).

Mathematical mistakes were significantly more frequent after waking up from SWS ($-2.6 \pm .6$) as compared to baseline ($p < .05$), and the interaction between time since awakening and SWS ($p < .05$) showed that it took about 12 min for performance to return to baseline levels. No other significant effects were found for sleep stages with respect to mathematical mistakes.

Mistakes on short-term memory and working memory were significantly more common after waking up from SWS and REM as compared to baseline ($p < .05$), and for N2 this was true for short-term memory ($p < .05$). The only significant interaction between time and sleep stage ($p < .05$) showed that SWS was worst initially and despite improvements across time, the performance was not estimated to be back to baseline in 15 min.

Neither episodic memory nor probabilistic inference performance were worse after awakening from sleep as compared to baseline.

Subjective sleepiness was higher after all sleep stages as compared to baseline ($p < .01$), but less after SWS as compared to the other stages ($p < .01$). Subjective sleepiness was not estimated to be back to baseline within 15 minutes after awakening.

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 three of the tests, while REM increased the mistakes for two tests, and N2 for one test.

Discussion

Basically all included cognitive functions had returned to normal within 12-13 minutes after awakening with worst performance after slow wave sleep, followed by REM. The exceptions being that short-term memory performance had not returned to baseline within then first 15 minutes when being awakened from SWS. Similarly, subjective sleepiness was not close to return to baseline within 15 minutes after awakening.

Performance was generally 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.

In addition, we found no scientific support for REM (which has been proposed) to prepare the brain for wakefulness.