

Supplementary Information

Impaired slow-wave sleep accounts for brain aging-related increases in anxiety

Eti Ben Simon, Vyoma D. Shah, Olivia Murillo, Zsofia Zavecz and Matthew Walker

*Correspondence: Eti Ben Simon etibens@berkeley.edu

Table S1. Brain volume of key functional networks and next-day anxiety/SWA associations

Functional Network	Volume (mean $\pm$ SD)	Overnight Anxiety Association (r)	SWA Association (log count, r)
Visual	4.17 $\pm$ 0.41	-0.18 ($P = 0.2$)	0.19 ($P = 0.16$)
Somatomotor	3.99 $\pm$ 0.34	-0.07 ($P = 0.6$)	0.18 ($P = 0.17$)
Attention (dorsal)	2.72 $\pm$ 0.22	-0.13 ($P = 0.36$)	0.28 (* $P = 0.04$)
Attention (ventral)	2.87 $\pm$ 0.23	-0.22 ($P = 0.11$)	0.25 ($P = 0.065$)
Limbic	2.95 $\pm$ 0.27	-0.09 ($P = 0.5$)	0.17 ($P = 0.21$)
Frontoparietal	3.75 $\pm$ 0.3	-0.17 ($P = 0.2$)	0.26 ($P = 0.056$)
Default Mode	6.42 $\pm$ 0.5	-0.2 ($P = 0.15$)	0.33 (* $P = 0.01$)

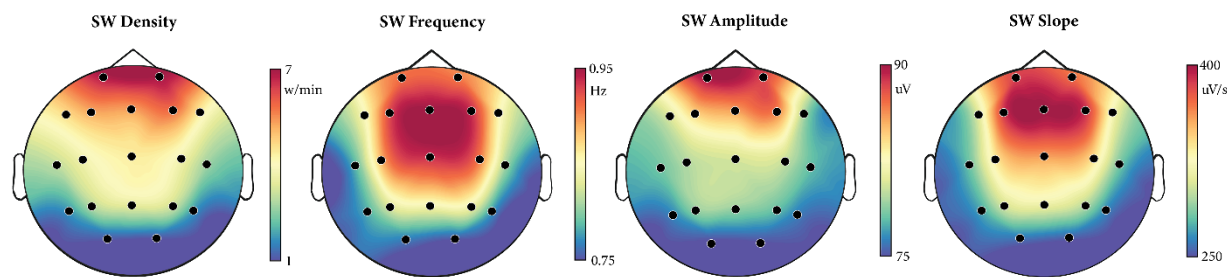
SWA = Slow Wave Activity, Network volumes normalized for Total Intracranial Volume. * $P < 0.05$

Table S2. Age-based analysis of main study variables

Covariate (mean ± SD)	69 and younger	70-77	over 78	age-based ANOVA
Trait Anxiety	28.17 ± 2.64	28.31 ± 5.58	29.19 ± 6.57	$F(2, 55) = 0.167$, $P = 0.85$
Volume in anxiety-sensitive regions	1.83 ± 0.08	1.69 ± 0.1	1.61 ± 0.15	$F(2, 52) = 7.129$, $*P = 0.002$
SWA (log count)	2.58 ± 0.15	2.37 ± 0.23	2.34 ± 0.22	$F(2, 58) = 3.66$, $*P = 0.032$

SWA = Slow Wave Activity, ROI volumes normalized for Total Intracranial Volume. * $P < 0.05$

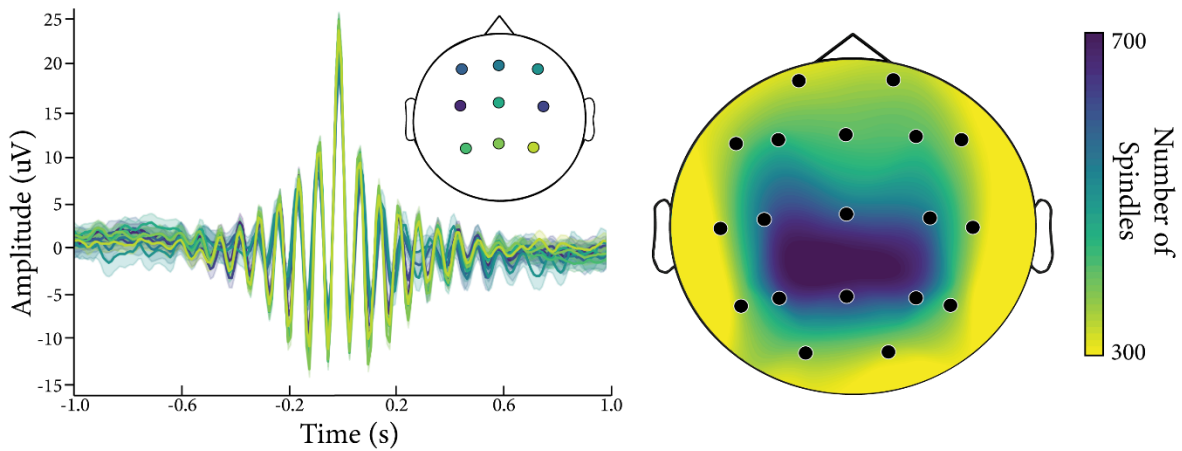
Fig-S1. Topographical distribution of NREM slow-wave parameters.



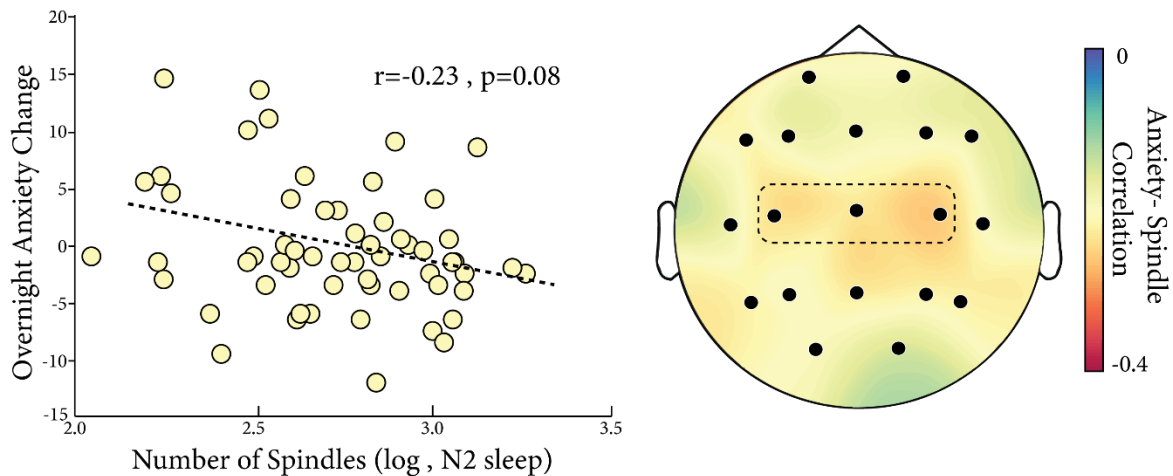
NREM slow-wave parameters at first visit averaged across participants (N=61, median average). Here, only channels with at least 20 detections across NREM sleep were included for each participant.

Fig-S2. NREM Spindles and Anxiety.

A NREM Spindles (12-15 Hz)



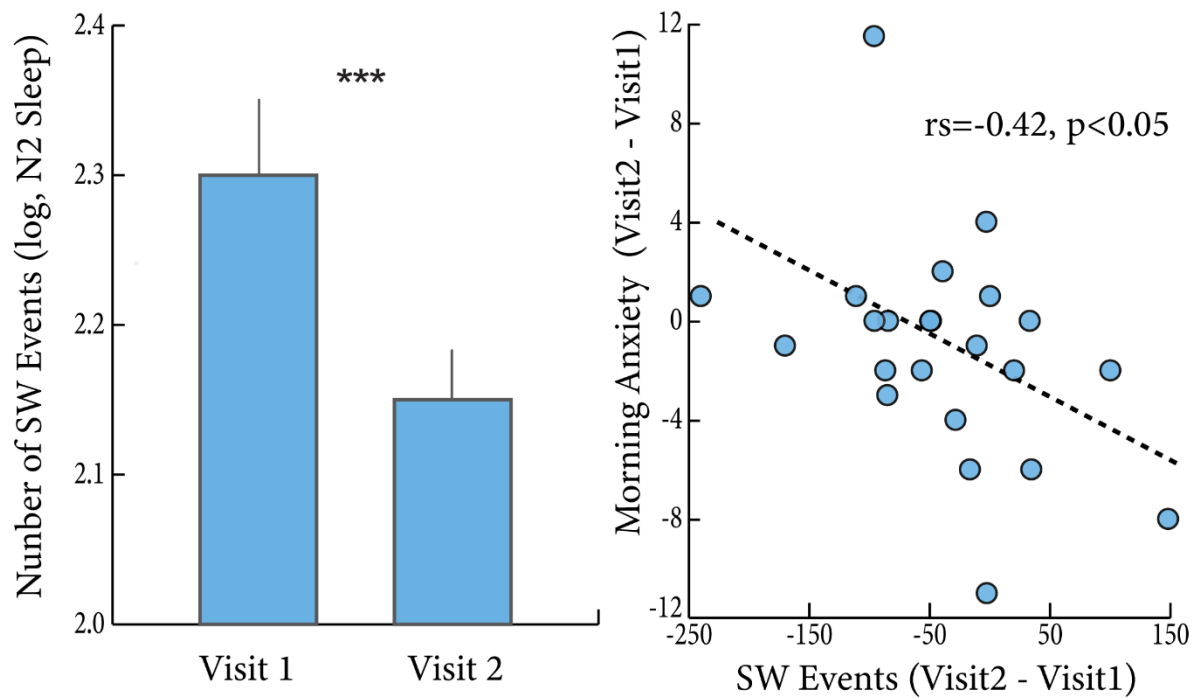
B Spindle Activity and Overnight Anxiety Regulation



(A) Detected spindles from NREM sleep (left panel, single subject example) and average spindle counts across participants (N=61, right panel).

(B) Increased number of spindles during NREM2 sleep was not significantly associated with lower next-day anxiety (N=58, $R = -0.23$, $P = 0.08$, left panel) in either a predefined central derivative (right panel, marked in a dotted line) or across the scalp (right panel).

Fig-S3. Longitudinal changes in NREM SWA and anxiety.



The number of NREM slow waves was significantly reduced from the first to the second visit (left panel, central derivative), a decrease that was associated with elevated anxiety levels at follow-up ($R_s = -0.42, P < 0.05, N=23$). *** $P < 0.005$