

Sleep-State Brain Circuits in TBI, PTSD, and Insomnia:

Implications for Military Readiness

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THE CONDITIONS

TBI / BLAST EXPOSURE
1 study · Stocker 2014 · n = 25 combat-exposed veterans · EEG-PET
Glucose metabolism is reduced across limbic, thalamic, insular and brainstem regions in both REM sleep and wakefulness.
d = 1.38 p = .01
PTSD
2 studies · Hasler 2013 (n = 36), Ebdlahad 2013 (n = 13 vs 12 MDD) · EEG-PET
Brainstem and limbic metabolism stay elevated through REM and run higher in PTSD than in depression.
r = 0.70 (brainstem vs eveningness) Z = 3.64 (PTSD > depression)
INSOMNIA
10 studies (9 with regional findings) · EEG-PET and EEG-fMRI
The thalamus, insula, cingulate, and brainstem should switch off for sleep, in insomnia they don't.
hyperarousal persists into sleep

THE SHARED CIRCUITS



1: Cingulate **2:** Thalamus **3:** Insula **4:** Brainstem **5:** Lateral temporal cortex **6:** Amygdala **7:** Hippocampus / parahippocampal

Every region shown is disrupted in ALL THREE conditions · right-hand links are functional interpretation, not data · regions matched by reported name not coordinates; studies differ in modality and analysis, and not all report coordinates

Three diagnoses. One set of circuits. Seven regions are disrupted in TBI, PTSD, and insomnia alike.

WHAT THEY GOVERN

Common to all three conditions

AROUSAL & VIGILANCE

Thalamocortical gating and brainstem arousal nuclei fail to disengage. Six studies implicate the brainstem, though not always the same region: pons, midbrain, reticular formation, pontine tegmentum, locus coeruleus.

EMOTIONAL REGULATION

Limbic circuits stay active through REM, the stage that should quiet them. The emotional-memory network stays engaged into sleep. REM's overnight down-regulation of emotional memory is lost.

COGNITIVE INTEGRATION

Saliency, sensory-gating and memory networks miss the overnight reorganization that consolidates memory and restores attention. The cingulate is implicated in 9 of the 12 studies with regional findings.

01 WHAT THE CLINIC MISSES

- Disrupted sleep is pervasive in military populations, degrading cognition, emotional regulation and readiness.
- PSG, actigraphy, and questionnaires capture sleep *architecture* but stay blind to the circuit dysfunction underneath it.
- Simultaneous EEG + neuroimaging resolves both: EEG gives the temporal anchor, fMRI and PET the spatial map.
- But EEG inside an MRI or PET scanner is hard : MR-safe caps, gradient and ballistocardiogram artifacts, setup few sites can run, uncomfortable environment. That difficulty, not the science, is why so little of this has reached service members.
- Once the circuits are mapped, sleep dysfunction becomes something you can measure, track and treat.

02 HOW WE BUILT THE EVIDENCE

First PRISMA-guided systematic review of simultaneous EEG–neuroimaging in human sleep.

- 205 studies met inclusion criteria. Only 13 addressed TBI, PTSD, or insomnia.
- Regions extracted from every paper's Results section, mapped to AAL3.
- 12 of 13 reported regional findings.
- 5 PET and 8 fMRI studies.
- All military studies are PET, so the cross-condition comparison rests on PET.

FROM 205 STUDIES TO 3

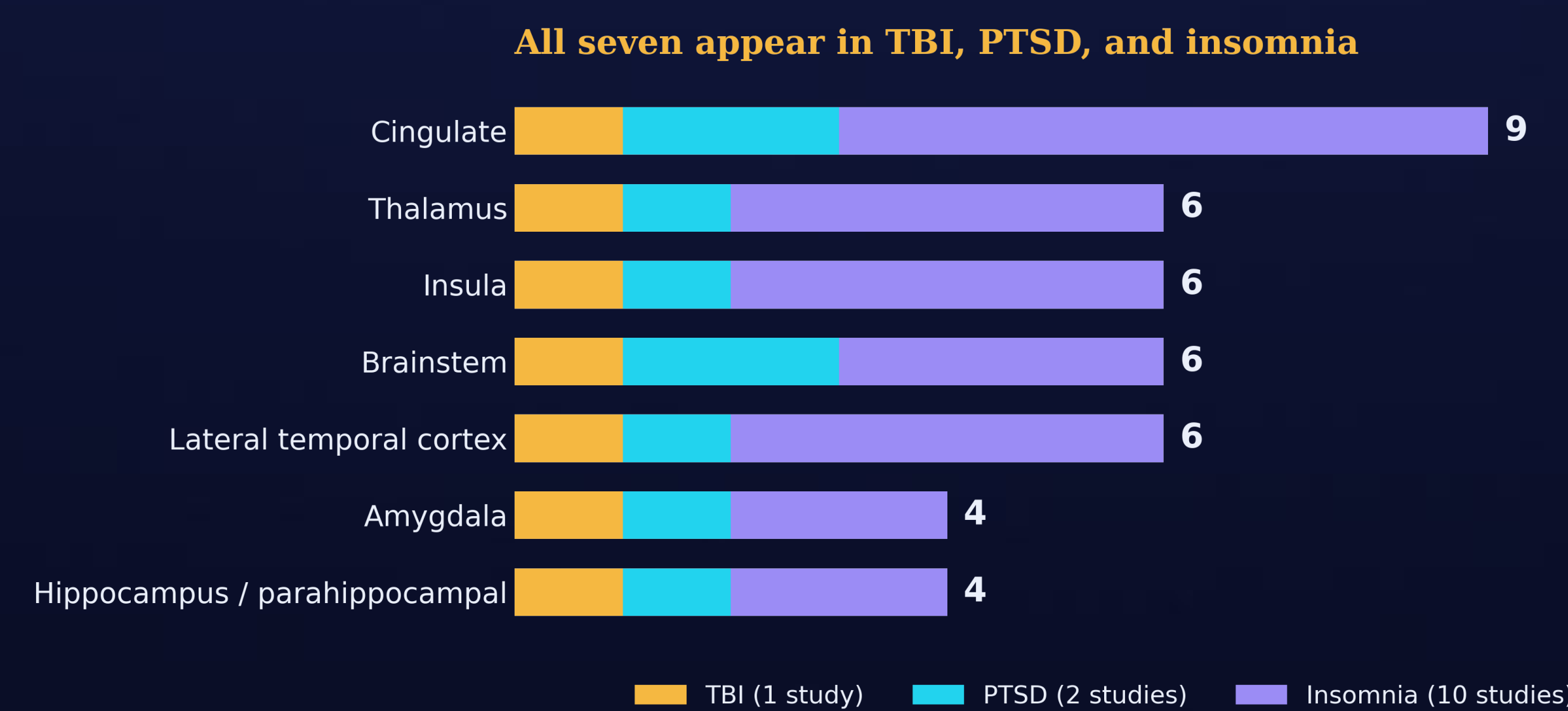


Three studies. 74 veterans. All PET. No relevant studies since 2014. That is the entire military sleep-neuroimaging evidence base.

THE CAPABILITY GAP

There is no biomarker of the sleep-circuit dysfunction in clinical use. The disruption is real, convergent across three diagnoses, and invisible to every tool now in the clinic. It is measurable, for instance an fMRI classifier already detects insomnia at 89% accuracy, but the science hasn't been translated to clinical or operational settings, least of all for service members.

03 WHICH BRAIN REGIONS CONVERGE



Bars count studies that implicate each region, not effect size or significance; some associations are strong, some weak, some uncorrected. Regions matched by reported name, not coordinates; studies mix PET and fMRI and differ in analysis.

Only **7 of 19** brain regions appeared across all three conditions; most did not, so the overlap is a genuine pattern, not a coincidence. And the base is thin: **TBI rests on one study, PTSD on two**, so we report where regions converge.

7 of 19

brain regions converged across all TBI, PTSD, and insomnia

REM sleep

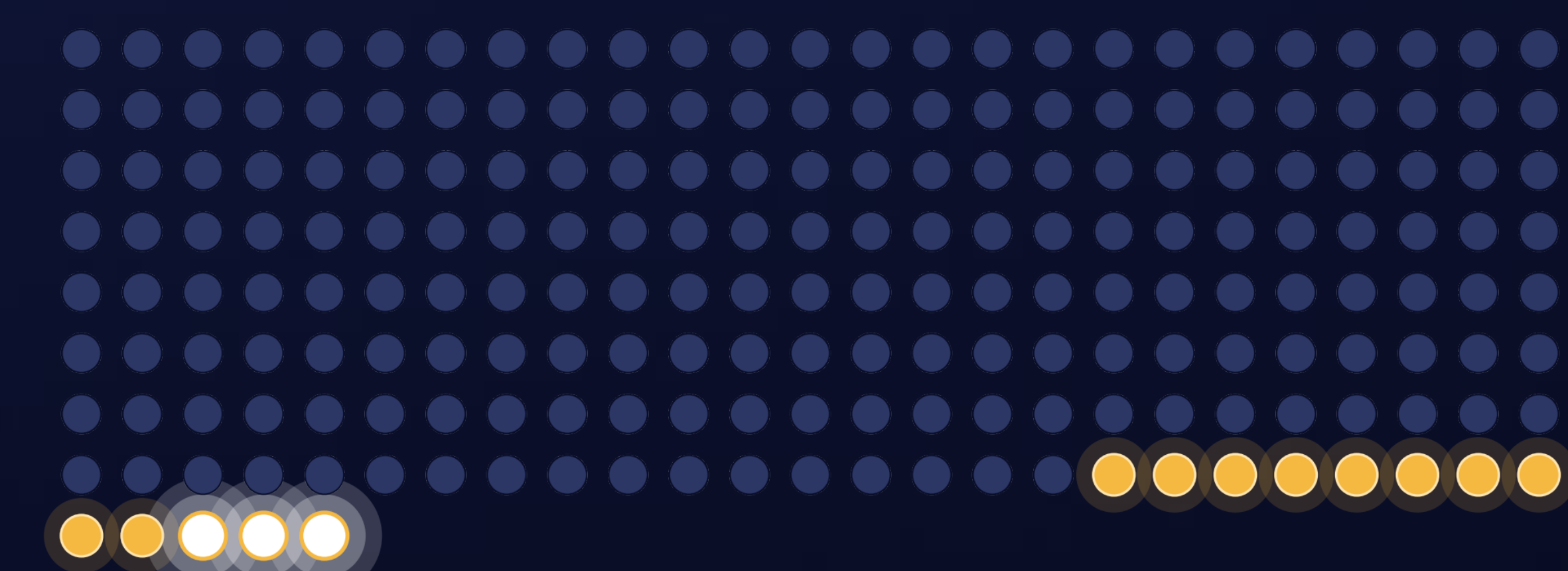
where the shared circuits surface in TBI & PTSD

NREM sleep

where they surface in insomnia

Direction differs by condition: the same regions show reduced metabolism in TBI, but elevated activity in PTSD and insomnia (PET studies).

04 THE EVIDENCE GAP



205 studies. **151** imaged healthy volunteers only. **13** address TBI, PTSD, or insomnia. **3** recruited service members.

N = 18

median sample size

52%

of studies had N < 20

0

military studies since 2014

THE ENTIRE MILITARY EVIDENCE BASE

Stocker 2014 TBI / blast · n = 25 **Hasler 2013** PTSD · n = 36
Ebdlahad 2013 PTSD · n = 13 All PET. All REM. All before 2015.

05 CONCLUSIONS

Convergent, clinically invisible and measurable. Seven circuits, three diagnoses.

These are the readiness circuits. Arousal, emotion, cognition.

The entire military evidence base is three papers. Prospective cohorts are urgently needed.

READ THE FULL REVIEW Pollatou et al., NeuroImage 2026 · doi.org/10.1016/j.neuroimage.2026.122122
WHAT IF SLEEP NEUROIMAGING DIDN'T NEED EEG? See the oral presentation on Aug 6: *Deep Learning Sleep Staging from ECG with Robust Automated Preprocessing: Toward Deployment in TBI and MRI environments* (MHSRS-26-5376), ML & AI in Military Health, Readiness, and Performance breakout session.

06 TWO ACTIONABLE PATHWAYS

From descriptive convergence to mechanistic validation

STRATIFY

Use the shared circuit signatures, such as REM limbic–brainstem hyperactivity or thalamocortical gating failure, to flag which service members' sleep dysfunction predicts readiness impairment.

EVALUATE

Test whether CBT-I, drug or neuromodulation therapy normalizes the networks, not just the sleep diary.