Real-Time Brain Health Monitoring During Blast Overpressure Using EEG Integrated Hearing Protection

NEURABLE

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Abstract

Blast overpressure exposure during breaching operations poses a significant risk for mTBI and impacts warfighter readiness. Current safety protocols rely on "minimum safe distance" (MSD), "blast dosing," and subjective symptom reporting, which often fail to capture known immediate physiological effects. A major gap remains in the ability to monitor brain function objectively, in real time, before symptoms or performance decrements appear. This study used EEG-integrated hearing protection headsets to record brain data from 12 participants during a multi-day breaching training program. Testing included resting-states collected before and after exercises and passive recording during live blast events.

Cohort analysis demonstrated statistically significant increases in Delta and Theta power over the week. Real-time monitoring revealed acute post-blast increases in Delta and Theta and decreases in Beta and Gamma power peaking 10–15 minutes post-exposure. This study delivers a comprehensive neural analysis spanning the acute and late-stage phases of blast overpressure exposure. The findings demonstrate that wearable, EEG-integrated hearing protection can identify biomarkers of cumulative and compounding neural strain, providing a pathway to mitigate cognitive risk and preserve force readiness.

Figure 1 (left). Neurable's AMP Neuro Hearing Protection Headset

Figure 2 (right). Operator wearing the Neurable AMP Neuro headset in the field

Background

1. THE CHALLENGE OF BLAST OVERPRESSURE

1. Breaching personnel are routinely exposed to blast overpressure from explosive shock waves.
2. High-level blast effects are well documented, but repeated low-level exposure remains a concern.
3. Current protocols use MSDs, dosing limits, body positioning, and limits on personnel near a charge.
4. Protection is supplemented by muzzle devices, hearing protection, helmets, and wearable blast gauges.
5. The system still leans on distance, dose accounting, and subjective symptom reporting.
6. Self-reporting is unreliable: adrenaline, confusion, and delayed symptom awareness can mask symptoms.

2. TWO ASSESSMENT PATHWAYS AFTER BLAST

POTENTIAL EXPOSURE
Pressure measurement
Round counting

NEURAL RESPONSE
Neural changes begin immediately after blast

CURRENT PRACTICE
10–60 MIN WINDOW MISSED
No objective brain measure is typically captured in this interval.

DELAYED ASSESSMENT
Imaging and cognitive testing occur hours or days later.

EEG-ENABLED PATHWAY
REAL-TIME EEG ASSESSMENT
Objective neural data can be collected within the 10–60 min post-blast window.

EEG SPECTRAL SIGNATURE
Delta ↑
Theta ↑
Alpha ↓

3. RESEARCH QUESTIONS

Q1 Does blast overpressure produce measurable EEG changes (Delta ↑, Theta ↑, Alpha ↓) independent of self-reported symptoms or performance decrement?

Q2 Does a personalized EEG baseline help evaluate cumulative day-over-day exposure across a week-long cycle?

Q3 What is the time course of EEG deviations after exposure, and what post-blast window is optimal for detection?

Results

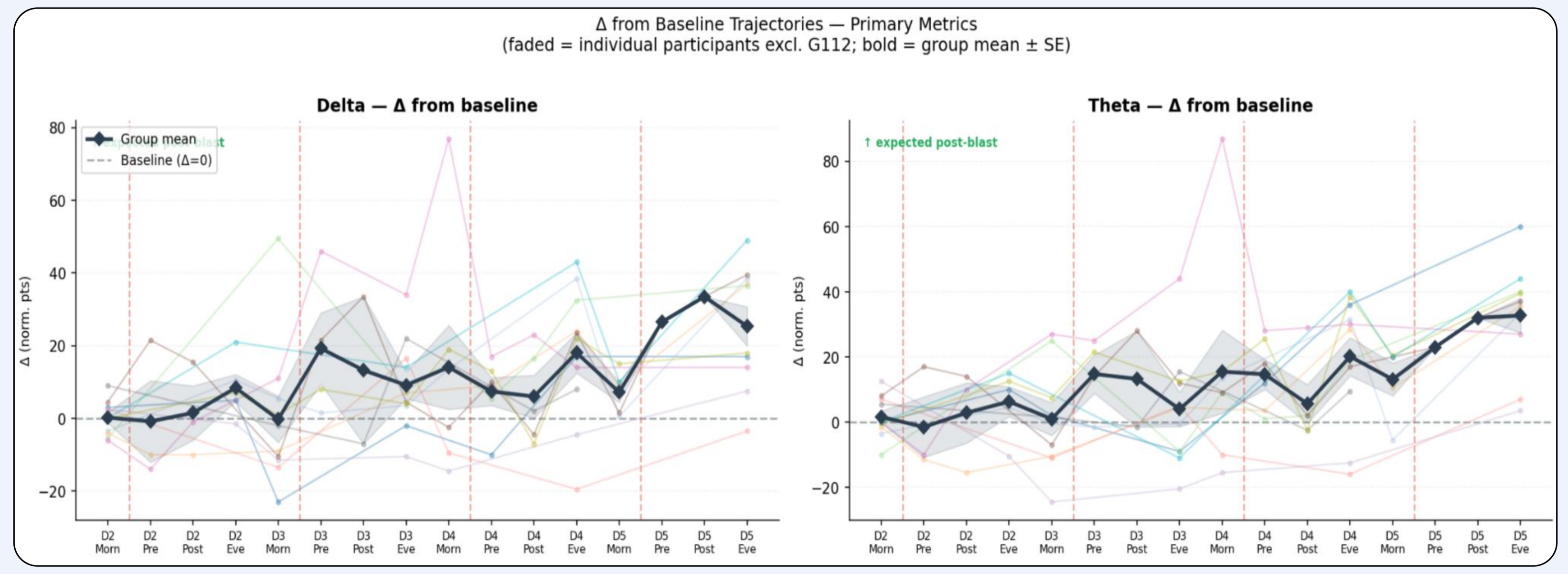


Figure 3. Spaghetti plots of normalized Delta and Theta power across the training week. Group averages are shown in black with gray variance shading; colored lines represent individual participants. Morning and evening data were available for all participants, while pre- and post-exposure data were limited to the AMP Neuro sub-cohort.

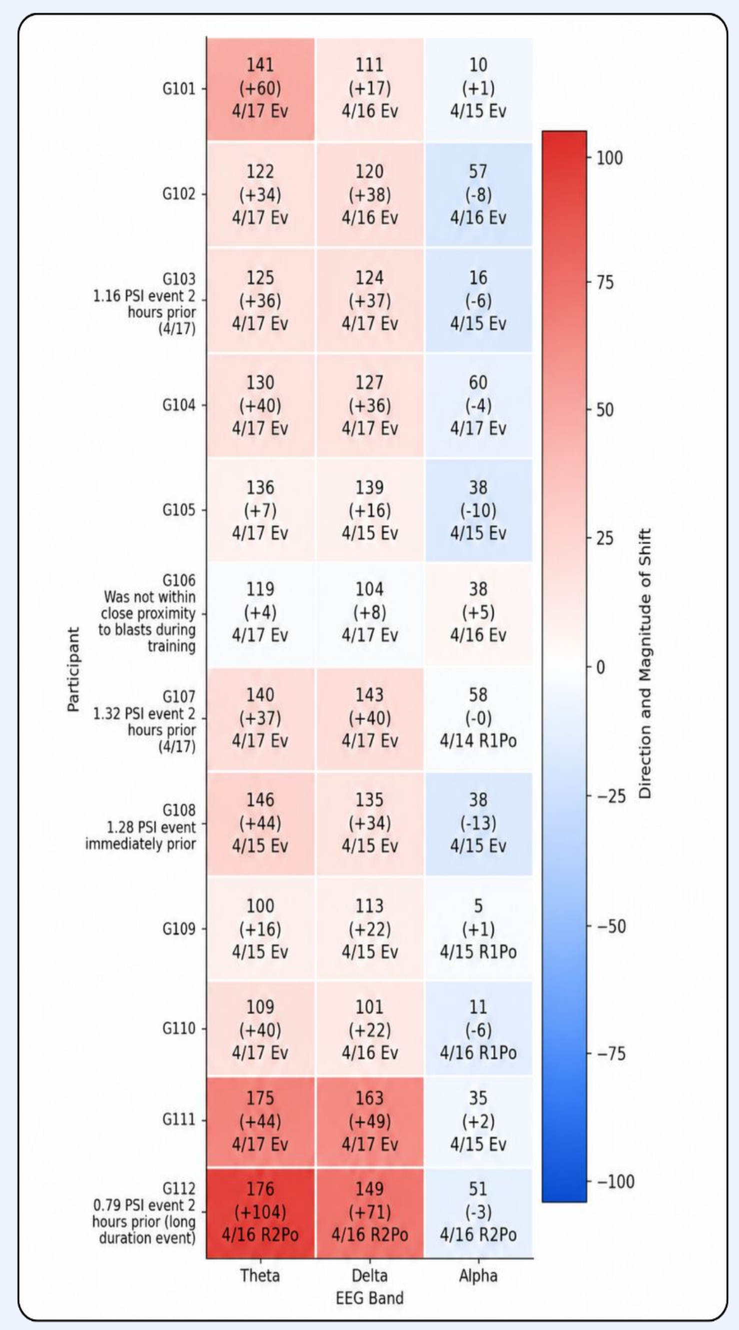


Figure 4 (above). Maximum neurophysiological changes from baseline across low-frequency EEG bands (maximum positive change for Delta and Theta, maximum negative change for Alpha). This matrix isolates the single testing session where each participant experienced their greatest deviation from their personalized baseline.

Figure 6 (below). Case study snapshot of participant G108 demonstrating a delayed, overnight escalation in cortical slowing metrics. All changes in Delta and Theta are relative to the baseline recording.

EEG Metric	Baseline Mean	End-Blast Mean	Mean Shift (Δ)	Wilcoxon (W)	Significance (p)	Effect Size (rbc)
Delta Power	94.9	121.5	+ 26.6	1	0.0010	0.974
Theta Power	96.3	131.1	+ 34.8	0	0.0005	1.000

Table 1. Summary of Wilcoxon significance testing

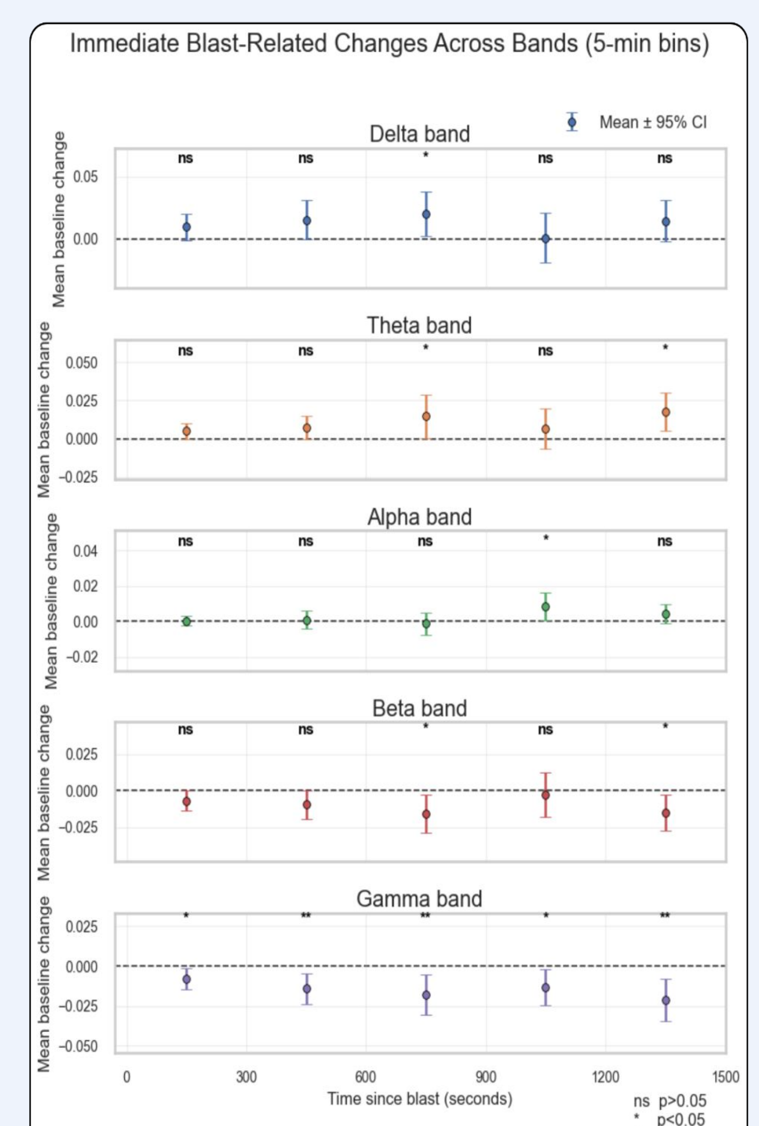
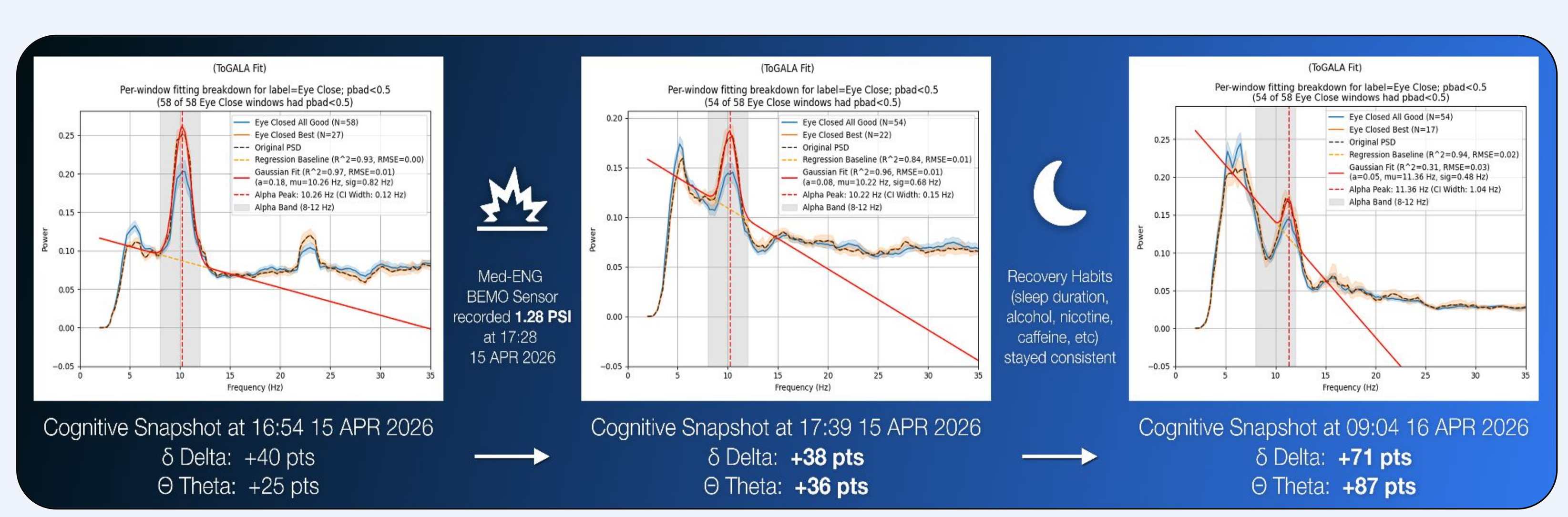


Figure 5. EEG data collected during blast exposure sessions reveals increased Delta Power, increased Theta Power, decreased Beta Power, and decreased Gamma Power following blast exposure timestamps



Methods

DAY 1: INTAKE AND BASELINE

1. Questionnaires & 2-Minute Baseline Snapshot
Full Cohort

DAYS 2–5: DAILY EXPOSURE LOOP

01. Morning Cognitive Snapshot
(Full Cohort)
with Daily Questionnaire

02A. Pre-Exposure Snapshot
(Sub-Cohort) with NSI Questionnaire

02B. Live Blast Passive Recording
(Sub-Cohort)

02C. Acute Post-Exposure Snapshot
(Sub-Cohort) with NSI Questionnaire

Repeat for Each Blast Block

03. Evening Cognitive Snapshot
(Full Cohort) with NSI Questionnaire

EEG-INTEGRATED HEARING PROTECTION

- AMP Neuro + MW75 Neuro
- AMP Neuro integrates Neurable dry EEG into Gentex Ops-Core hearing protection while retaining full hearing protection
- 12 dry EEG channels (6 around each ear)
- AMP Neuro: local recording at 500 Hz; Bluetooth stream at 125 Hz
- MW75 Neuro: 12 dry EEG channels streamed via Bluetooth at 500 Hz; no on-device recording

SUBJECTS

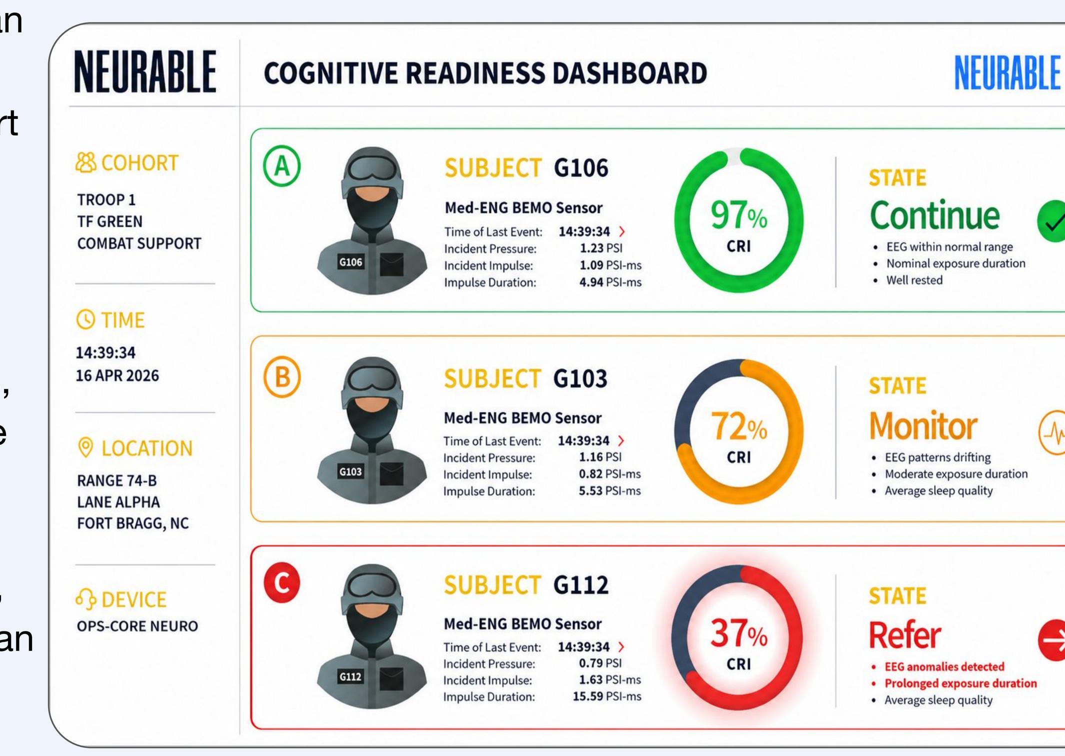
- 12 participants in an observational study
- G112: instructor with routine exposure
- Other 11 participants: limited prior exposure
- All participated during existing breaching training
- No blast exposures were added for the study
- All maintained instructor-set MSD

*The EEG data during the training sessions (during blast training) was collected from participants who were standing and freely moving. To control for motion artifacts, Neurable's proprietary Novel Motion Artifact Rejection (NMAR) algorithm was used in preprocessing before spectral power extraction.

Future Direction

A future tool (pictured right) could translate signals into an operator and commander alerting and decision-support system.

Rather than presenting raw EEG bands or making deterministic medical claims, the system would synthesize individualized baseline deviation, acute post-event change, exposure metadata, and recovery trajectory into an interpretable Cognitive Readiness Index (CRI) or similar risk-stratification layer.



Acknowledgements

We would like to thank the Guild Solutions Group for hosting the training, Med-Eng for providing blast sensors to supplement data collection, and Dr. Brian Edlow for consultation and protocol evaluation.

References