LASIR Laboratory for Systems Integrity & Reliability

School of Engineering

VANDERBILT UNIVERSITY MEDICAL CENTER

Measurement of optic pathway strain in model head/brain in repeat low-level blast environments

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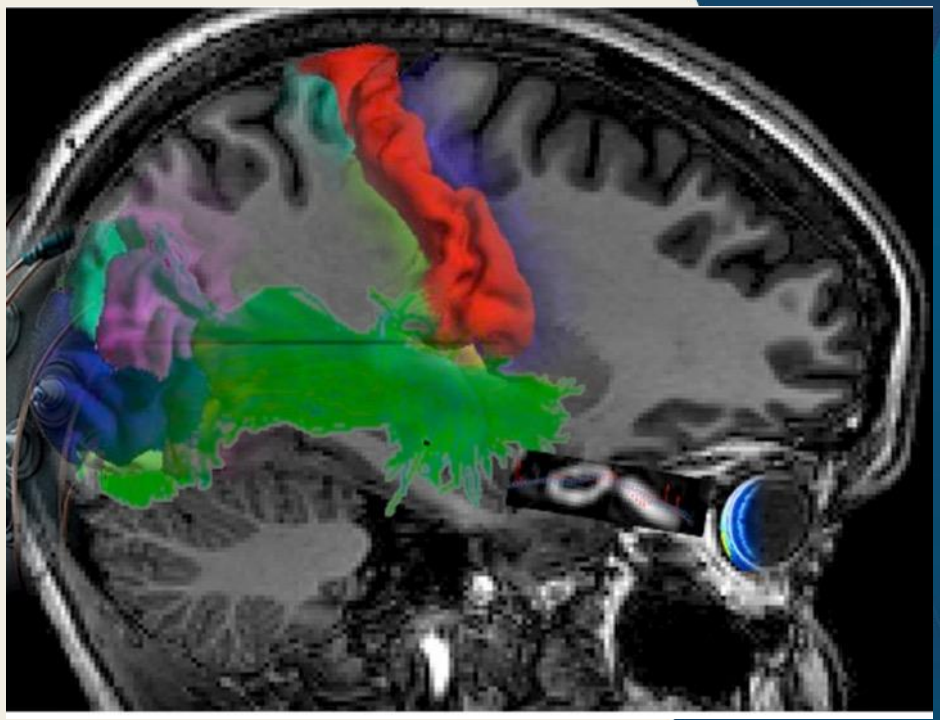
The connection between vision and head injury

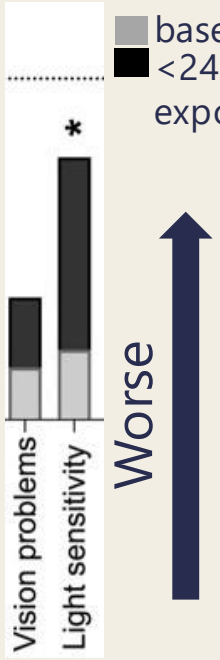
- Visual dysfunction reported in ~ 80% of brain trauma patients regardless of injury severity
  - **Merezhinskaya et al., 2019**
- Patients have normal visual acuity and no obvious eye damage
- Visual areas encompass ~50% of the brain

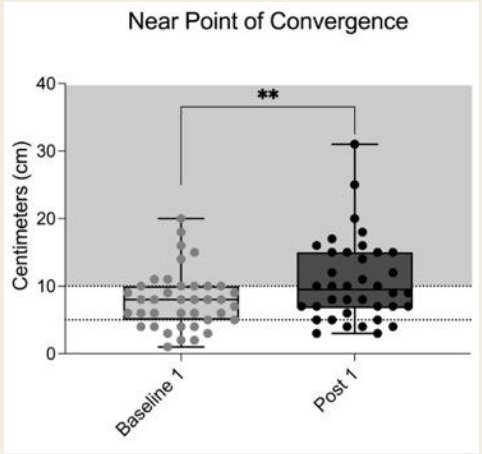


The connection between vision and head injury

Acute vision deficits after single event repeat low-level blast exposure

Percent of soldiers reporting vision symptoms

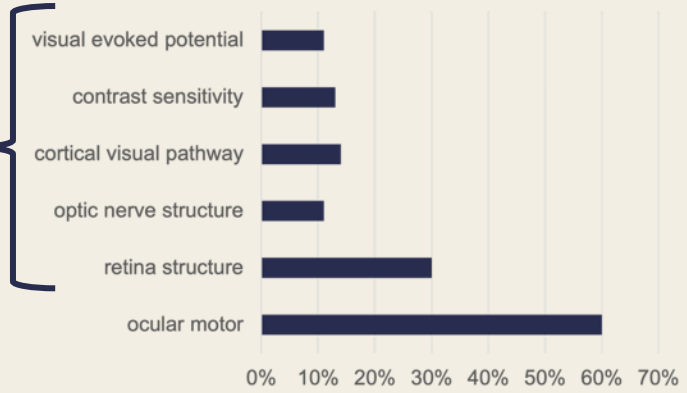


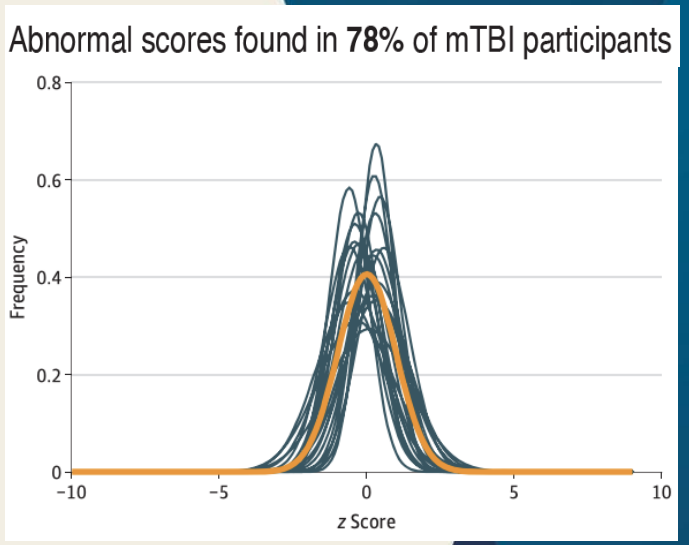


Conner et al., J. Neurotrauma (in review)

Chronic vision deficits after mild traumatic brain injury

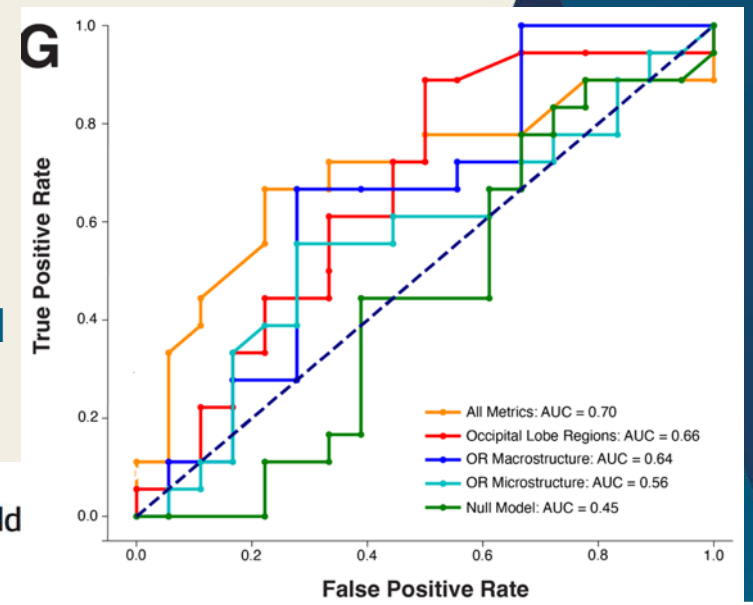
Retinal ganglion cell/ optic nerve - associated





Machine learning algorithm applied to tractography of visual pathway from MRI.

72% accuracy rate for correctly classifying patients as control or TBI



JAMA Ophthalmology | Original Investigation | AI IN OPHTHALMOLOGY

Primary Visual Pathway Changes in Individuals With Chronic Mild Traumatic Brain Injury

Marselle A. Rasdall, MD; Chloe Cho, BS; Amy N. Stahl, AuD; David A. Tovar, MD, PhD; Patrick Lavin, MD; Cailey I. Kerley, PhD; Qingxia Chen, PhD; Xiangyu Ji, MS; Marcus H. Colyer, MD; Lucas Groves, MD; Reid Longmuir, MD; Amy Chomsky, MD; Martin J. Gallagher, MD, PhD; Adam Anderson, PhD; Bennett A. Landman, PhD; Tonia S. Rex, PhD

Protecting the visual pathway from injury

- Eye protection is designed and tested to block ballistics
  - It saves eyes.
  - It is not designed to protect against blast or percussive forces.

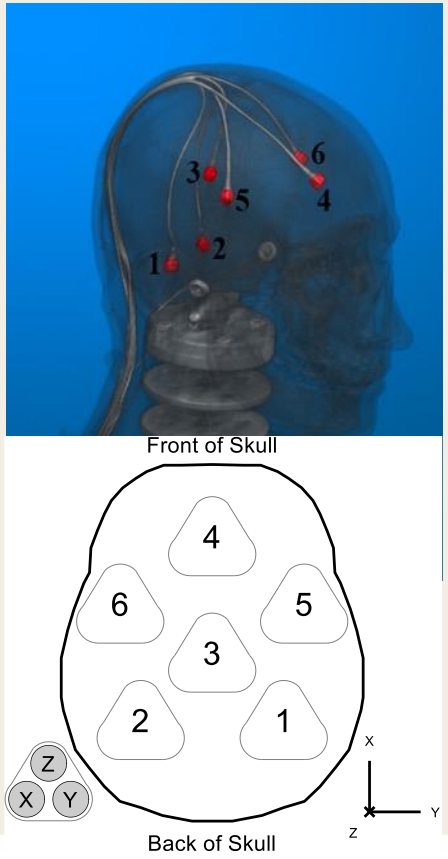
How effective is current eye pro at blocking blast forces?

- Need a method for testing eye protection against blast in order to answer this question.
- Thus, the development of our biofidelic instrumented head-form (BIHF) that includes a model optic pathway
- Here we show results from explosive breaching and mortar firing.

Biofidelic Instrumented Head-Form (BIHF)

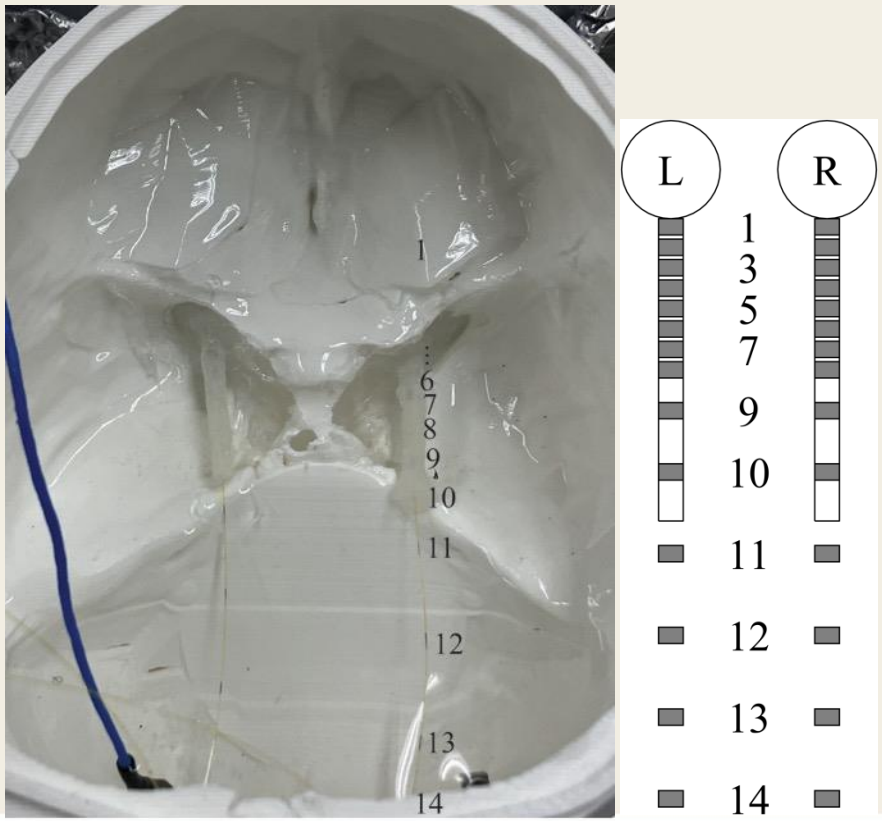
Acceleration

Six triaxial accelerometers in the brain model



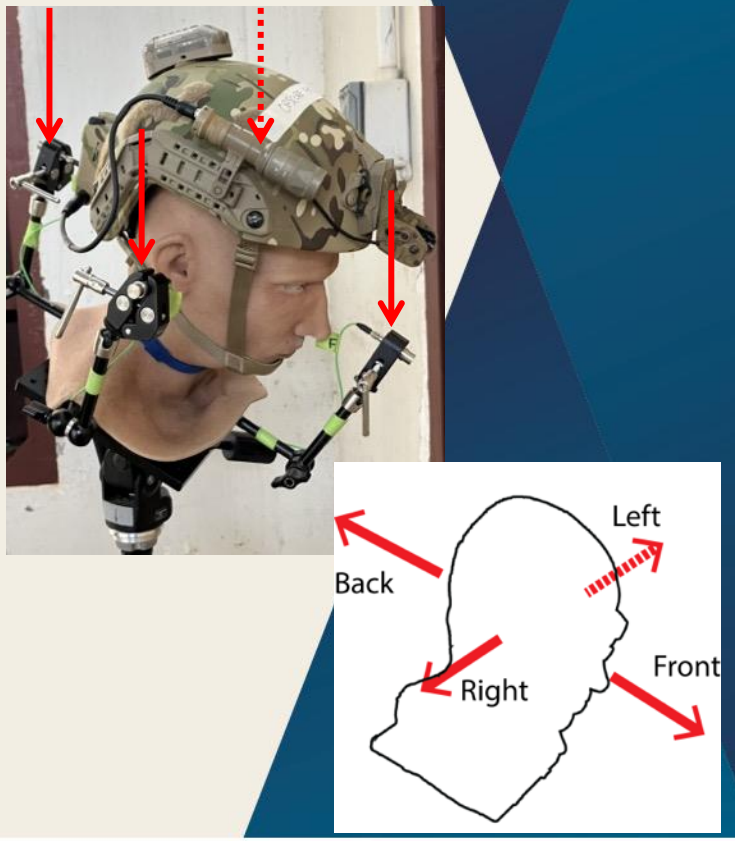
Strain

Two, 14 sensor fiber optic strain arrays embedded in the eye/optic nerve model



Pressure

Four external pressure sensors



Breacher environment test set-up

Blast exposures per BIHF configuration:
Five double strand,1x12”+1x16” machete door charges per BIHF configuration

BIHF configurations:

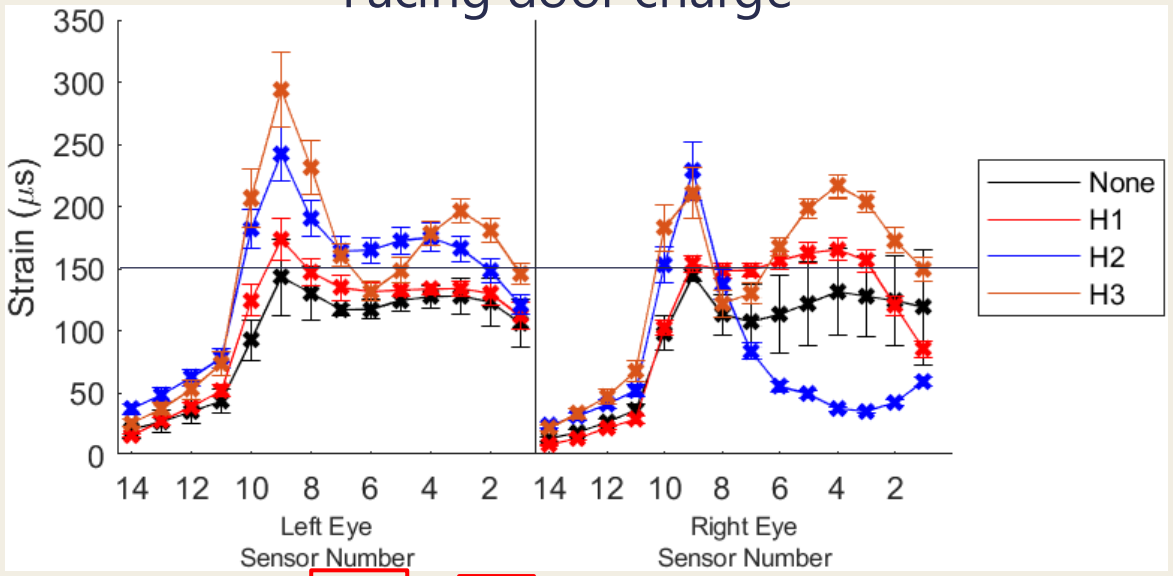
Test 1: Different locations and orientations to charge (0º or 90º), different helmets

Test 2: Same position and head tilt; helmets, eye pro, helmet shield, ear pro

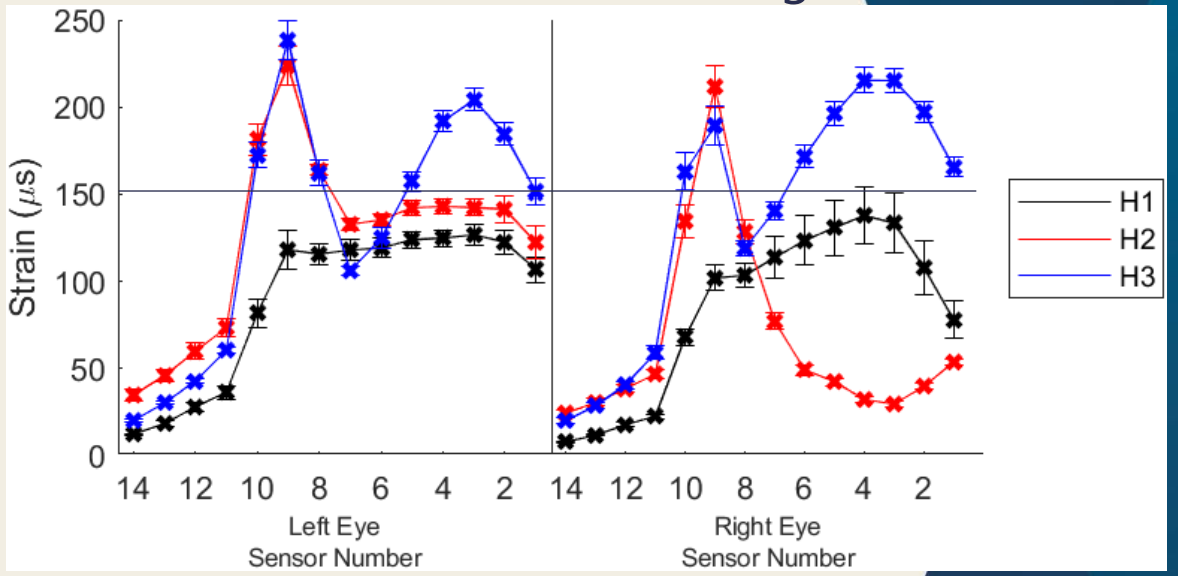
Same room for both tests

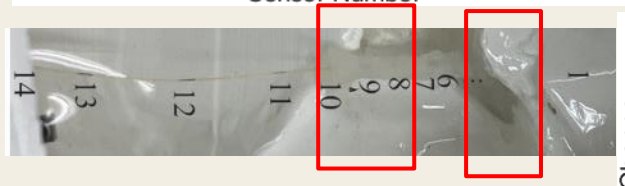
Helmets affect optic pathway strain during breaching

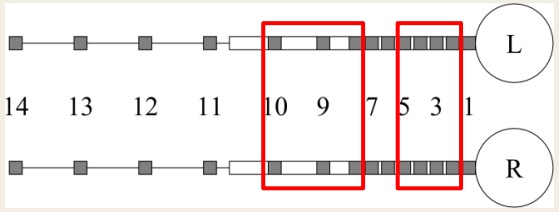
Facing door charge

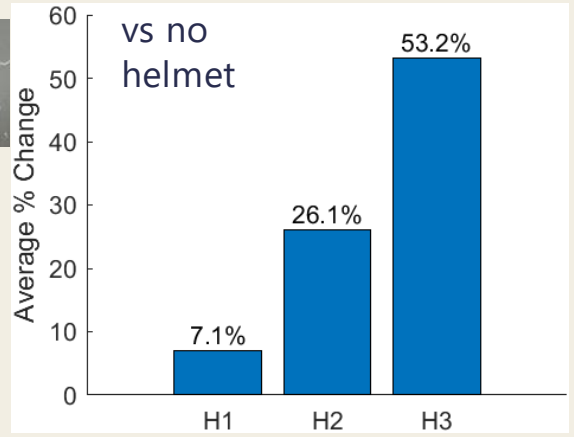


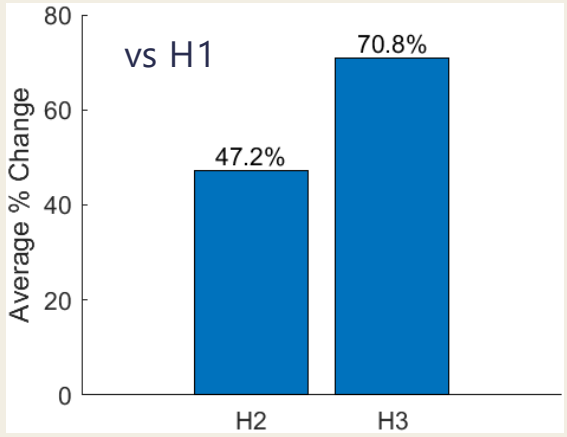
90° from door charge









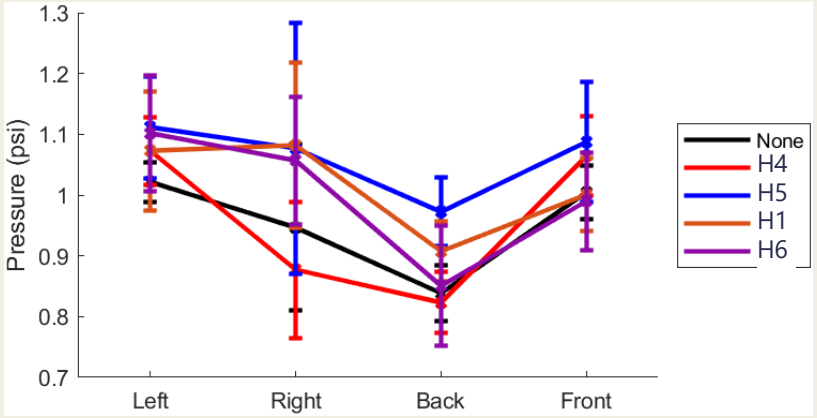


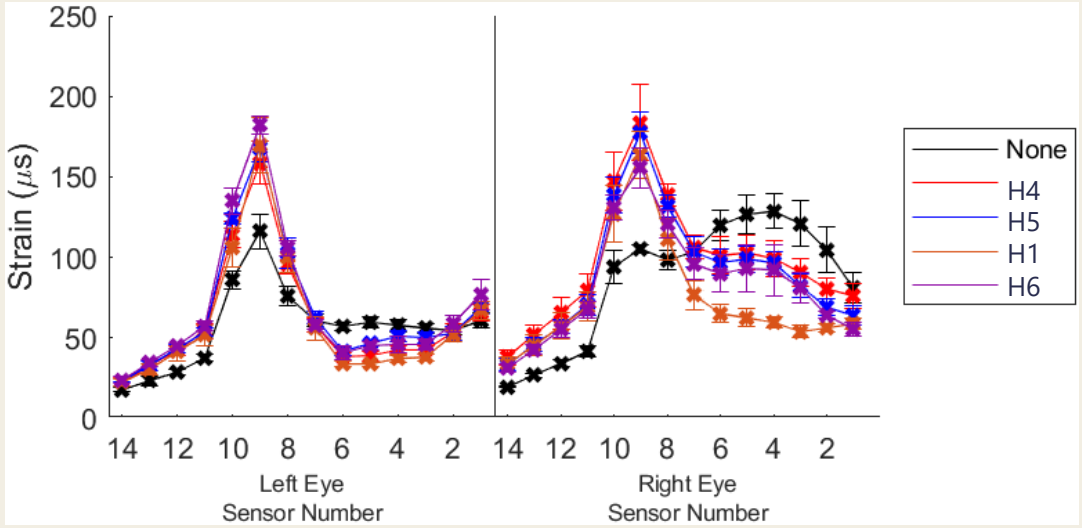
H1 is the best helmet option.

All helmets increase strain, particularly in the optic nerve and tract regions

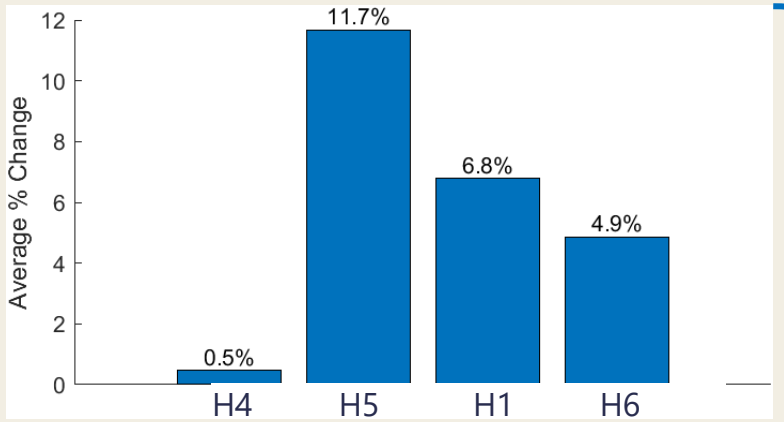
Breaching with tilted orientation protects the left optic nerve from strain

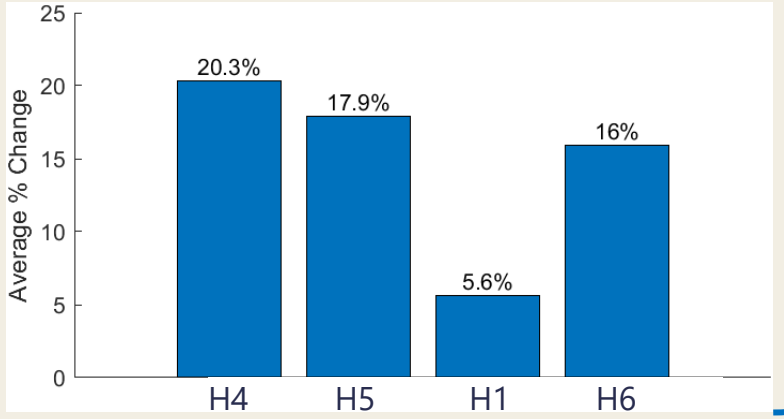
Input BOP





vs no helmet





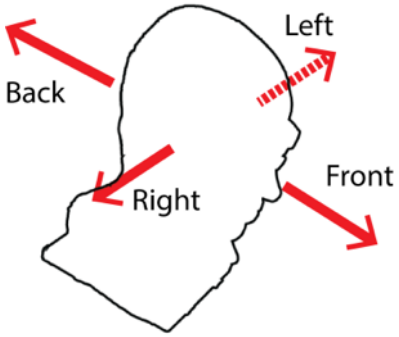
Roughly accounting for differences in input BOP:

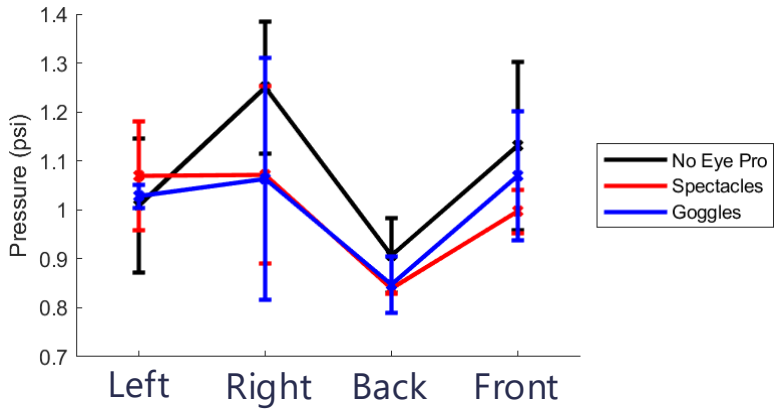
20% 6% -1% 11%

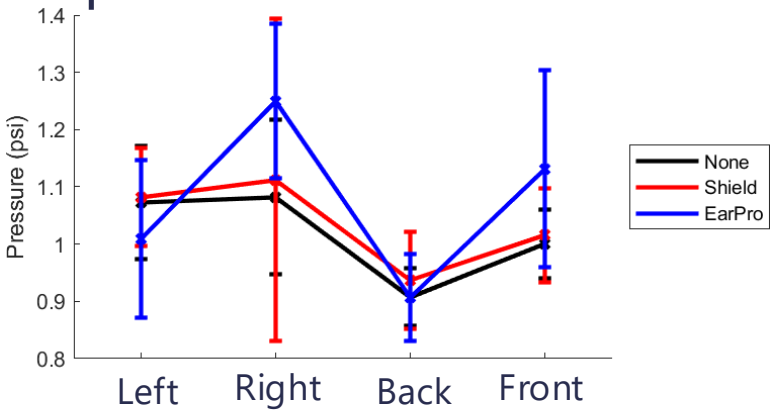
- H1 was protective.
- H4 performed the worst.

Effect of non-helmet PPE

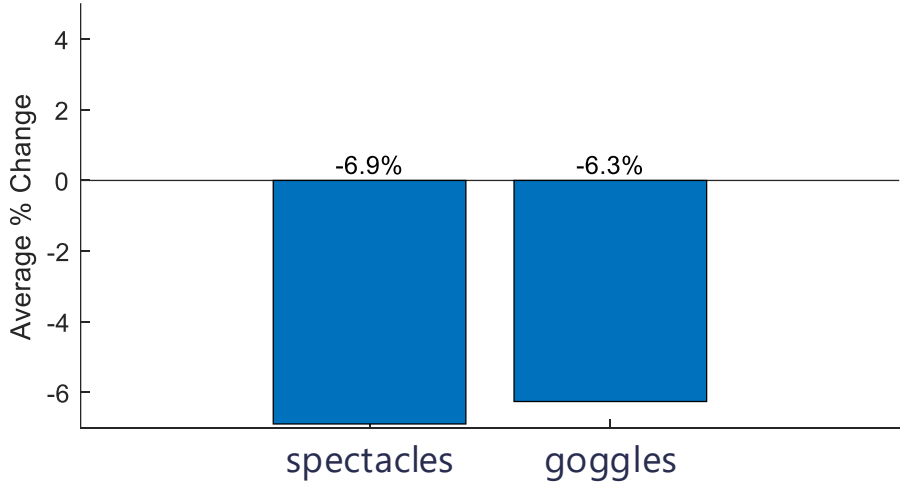
Peak BOP range of 0.8 – 1.4psi

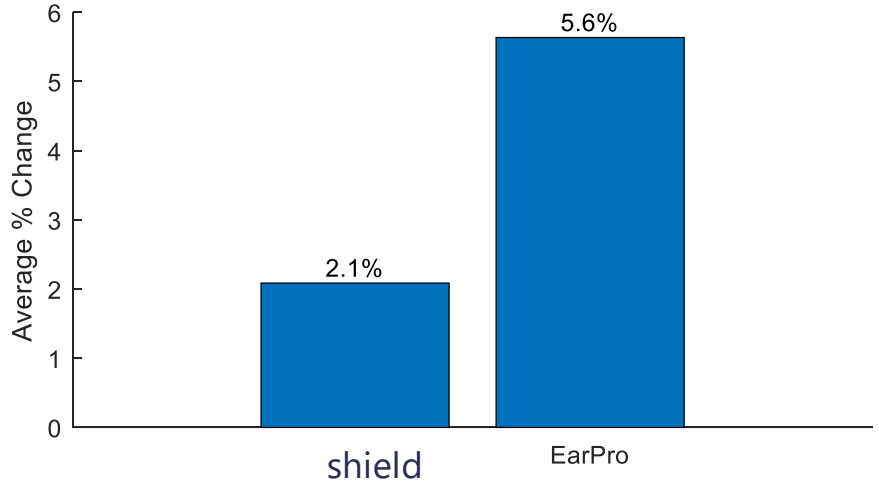






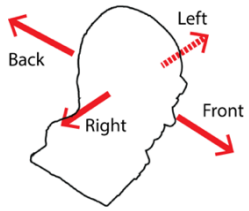
Less than 7% difference in average BOP relative to no eye pro condition

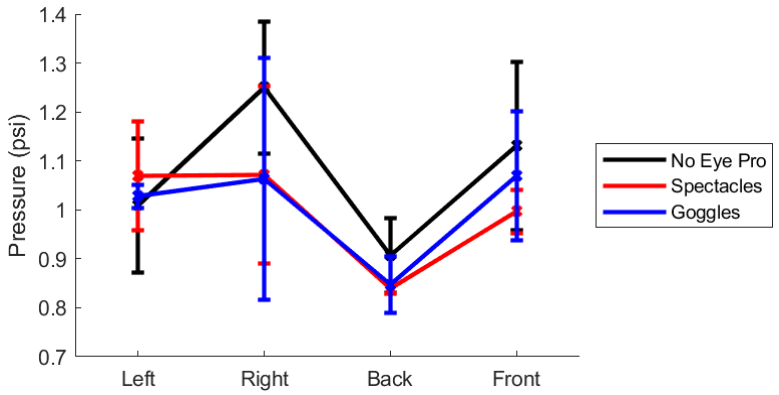


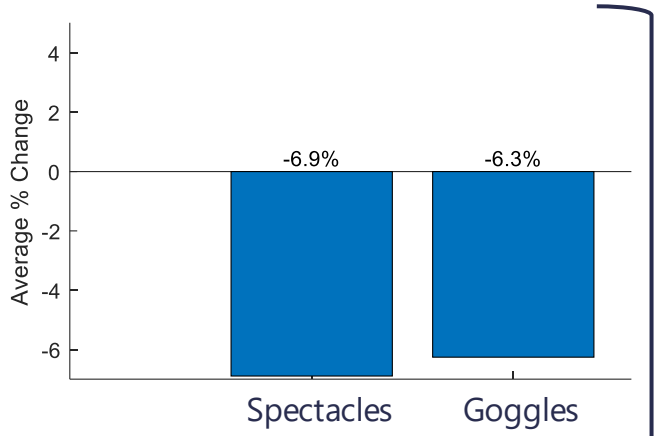


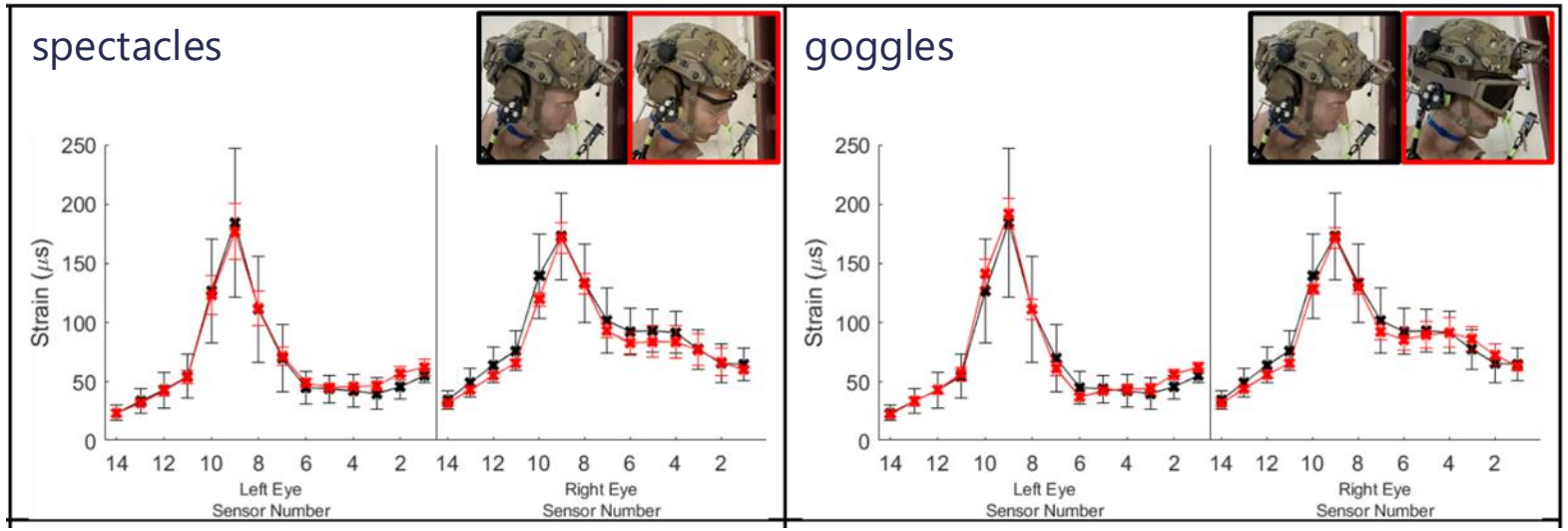
Effect of eye protection during explosive breaching

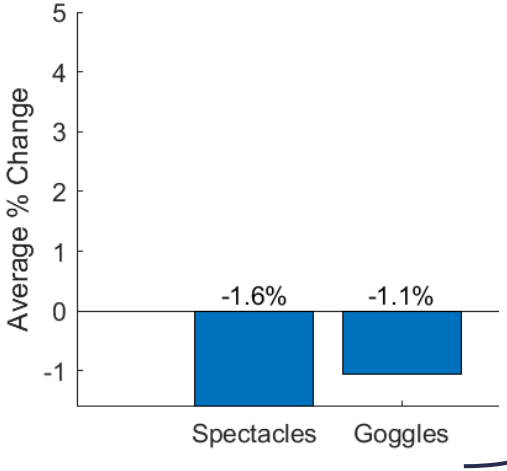
Input BOP







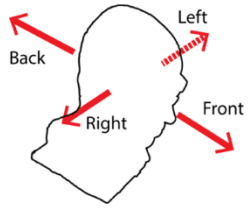


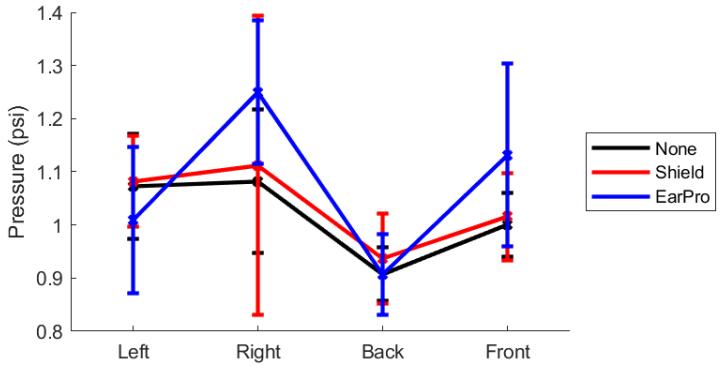


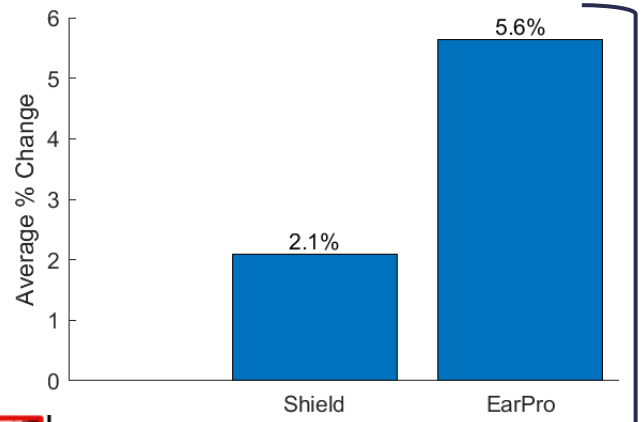
~5% increase

Effect of shield or ear pro during explosive breaching

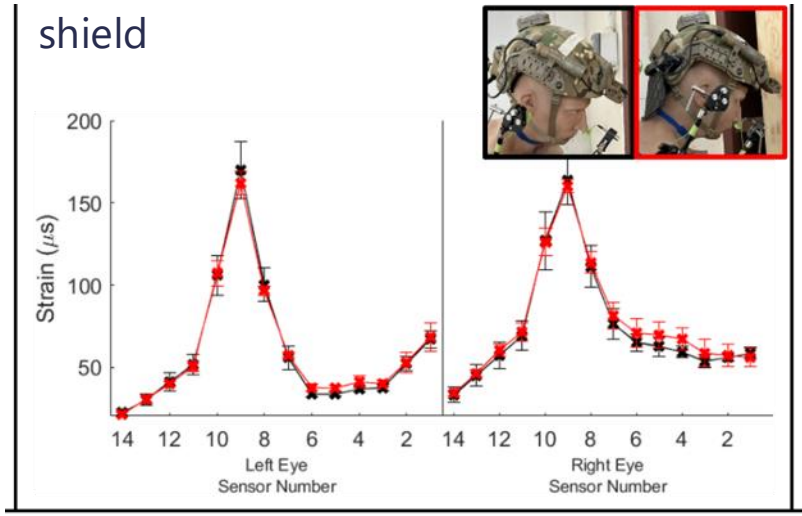
Input BOP



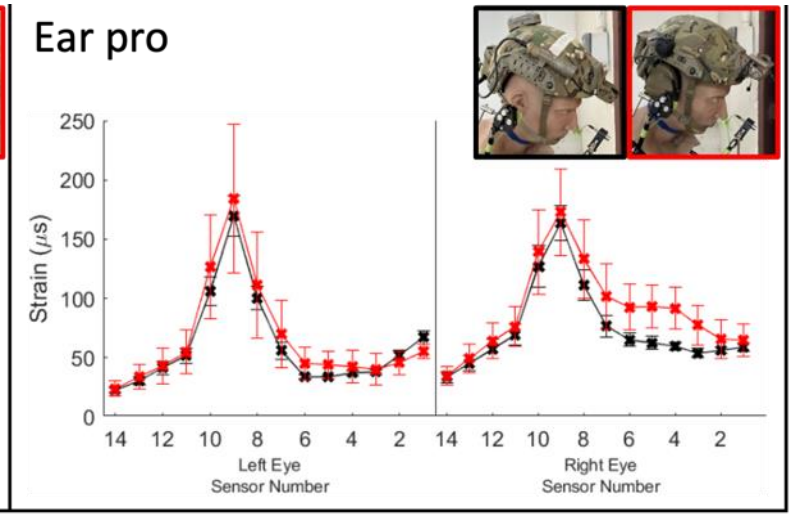


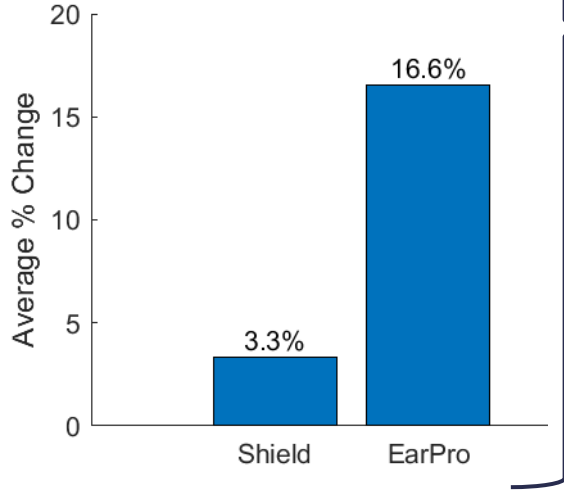


shield



Ear pro





Shield: no effect

Ear pro: 11% increase

Explosive Breaching Summary

1. **Explosive breaching increased strain particularly in the model distal optic nerve/optic tract**
2. **Eye pro caused slight increase in strain to the optic pathway**
3. **There was no difference between goggles and spectacles**
4. **Ear pro increased strain to the model proximal optic nerve**

Better eye protection is needed to prevent infiltration of blast energy through the eyes and into the brain.

Mortar firing test set-up

5 exposures per BIHF configuration:

120mm, level 1 charges
Two positions modeling gunner and assistant gunner

Configurations:

No helmet

3 different helmets

Underwash shield

Spectacles

Little variability in average peak pressures across all configurations

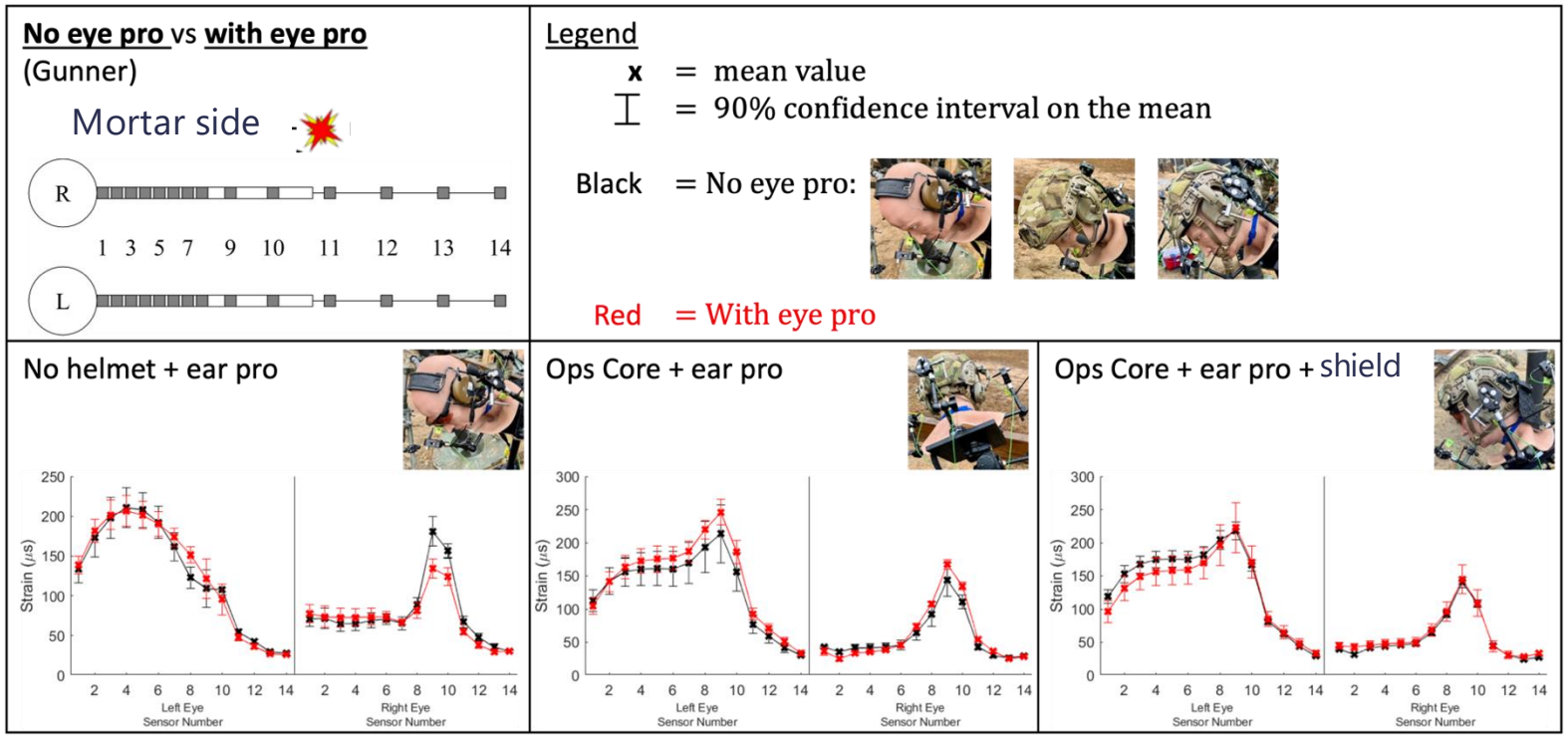
Gunner BOP

Sensor	Mean Peak (psi)	Standard Deviation (psi)
Left	1.7	0.22
Right	1.6	0.22
Back	2.7	0.34
Front	1.2	0.13

Assistant Gunner BOP

Sensor	Mean Peak (psi)	Standard Deviation (psi)
Left	2.0	0.21
Right	1.7	0.28
Back	3.0	0.32
Front	1.2	0.12

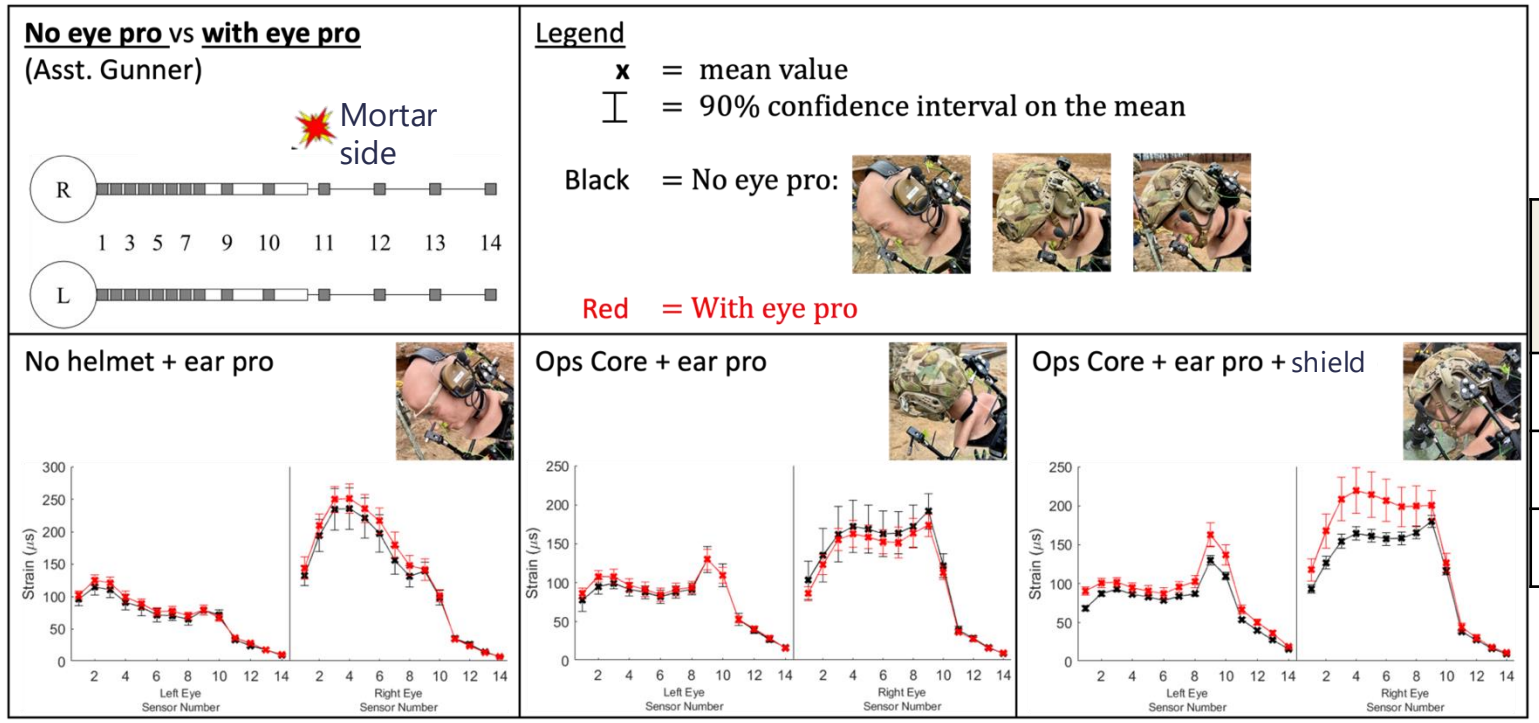
Eye protection during mortar firing: Gunner position



Sensor	mean peak BOP (psi +/- sd)
Left	1.7 +/- 0.2
Right	1.6 +/- 0.2
Back	2.7 +/- 0.3
Front	1.2 +/- 0.1

Configuration	Average change in strain relative to **no eye pro**
No helmet + ear pro	–2.4%
Ops Core + ear pro	+6.1%
Ops Core + ear pro + shield	+3%

Eye protection during mortar firing: Assistant Gunner position



Configuration	Average change in strain relative to **no eye pro**
No helmet + ear pro	+5.5%
Ops Core + ear pro	–0.8%
Ops Core + ear pro + shield	+20.6%

Mortar Firing Summary

1. **Eye pro (spectacles) mostly increased strain to the optic pathway, but only slightly**
2. **The effect of eye pro was influenced by every factor tested**
3. **The combined use of eye pro and the Pelta 6 significantly increased optic pathway strain, but only in the Assistant Gunner position.**

Better eye protection is needed to prevent infiltration of blast energy through the eyes and into the brain.

It is important to empirically measure how PPE interacts.

Team

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Research to Prevent Blindness Unrestricted Funds

Best performing helmet with required ear pro performs similarly with or without eye pro.

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