LASIR Laboratory for Systems Integrity & Reliability

School of Engineering

VANDERBILT UNIVERSITY MEDICAL CENTER

Measurement of Blast Energy Propagation into the Brain: Comparing PPE to Rapidly Inform Command Risk Management

Tonia Rex, PhD

Vice Chair & Professor

Vanderbilt Eye Institute

Vanderbilt University Medical Center

Disclosure

- Tonia Rex, PhD; Douglas Adams, PhD; Janette Meyer, PhD; Garrett Thorne; & Sariah D'Empaire-Salomon are co-inventors on BIHF, patent-pending, US provisional patent application #63/751,564
- Axon Defense Systems, LLC holds option for license on BIHF

Context

- In a routine, three-day training event, Ranger mortarmen accumulate more repetitive low-level blast (rLLB) exposures than a Carl-Gustav Range Safety Officer does over three-years, in some cases even exceeding 1,300 psi of cumulative, rLLB exposure.

- Over 60% of Ranger mortarmen in a recent study self-reported symptoms associated with brain injury and symptom severity was higher in those with a longer history as mortarmen, indicating a potential cumulative effect.

- Immediately actionable mitigation efforts are needed that don't hinder training required to maintain lethality.

- Data from us (Rex & Adams) and others (Bartsch) showed that helmets could increase pressure near the head and increase the amount of blast energy reaching the brain in other rLLB environments.

- The Regimental Brain Protection Task Force assembled a team of experts to answer a Ranger mortarman's question, **"will firing mortars without a helmet reduce blast overpressure to the brain?"**

Current Approaches

- Blast protection devices are being designed to offer protection from blast overpressure
- Need an objective and quantitative way to assess their efficacy

https://overpressured.com/pelta-6/

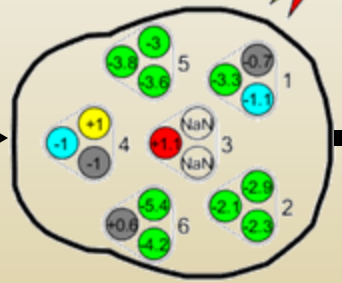
https://www.galvion.com/case-study/advancing-head-and-face-protection

Do They Work?

Design

Validation testing in realistic environment

Quantitative results



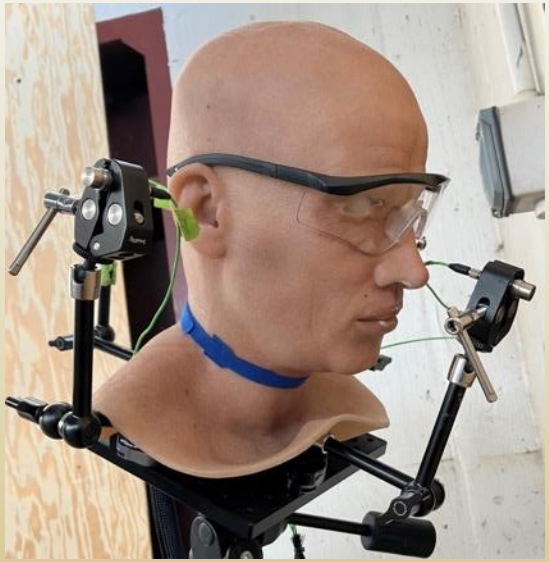
Success?

Yes

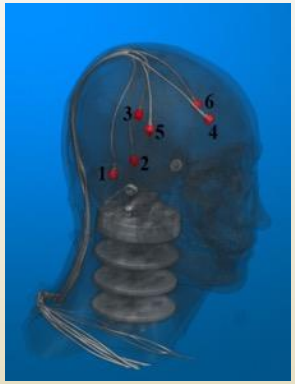
Production
Procurement
Etc.

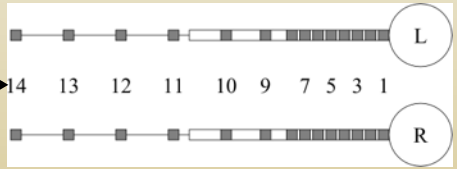
No

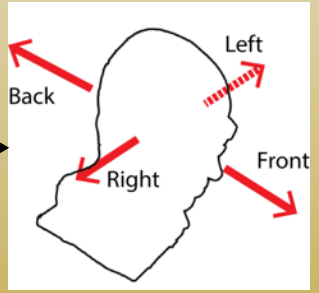
Biofidelic Instrumented Head Form (BIHF)



- 3D printed skull
- Silicone brain model
  - 6 embedded accelerometers
- Silicone eye/optic nerve model
  - 14 embedded strain sensors
- Silicone mask to simulate skin layer
- Four, external pressure sensors





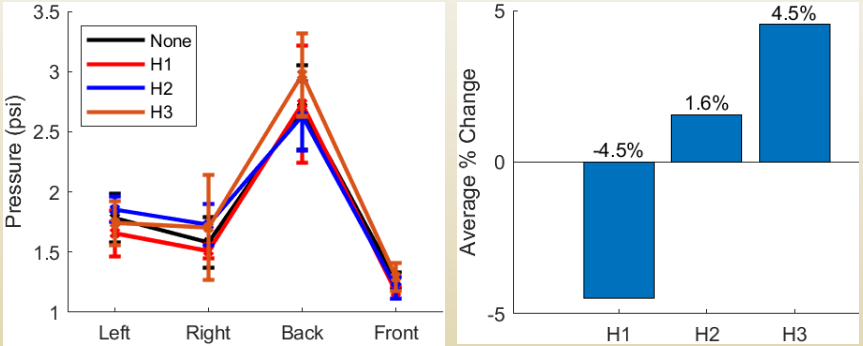


Test Environment: Mortar Range

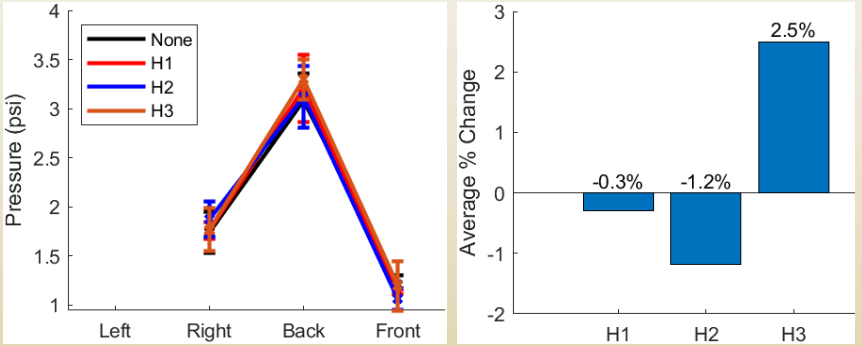
- Two BIHFs were positioned to mimic the gunner and assistant gunner, who crouch and turn slightly away from the barrel
  - Soldiers were still present, so BIHF positioning was approximate to give the crew room to perform operations
- Eight configurations were tested and compared to a no helmet control:
  - Ops Core helmet (H1) + Ear pro $\pm$ helmet shield
  - H1 + Ear pro + Eye pro $\pm$ helmet shield
  - ACH helmet (H2) + Ear pro + Eye pro $\pm$ helmet shield
  - Bump helmet (H3) + Ear pro + Eye pro $\pm$ helmet shield
- Five mortar rounds per configuration
  - Data acquired with BIHFs and external pressure sensors

Similar input BOP

Gunner position

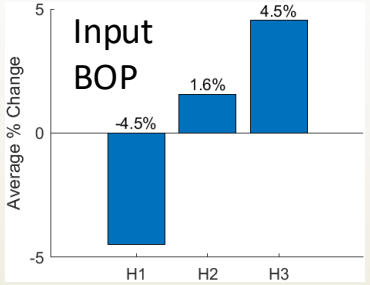


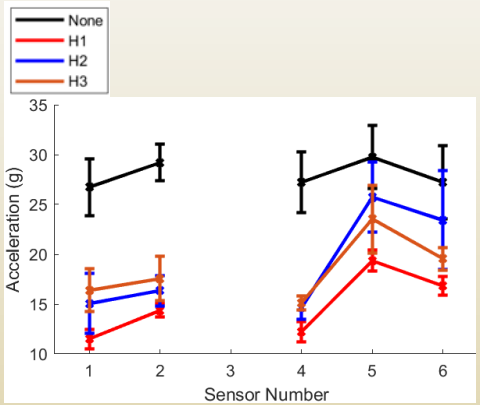
Assistant Gunner position

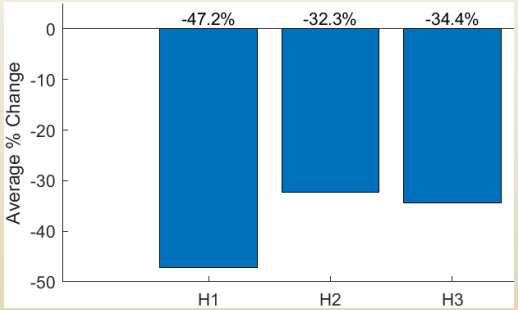


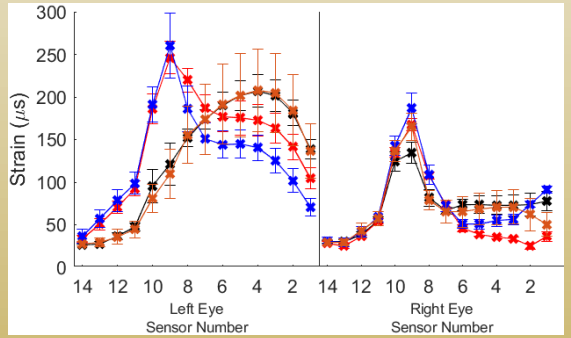
- The highest BOP was detected at the back of the head, as predicted.
- Input pressure was very similar during testing of each helmet compared to the no helmet control.

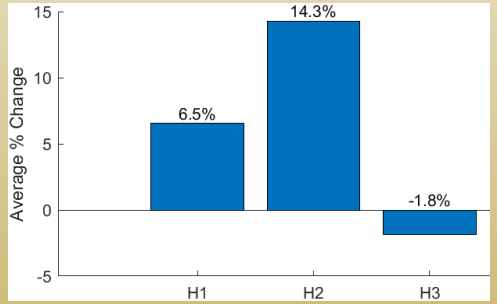
Gunner position: Helmets are unequally protective







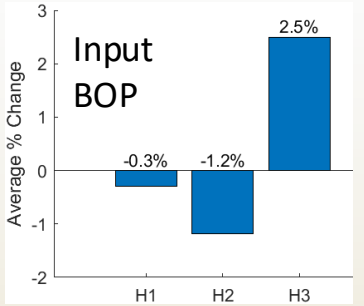


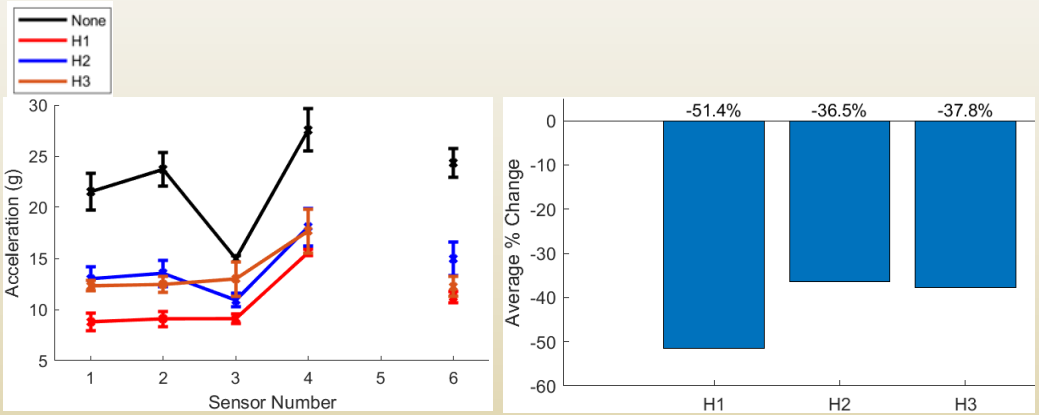


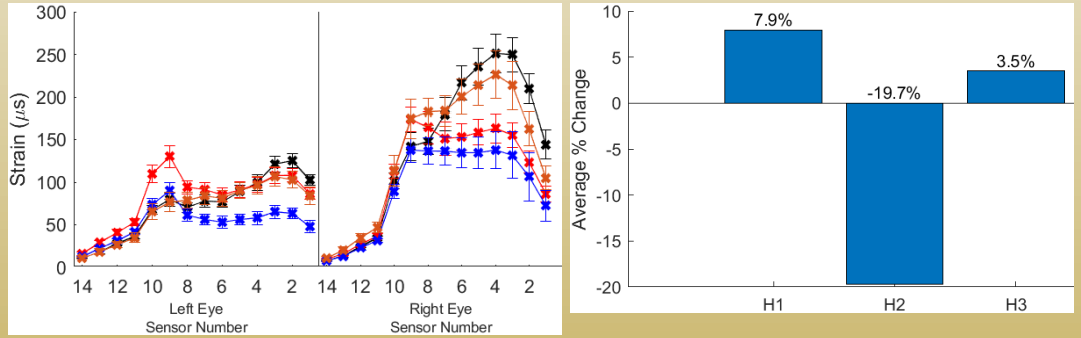
- All brain sensors measured lower accelerations with helmets. Helmet 1 was most effective even taking into consider slight differences in input BOP.
- Helmets had the greatest effect on the front and back of the brain.
- Helmets 1 & 2 increased optic tract strain, but decreased optic nerve strain.
- Helmet 3 increased strain the least.

Overall, helmets are protective and should be worn during mortar firing.

Assistant Gunner position: Helmets are unequally protective







- All brain sensors measured lower accelerations with helmets. Helmet 1 was most effective even taking into consider slight differences in input BOP.
- Helmets had the greatest effect on the front and back of the brain.
- Helmets 1 & 3 increased strain.
- Helmet 2 decreased strain.

Overall, helmets are protective and should be worn during mortar firing.

Back helmet shield worked best with Helmet 2

GUNNER POSITION

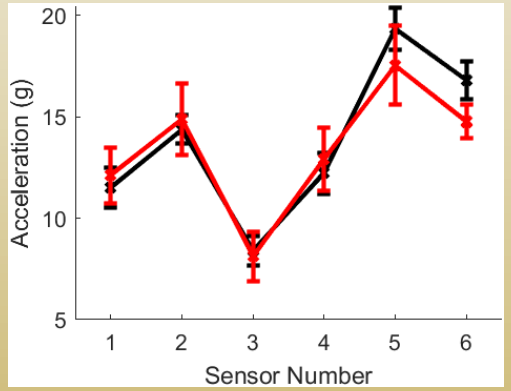
All Plots: Black Line: NO Shield **x** = mean value I = 90% confidence interval on the mean

Red Line: H1 + Shield

Red Line: H2 + Shield

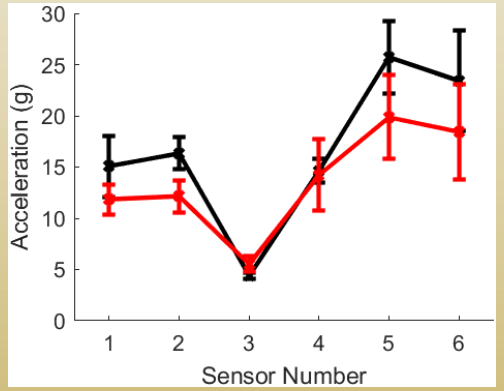
Red Line: H3 + Shield

Acceleration



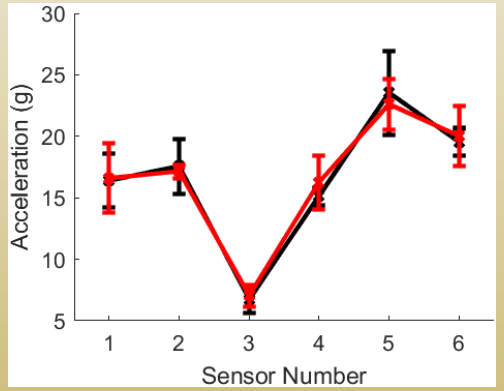
Average % change = – 1.7%

Acceleration



Average % change = – 11.4%

Acceleration



Average % change = + 1.5%

Back helmet shield worked best with helmet 1

ASST. GUNNER POSITION

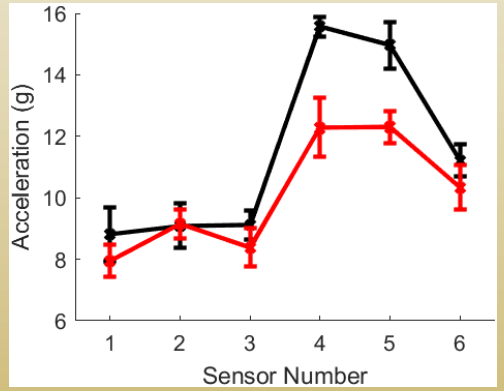
All Plots: Black Line: NO PELTA-6 **x** = mean value ⌶ = 90% confidence interval on the mean

Red Line: H1 + Pelta-6

Red Line: H2 + Pelta-6

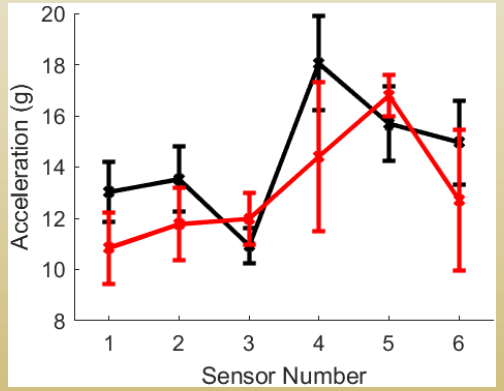
Red Line: H3 + Pelta-6

Acceleration



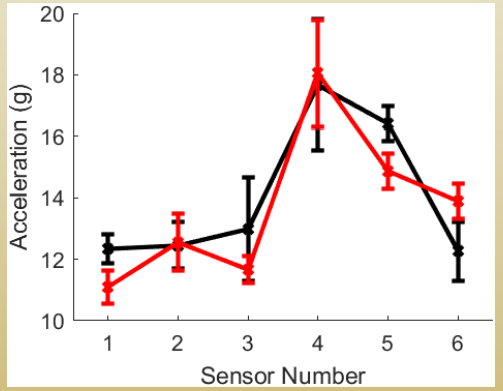
Average % change = – 10.6%

Acceleration

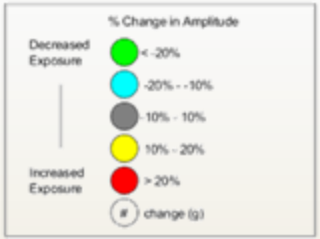


Average % change = – 8.1 %

Acceleration

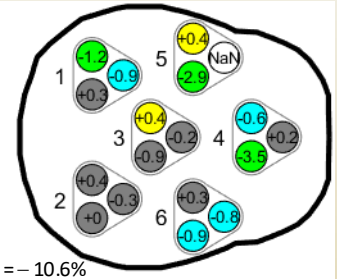


Average % change = – 2.2%



Overall, H2 performed best

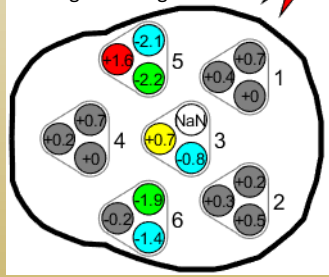
H1 With vs Without Shield



Asst. Gunner

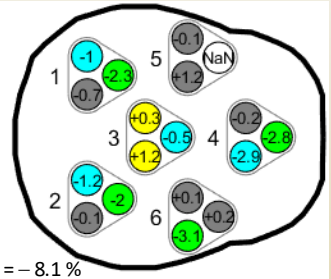
Average % change = – 10.6%

Average % change = – 1.7%



Gunner

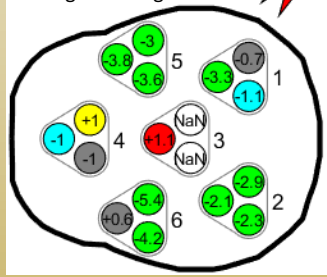
H2 With vs Without Shield



Asst. Gunner

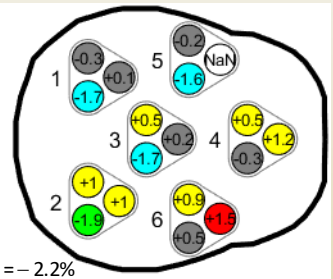
Average % change = – 8.1 %

Average % change = – 11.4%



Gunner

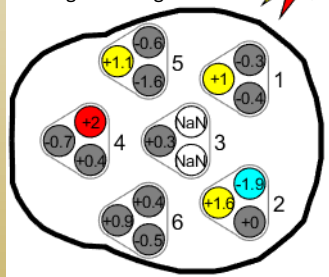
H3 With vs Without Shield



Asst. Gunner

Average % change = – 2.2%

Average % change = + 1.5%



Gunner

Shield did not protect against Gunner strain

GUNNER POSITION

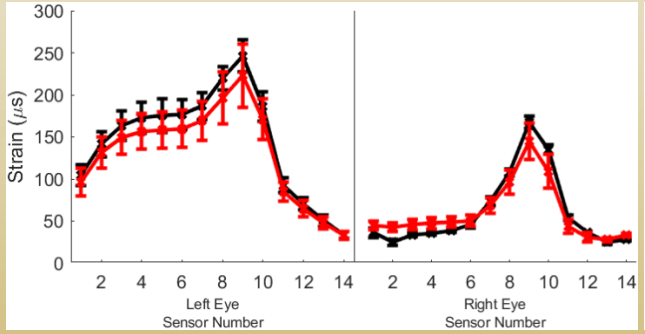
All Plots: Black Line: NO Shield **x** = mean value I = 90% confidence interval on the mean

Red Line: H1 + Shield

Red Line: H2 + Shield

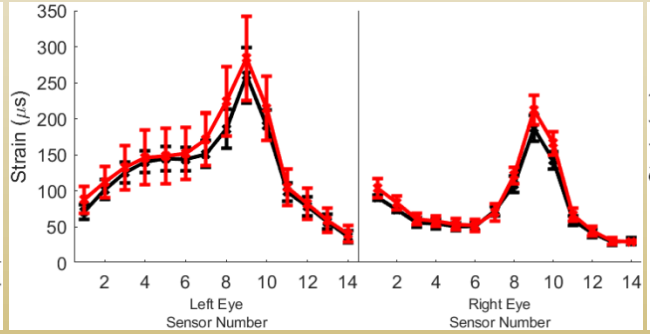
Red Line: H3 + Shield

Strain



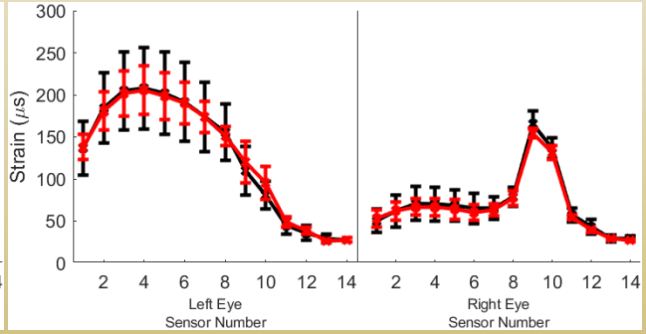
Average % change = + 1.2%

Strain



Average % change = + 8.8%

Strain



Average % change = – 1.1%

Only H3 + shield decreased AG strain

ASST. GUNNER POSITION

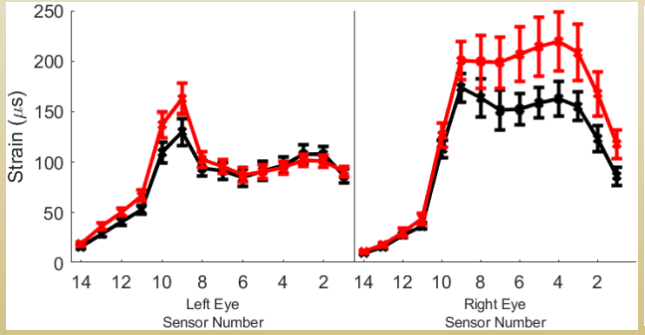
All Plots: Black Line: NO Shield **x** = mean value I = 90% confidence interval on the mean

Red Line: H1 + Shield

Red Line: H2 + Shield

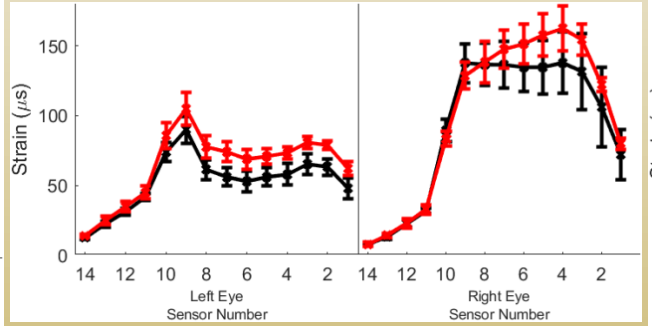
Red Line: H3 + Shield

Strain



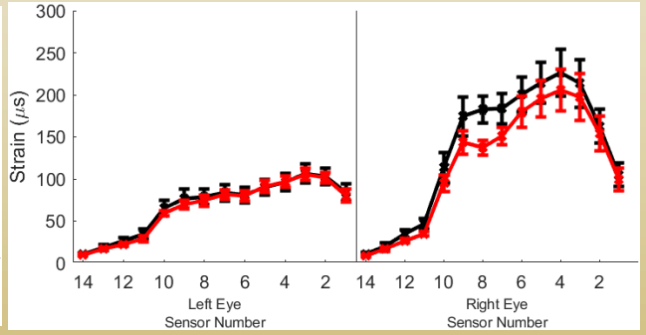
Average % change = + 18.0%

Strain

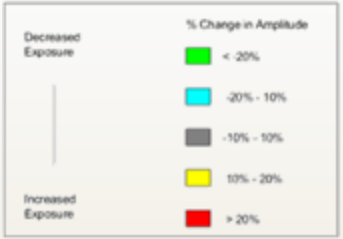


Average % change = + 14.1%

Strain



Average % change = – 10.3%

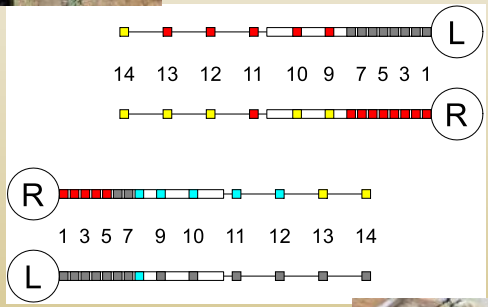


Helmet 3 + shield was best combination

H1 With vs Without shield

Asst. Gunner

Average % change = **+18.0%**



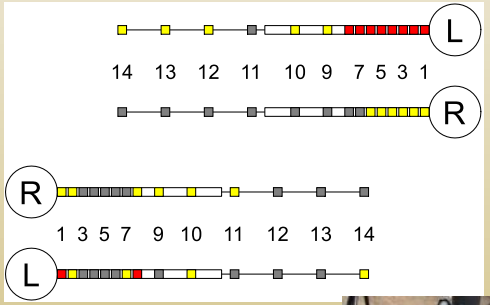
Average % change = **+1.2%**

Gunner

H2 With vs Without shield

Asst. Gunner

Average % change = **+14.1%**



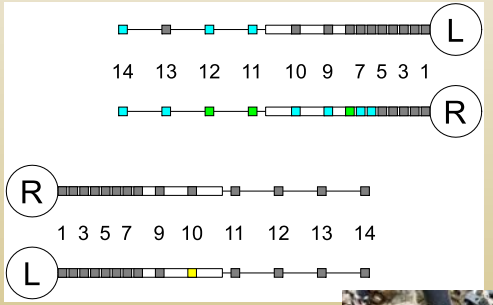
Average % change = **+8.8%**

Gunner

H3 With vs Without shield

Asst. Gunner

Average % change = **–10.3%**



Average % change = **–1.1%**

Gunner

Conclusions

- Helmets are protective in the mortar environment and should be worn.
- Helmets do not all perform the same. Empirical measurements are needed.
- The effectiveness of the helmet shield to reduce measured accelerations and strains within the BIHF was inconsistent
  - Significant decreases in acceleration often corresponded to increases in strain
  - Performance varied with helmet type
- BIHF did not simulate the torso, which may be important to the helmet shield performance
  - BIHF torso is currently under development
- This work demonstrates a novel approach to RDT&E of PPE for the DoW, which includes the emerging health threat represented by BOP.
- This work directly led to a report and recommendation to an Operational Commander within weeks, allowing them to make a data-driven risk management decision for their unit.

Team

CPT Sean Kratchman, SFC Mark Wells, & LTC Andrew Oh, 75th Ranger Regiment

Janette J. Meyer, PhD, Garrett Thorne, Sariah D'Empaire-Salomon, & Douglas Adams, PhD, Vanderbilt University School of Engineering

Pete Alt, 3rd Operational Support Group

Funding

DoW W911NF2120078, HT9425-25-1-0529, & HT9425-24-1-0563; NIH NEI R01EY036252, P30EY008126, T32 EY007135-29; Maj. Gen. (Ret) Stephen L. Jones, MD Fund; Hayes Directorship; Research to Prevent Blindness Unrestricted Funds