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Evaluation of Environmental Sensors in Training: Performance Outcomes and Symptoms during Airborne and Combatives Training

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14. ABSTRACT
Mild traumatic brain injury (mTBI) continues to be a significant issue facing the U.S. military. The current report presents a detailed methodology and preliminary data trends for the Environmental Sensors in Training program to better understand the feasibility and potential validity of using biomechanical environmental sensor technologies to improve the detection of potentially concussive events. Participants from two military training programs (Airborne and Combatives) completed several self-report measures (Military Acute Concussion Evaluation, Post-Traumatic Stress Disorder Checklist, Concussion History Questionnaire) and a neurocognitive test battery called DETECT (Display Enhanced Testing for Cognitive Impairment and mTBI) at multiple time points during training while wearing biomechanical environmental sensors. Results indicate that head impacts are common during training operations; however, loss of consciousness and amnesia after following a head impact were rare. For participants reporting a head impact, headache was the most commonly reported symptom. Trends in DETECT neurocognitive data suggest some differing patterns of performance for participants experiencing a head impact compared to participants who did not. Methodology and recommendations are discussed.

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mTBI, injury assessment, biomechanical environmental sensors, ESiT

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Introduction

Traumatic brain injury (TBI) has been labeled as the "signature injury" of Operation Iraqi Freedom and Operation Enduring Freedom (OIF and OEF). More than 20% of Service members deployed to Iraq or Afghanistan are estimated to have sustained at least one TBI (Terrio, 2009). Depending on the severity of the TBI, symptoms may last from a few days to several years following the injurious event. Moreover, repeated TBIs may result in more severe and long-term consequences. The Defense and Veterans Brain Injury Center (DVBIC), in conjunction with the Armed Forces Health Surveillance Center, track TBI diagnoses for all U.S. military personnel (deployed and non-deployed). DVBIC reported that 383,947 TBI diagnoses of all severities were made between 2000 and 2018-Q1 (DVBIC, 2019). Of the diagnosed TBI cases, 82.3% (315,897) were classified as mild (also referred to as concussion) in severity. In 2013, it was recognized that at least 80% of TBI diagnoses were made in a non-deployed (garrison) setting (Helmick et al., 2015; Department of Defense [DoD] Report to Congress, 2013). TBI diagnoses in the non-deployed setting may be the result of vehicle crashes (private or military-owned), falls, sports and recreational activities, or military training. A mild TBI (mTBI) is generally characterized by less than one hour of loss of consciousness (LOC), less than 24 hours of a confused or disoriented state and memory loss, and normal results from structural brain imaging (Forde et al., 2014). Due to mTBI prevalence and difficulty in the identification/diagnosis, a high priority has been placed on an objective method for the accurate and timely identification of a potentially injurious exposure and subsequent diagnoses. Correctly identifying a potentially injurious event can assist clinicians with early and accurate diagnoses of mTBI. Furthermore, this information can be useful in evaluating return-to-duty status (Defense Centers of Excellence, 2010).

The current process for diagnosing mTBI begins following an exposure to a concussive event. Within 12 hours of the event, the Soldier may be ordered by a medic or supervisor to have an assessment due to loss of consciousness (LOC), an obvious alteration of consciousness (memory loss, confusion, dizziness, etc.), or based on specified criteria (e.g., the Soldier was within 15 meters of the blast) (Headquarters, Department of the Army, 2013; Department of Defense, 2012). In addition to being ordered to have an assessment, a Soldier may self-report due to symptoms and/or involvement in a possible TBI-causing incident. After a Soldier reports for an assessment, a combat medic or a clinician will administer the Military Acute Concussion Evaluation (MACE) or other comparable medical evaluation (Headquarters, Department of the Army, 2013; Department of Defense, 2012). The MACE consists of several screening questions (incident description, any LOC or alterations in consciousness, whether a head impact was sustained, and concussion history), a cognitive exam (memory and concentration tests), and a neurological exam (balance, eye, speech, and motor tests) (DCoE, 2010). The updated MACE 2 also includes vestibular-ocular-motor assessment (DVBIC, 2018). The evaluation is heavily reliant on self-reporting for initiation and completion. The difficulties in administering the MACE exam in an operational/training environment often result in a clinician or combat medic having to make a determination of whether a Soldier has suffered an mTBI either at the time of the event (rapid evaluation) or at some point following medical evacuation (full evaluation). Both situations are not ideal for diagnosing an mTBI and may result in undiagnosed or misdiagnosed mTBIs due to omission of important symptoms or allowing symptoms to change over a prolonged period of time before a diagnosis. Without an accurate diagnosis of mTBI, Soldiers may go untreated and be allowed to return-to-duty while still affected and vulnerable to damaging secondary effects. Therefore, finding innovative ways to accurately diagnose mTBI in an operational setting remains an important research initiative.

Using environmental sensors capable of detecting impact exposure from potentially concussive events offers one avenue for additional data to be used in diagnosing mTBI. Biomechanical data from potentially concussive events could provide objective information for combat medics or supervisors to direct the course of action for a Soldier exposed to a potentially concussive event. However, there are still several challenges with using environmental sensors including ease-of-use in the field and validity in terms of relating to mTBI sequela. Additionally, a "threshold" has yet to be identified that provides a reliable indication of mTBI (Harmon et al., 2019; Guskewicz & Mihalik, 2011). Thus, environmental sensors may be aid in diagnosing mTBI when paired with sensitive performance measures, such as neuropsychological or vestibular functioning tests.

Other than the MACE, several other assessments have been evaluated for use in mTBI screening and diagnosis with limited success. For example, Nelson et al. (2016) compared three computerized neurocognitive batteries for assessing concussion in athletes. The results suggested that neurocognitive assessment enhanced identification of clinical impairment in a very brief period following injury (e.g., 24 hours). Given that it is not always feasible to test a Soldier in such a short window of time following an event, it is unlikely that such a test will be useful in the field. Resch et al. (2016) compared the sensitivity and specificity of three individual evaluations as well as a combination of all three: a computerized neurocognitive test, a vestibular/balance test, and a symptoms scale. The findings showed that subjects were correctly classified as injured/concussed 80-100% of the time when all three evaluations were used, whereas individual assessments correctly classified subjects up to 52.5% of the time when used in isolation. As such, we evaluated numerous tests in the present study in order to cast a wider net towards correlating sensor data back to performance changes following an event. The tests were chosen based on the findings of a previous study (Traynham et al., 2016) in which our research team evaluated the deployable feasibility of various mTBI assessments including several individual cognitive performance tests, visual/oculomotor tests, and an integrated neurocognitive testing system called DETECT (Display Enhanced Testing for Cognitive Impairment and mTBI). Based on administration times, qualitative feedback from test administrators, and participant responses to an ease-of-use survey, the DETECT neurocognitive battery was selected as the most feasible cognitive instrument for evaluating mTBI. Because of its compact system design and integrated modules that span several functional domains, the DETECT system was deemed a more field-ready assessment for our purposes. Moreover, DETECT may be a lucrative means for validating environmental sensor technologies for identifying mTBI.

The purpose of the current report is to present a detailed methodology and preliminary data for the Environmental Sensors in Training (ESiT) program. Here, we describe the methods employed and the results obtained from two military training operations: Airborne and Combatives. At several time points during training, Service members completed self-report measures and the DETECT neurocognitive testing system. Service members also wore environmental sensors during training to obtain objective head impact data. The focus of this report is on self-report and DETECT results, as these sources of data are the foundation for validating environmental sensors as a means to detect concussive events. This report is divided into two phases. Phase 1 details the results from Airborne training, and Phase 2 details results from Combatives training.

Phase 1 - Airborne

Phase 1 of the current study utilized data collected from Service members completing the Basic Airborne Course (BAC). The BAC is a structured Airborne training environment where varying levels of head impact are likely. The BAC consists of three weeks of exercises teaching Service members to jump from a plane and land safely. During the training, Service members may be at risk for head impacts while landing. During the first two weeks, Service members learn the Parachutist Landing Fall (PLF) as a technique to minimize injury during landing and must perfect the technique while falling in multiple directions. The first week of exercises are the Service members' first exposure to PLFs and include many repetitions while students learn the new technique. The second week of exercises build on experience from the first week and introduces new skills requiring fewer repetitions. In the final week, Service members combine skills learned in the first two weeks to perform six complete jumps from an airplane.

Methods

Participants

A total of 51 Service members undergoing the Basic Airborne Training Course at Fort Benning, GA, volunteered for Phase 1. Participants were required to be Active Duty (including Guard and Reserve members on orders), at least 17 years old, and fluent in the English language. Additionally, Soldiers with skin allergies or disorders were excluded due to the adhesive from the environmental sensors. Two participants withdrew from the study immediately and did not provide any data. Additionally, 15 participants withdrew from the study at various time points. Their data are presented separately from those that completed all four weeks of the study. In total, 34 participants completed all testing sessions.

Materials

Military Acute Concussion Evaluation (MACE).

The MACE (French, McCrea, & Baggett, 2008) is a concussion screening tool for the acute assessment of Service members involved in a potentially concussive event in theater. The MACE has been validated as a tool for assessing concussion symptoms following head trauma and offers alternative form versions (forms A, B, and C). The MACE consists of three components: symptom assessment (description of head injury and event conditions, history of concussion, and medical symptoms accompanying a head injury/blow to the head), cognitive exam (a series of tests measuring memory, concentration, and orientation), and neurological screening (clinical investigation of pupil response, eye tracking, speech fluency, and gait). For this report, we present the results of the symptom assessment and qualitative reports of head impact causes.

Display Enhanced Testing for Cognitive Impairment and mTBI (DETECT) System.

The DETECT system (see Figure 1) is a rugged, portable assessment tool designed for use in field and triage settings for the evaluation of functional neurologic impairment after a potential concussive injury. DETECT is comprised of an enhanced heads-up display visor, noise-reducing headphones, and a handheld display for test battery administration, subject response inputs, and user data output. These features provide an immersive environment for multimodal neurologic assessment in remote, noisy, or distracting environments. Test responses are recorded via integrated sensors within the visor and the handheld unit including push button responses and accelerometer detection.

Figure 1. Display Enhanced Testing for Cognitive Impairment and mTBI (DETECT).

The multimodal neurologic test module for the DETECT system includes a battery of neuropsychological tests (NP), a non-postural balance/sensory integration assessment (NPB), a vestibular-oculomotor performance task (VO), and a reaction time test. Because of technical difficulties with the reaction time test, this module was not included in analyses. All components (i.e., instructions, practice tests) are delivered via the DETECT system. Total completion time for the DETECT is approximately 20 minutes. Specifics for the three modules are as follows:

1) NP: The test battery evaluates information processing speed, episodic memory, working memory, and executive function. Assessments include immediate word recognition, complex attention test, simple attention test, and delayed word recognition. The NP assessment uses a validated proprietary algorithm to determine final scores (Wright et al., 2011).

    a. Immediate Word Recognition – During this test, participants are shown 12 target words individually for 3 s each to memorize. Next, the system presents 24 words to participants (12 target words and 12 distractor words), requiring the participant to indicate if a presented word was shown during the memorization phase. Reaction time and accuracy are recorded.

    b. Complex Attention Task – An object is presented with three characteristics: shape, color, and internal line orientation. Participants must identify if the object presented matches the shape, color, and internal line orientation of target patterns presented at the beginning of the task instructions. Mean reaction time and accuracy are recorded.

    c. Arrow Attention Task – The arrow task is a conditional choice reaction time test. In this test, the participant responds to a series of 10 arrows pointing either left or right. If the arrow is blue, then participants click the button that indicates the direction the arrow is pointing. If the arrow if red, then participants click the button that indicates the opposite direction the arrow is pointing. Arrows are displayed for 2 s. If a response is not made within 2 s, a timeout is recorded. Reaction time and accuracy are recorded.

d. Delayed Word Recognition – After the two attention tasks, participants are shown the 24 test words from the immediate word recall task and indicate if the presented word was one of the 12 target words given during the immediate word recognition. Reaction time and accuracy are recorded.

2) NPB: Orthopedic injuries can contaminate the results of balance tests. Therefore, this test measures the ability to process and integrate vestibular and sensory information in order to maintain balance from a seated position. Prior research has shown that head injuries can impair vestibular functioning (Guskiewicz et al., 2003). The NPB test requires participants to maintain a visual target within a target space by tilting their head. A visualization of a seesaw on a playground is presented to participants with a green cube at the center (fulcrum) of the seesaw to indicate a target zone. During each trial, a ball is placed on the seesaw at one end and participants must tilt their head in order to move and maintain the ball in the target zone. A red line is displayed to participants indicating which direction to tilt their head. Once the ball is in the target zone, a 3 s countdown begins (displayed on the ball). If the ball is kept in the target zone for 3 s, the trial is recorded as successful. A calibration is completed at the beginning of the test with participants sitting up straight in a chair. The task consists of three levels of difficulty: easy, hard, and seasick. Three trials of each difficulty are completed, resulting in nine total trials. During the seasick condition, the horizontal axis moves independently of head tilts. The following are outcome measures generated by the module:

a. JERKINESS (JERK) – A measure of variability in ball control (higher values indicate worse performance).

b. Mean Acceleration X-Direction (Mean Accl. X) – Mean acceleration of the ball in the X-axis direction (higher values indicate worse performance).

c. Total in-gate time (TIGT) – Total time the ball spends inside the target zone, as a percentage of the total trial time (higher values indicate better performance).

d. Correlation coefficient (CC) – The correlation coefficient measures the correlation between the acceleration obtained by the double integration of the position of the ball in the X-axis and the acceleration obtained projecting the gravity vector along the X-axis. This quantity expresses how skilled the user is in adapting to rapid changes of ball dynamics (higher positive values indicate better performance).

e. Approximate Entropy of Position (ApEntr Pos)/Acceleration (ApEntr Accl) – Approximate entropy is a measure of randomness in a time series signal. DETECT outputs approximate entropy values for position and acceleration. Values closer to zero indicate complete regularity in a time series signal. Lower entropy values have been associated with concussion (Cavanaugh et al., 2005).

f. Sample Entropy of Position (SampEntr Pos) – Sample entropy eliminate the intrinsic bias towards regularity and consistency found with approximate entropy. As with approximate entropy, lower are associated with concussion.

3) VO: The vestibular/oculomotor integrity module assesses injury to pathways controlling oculomotor function suspected to be impaired by mild head injury (DiCesare, Kiefer, Nalepka, & Myer, 2017; Peterson, 2010). This task contains a black arc that appears in the visual field on the DETECT screen with a blue ball on the arc near the bottom of the visual field. A target zone (a red outline of the ball) is presented at a different location on the arc. At the beginning of a trial, the blue ball begins to move along the arc towards the target zone at a constant speed. Participants must press a bottom on the handheld device to indicate when the ball is in the target zone. The module is 4 min in duration and consists of two ball speeds (fast vs. slow). Moreover, on some trials the ball is visible to begin with and then turns invisible. The participant must then must estimate the speed of the ball during its trajectory. Outcome measures reported include mean difference and mean absolute error for visible fast, visible slow, invisible slow, invisible fast targets from the target zone.

Post Traumatic Stress Disorder Checklist – Military Version (PCLM).

The Post Traumatic Stress Disorder (PTSD) Checklist-Military version (PCLM) is a well-validated, 18-item self-report measure of PTSD for military personnel (McDonald & Calhoun, 2010). It is used by the Department of Veterans Affairs to screen individuals for PTSD, diagnose PTSD, and monitor symptom changes during and after treatment. Participants rate from 0 (*not at all*) to 4 (*extremely*) the severity of symptoms relating to PTSD in a military setting. Higher total scores indicate the endorsement of more PTSD symptoms.

Concussion History Questionnaire.

This questionnaire was developed in-house to capture participants' experiences with concussion and head injury. It was administered pre and post training. The pre-training version of the questionnaire asked participants about past experiences with head injury and concussions, while the post-training version asked participants whether they were evaluated and/or diagnosed with a concussion during training. It should be noted that all responses to this questionnaire are anecdotal.

Environmental Sensors.

Three types of environmental sensors were used to collect various measures of exposure. Participants wore one sensor adhered to the mastoid bone behind the ear, one sensor embedded within an elastic portion of a headband, and one sensor mounted within the participant's helmet. Data processing procedures and results from environmental sensors are not presented here.

Procedure

At the end of training activities, participants were escorted to a nearby area where a trained member of the research team administered the DETECT and questionnaires. Testing occurred at four times during the study: baseline (Day 1 of training: in-processing day), Week 1 (end of day Friday of week 1), Week 2 (end of day Friday of week 2) and Week 3 (following final jump exercise in week 3). Participants completed the PCLM and Concussion History Questionnaire at baseline and week 3. The MACE and DETECT were completed at all four testing sessions.

Results

MACE

Table 1 displays frequencies for MACE items pertaining to incidents and head impacts during the course of training for the 34 participants completing the study. During training, a majority of participants reported a head impact: Week 1 = 63.64% (*n* = 21); Week 2 = 64.71% (*n* = 22); Week 3 = 67.65% (*n* = 23). Two participants reported a non-training related (e.g., hitting head on bunk) head injury at baseline testing. During training, one participant reported amnesia before the head impact and two participants reported amnesia after the head impact. Three participants reported losing consciousness during training: one for less than one minute, one for 3-4 min, and one lost consciousness due to illness. Table 2 displays frequencies for MACE items for participants who withdrew prior to study completion. Causes of incidents are summarized in Table 3. Many participants did not provide sufficient detail to ascertain the exact cause of their incident from training. However, for those that provided sufficient detail, during Week 1 the most common cause of an incident was during parachute landing fall drills. Incidents during Week 2 were mostly caused by swing landing training and incidents during Week 3 were mostly caused by head impacts during combat jumps.

MACE symptoms for those experiencing a head impact are displayed in Figures 1 and 2 for completing and non-completing participants, respectively. The most frequent symptom reported by participants experiencing a head impact was headache, followed by difficulty concentrating and dizziness. One participant reported having a sore neck during Week 2 (not pictured). No participants reported experiencing memory problems.

Table 1. Airborne MACE Incident Responses by Training Week for Participants Completing the Study

	Training Week											
	Baseline			1			2			3		
MACE Item	*N*	*Yes*	*No*	*N*	*Yes*	*No*	*N*	*Yes*	*No*	*N*	*Yes*	*No*
1. Was there an incident?	34	3	31	33†	24	9	34	24	10	34	24	10
2. Dazed, Confused, Saw Stars	3	0	3	19*	1	18	22▲	2	20	22	3	19
3. Head impact	3	3	0	23†	21	2	22▲	22	1	23†	23	0
4. Was a helmet worn?	3	0	3	23†	23	0	24	24	0	23†	23	0
5. Amnesia before incident	3	0	3	23†	1	22	23†	0	23	23†	0	23
6. Amnesia after incident	3	0	3	23†	0	23	24	1	23	23†	1	22
7. Loss of consciousness	3	0	3	23†	1[a]	22	24	0	24	23†	1[b]	22

Note. [a]Participant lost consciousness for less than one minute. [b]Participant lost consciousness due to illness. †One participant did not respond. ▲Two participants did not respond. *Five participants did not respond

Table 2. Airborne MACE Incident Responses by Training Week for Participants Withdrawn Prior to Study Completion

	Training Week								
	Baseline			1			2		
MACE Item	*N*	*Yes*	*No*	*N*	*Yes*	*No*	*N*	*Yes*	*No*
1. Was there an incident?	20	2	18	6	5	1	3	3	0
2. Dazed, Confused, Saw Stars	2	1	1	3▲	1	2	3	1	2
3. Head impact	2	2	0	5	5	0	3	3	0
4. Was a helmet worn?	2	0	2	5	5	0	3	3	0
5. Amnesia before incident	2	0	2	5	0	5	3	0	3
6. Amnesia after incident	2	0	2	5	0	5	3	1	2
7. Loss of consciousness	2	0	2	4†	0	4	3	1[a]	2

Note. [a]Participant lost consciousness for 3-4 min. †One participant did not respond. ▲Two participants did not respond.

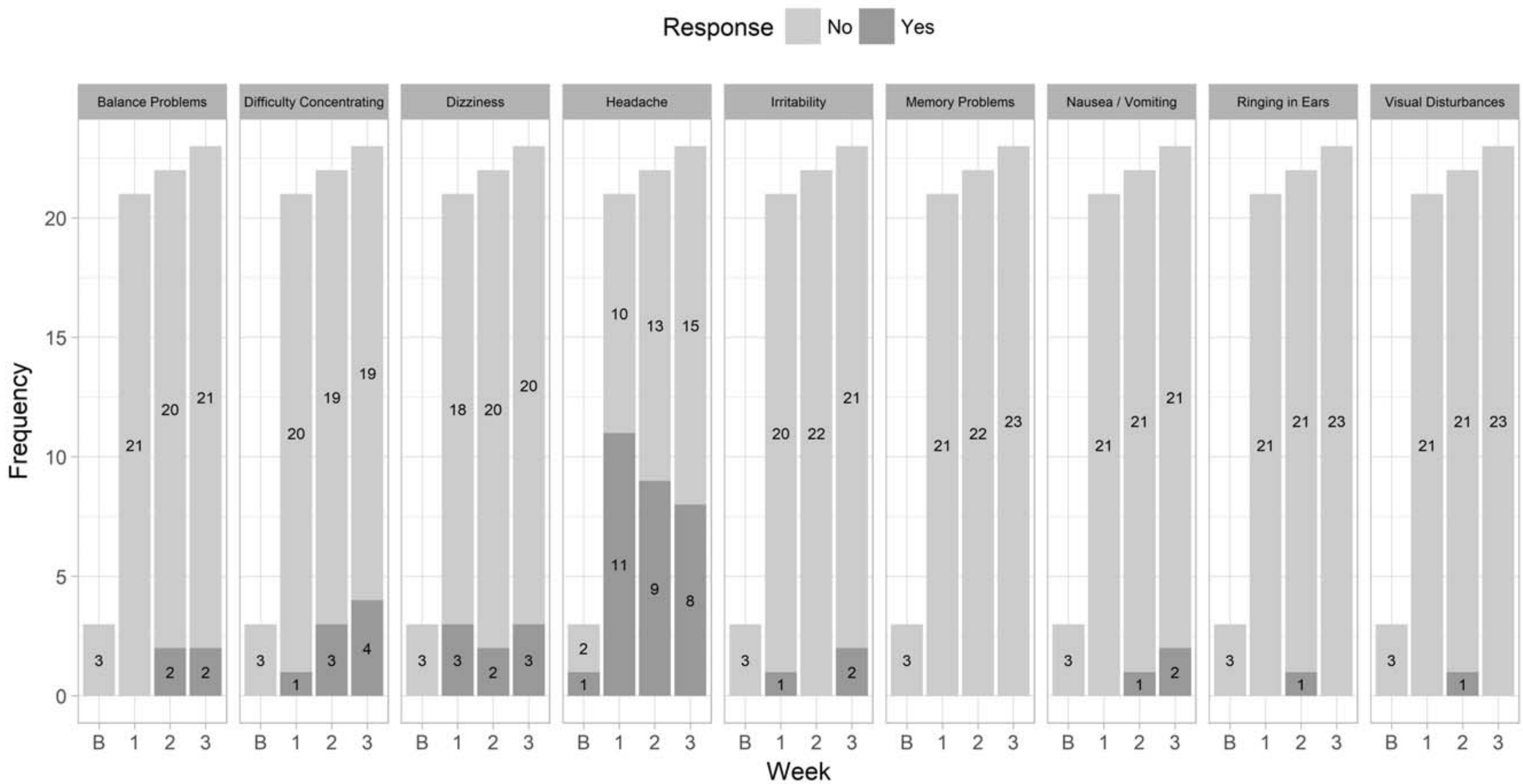

Figure 2. Airborne MACE symptom frequencies for completing participants reporting a head impact by training week. B = Baseline.

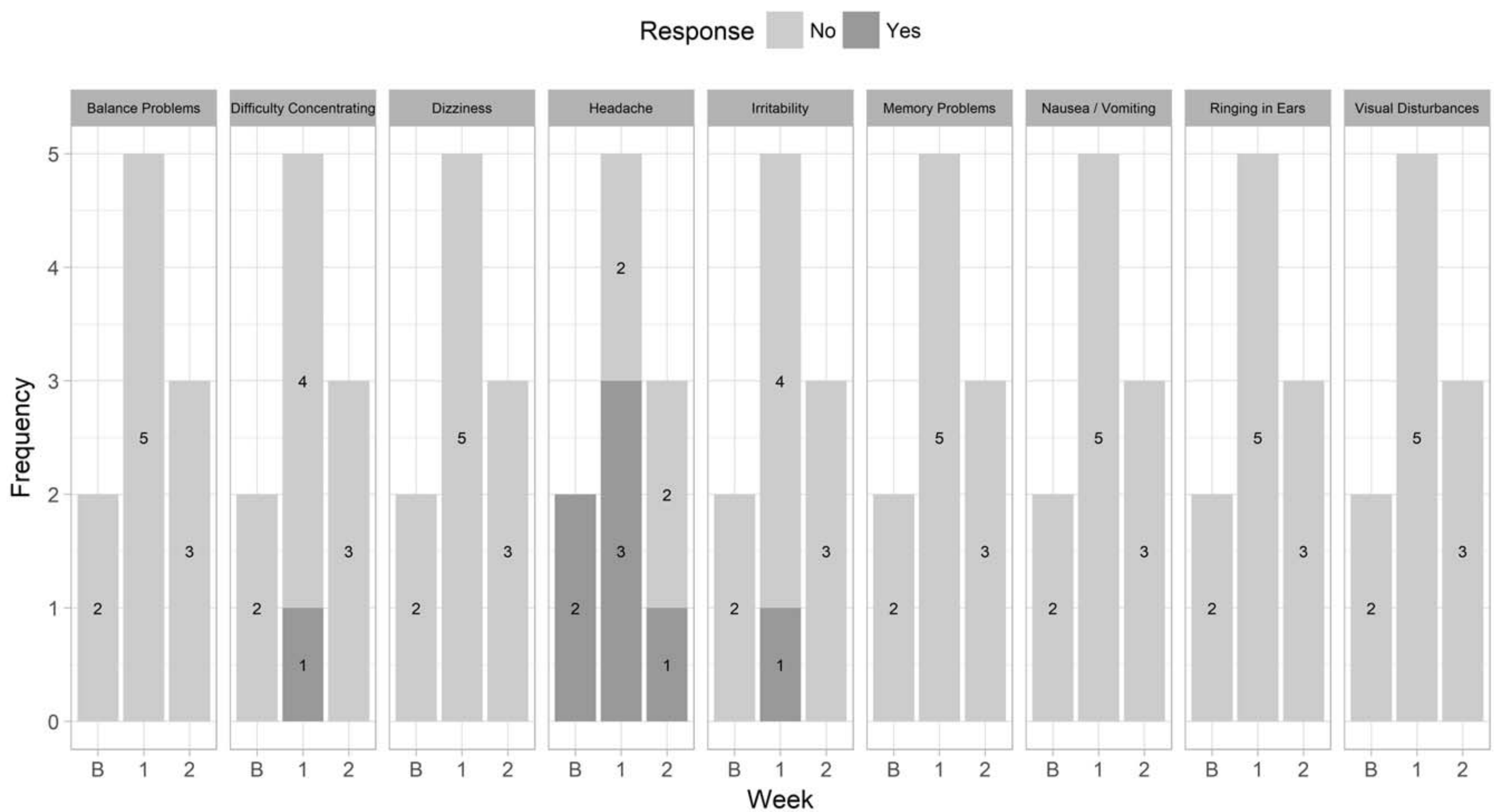

Figure 3. Airborne MACE symptom frequencies for non-completing participants reporting a head impact by training week. B = Baseline.

Table 3. Causes of Head Impacts for Airborne Participants by Training Week and Study Completion Status

Week	Completing Participants	Non-Completing Participants
Baseline	Non-training related = 3	Non-training related = 2
Week 1	Parachute landing fall drills = 11 Unspecified fall = 6 Kicked = 1 Pushed = 1 Zip line = 1 Unspecified = 1	Parachute landing fall drills = 3 Unspecified fall = 1
Week 2	Tower jumps = 1 Unspecified fall = 5 Swing landing trainer = 16	Unspecified = 1 Swing landing trainer = 2
Week 3	Parachute landing fall drills = 2 Jump landing = 5 Exiting aircraft = 2 Parachute impact = 2 Unspecified impact during jumps = 10 Unspecified fall = 2	

Concussion History Questionnaire

Concussion history questionnaire results for participants completing the study are summarized in Table 4. Prior to training, 20.59% (*n* = 7) participants experienced a head injury or concussion. Six participants reported experiencing a hit or blow to the head that led to confusion, prolonged headaches, or memory problems, and 17.65% (*n* = 6) of participants reported LOC. Moreover, 14.71% (*n* = 5) of participants reported being hospitalized or evaluated by a doctor for a concussion. Overall, during training, 26.47% (*n* = 9) of participants reported experiencing a head injury or concussion (none of which reported having been evaluated by a doctor or subsequently a concussion diagnosis). Two participants reported losing consciousness for less than one minute. Moreover, 26.47% (*n* = 9) participants reported experiencing frequent headaches, all of whom experienced at least one head impact.

Table 4. Airborne Concussion History Questionnaire Results for Participants Completing the Study

Question	Pre		Post	
	N	Frequency	*N*	Frequency
1. **Have you ever had a head injury or concussion?** (During training, did you experience a head injury or concussion?)	34	Yes = 7 No = 27	34	Yes = 9 No = 25
2. **If yes, how many head injuries or concussion have you had?** (If yes, how many head injuries or concussions did you experience?)	7	1 Injury = 3 2 Injuries = 1 3 Injuries = 2 6+ Injuries = 1	9	1 Injury = 4 2 Injuries = 5
3. **Have you ever had a hit or blow to the head that caused confusion, prolonged headaches, or memory problems?** (During Training, did you experience a hit or blow to the head that caused confusion, prolonged headaches, or memory problems?)	32†	Yes = 5 No = 27	34	Yes = 8 No = 26
4. **Have you ever been "knocked-out" or lost consciousness?** (During training, did you experience being "knocked-out or losing consciousness?)	34	Yes = 6 No = 28	34	Yes = 2 No = 32
5. **If yes, how long were you unconscious?**	5†	< 1 min = 2 1 to 5 min = 3	1†	< 1 min = 1
6. **Have you ever been hospitalized or evaluated by a doctor for a concussion?** (During training, were you evaluated by a doctor for a concussion?)	34	Yes = 5 No = 29	34	Yes = 0 No = 34
7. **How long did it take you to fully recover from your concussion?** (If so, were you diagnosed with a concussion?)	5	1-2 days = 1 1-2 weeks = 2 1 month = 1 > 1 month = 1	0	NA
8. **Do you get frequent headaches?** (During training, did you experience frequent headaches?)	34	Yes = 3 No = 31	34	Yes = 9 No = 25
9. **If yes, how frequently do** (did) **you get headaches?**	3	Once per week = 1 Twice per week = 1 Every other day = 1	9	< 1 week daily = 4 Daily = 1 During training = 3 2-3 times per week = 1

Note. Bold-face type indicate pre-training question wording. Parenthetical text indicates post-training wording. †Two participants failed to respond.

Table 5 displays concussion questionnaire results for participants who did not complete the study. Prior to training, 25% (n = 4) of participants reported a previous head injury or concussion, with three out of four participants experiencing two prior injuries. Furthermore, three participants reported previously losing consciousness due to a head impact with reported durations between 1-2 min. Two participants reported being hospitalized or evaluated by doctor.

Table 5. Airborne Pre-Training Concussion History Questionnaire for Participants not Completing the Study.

Question	*N*	Frequency
1. Have you ever had a head injury or concussion?	20	Yes = 4 No = 16
2. If yes, how many head inquiries or concussion have you had?	4	1 Injury = 1 2 Injuries = 3
3. Have you ever had a hit or blow to the head that caused confusion, prolonged headaches, or memory problems?	20	Yes = 3 No = 17
4. Have you ever been “knocked-out” or lost consciousness?	20	Yes = 3 No = 17
5. If yes, how long were you unconscious?	3	1 min = 1 2 min = 1 Not sure = 1
6. Have you ever been hospitalized or evaluated by a doctor for a concussion?	20	Yes = 2 No = 18
7. How long did it take you to fully recover from your concussion?	1[†]	1 Month = 1
8. Do you get frequent headaches?	20	Yes = 1 No = 19
9. If yes, how frequently do you get headaches?	1	Daily = 1

Note. [†]One participant did not respond.

PCLM

Frequencies for PCLM individual items are displayed in Table A1 in Appendix A for participants completing the study. Overall, the average total PCLM score was 19.62 (SD = 3.46) for those who completed the study. The most frequently endorsed symptom was being “super alert” or watchful, followed by having difficulties concentrating. Two participants reported that someone has indicated that they have changed due to a stressful military experience. It should be noted that the response rate for this item (70%) was the lowest of all items.

For participants not completing the study (withdrawn), average total PCLM scores were slightly lower (M = 18.05, SD = 1.85) than those who completed all testing sessions. Individual item frequencies are displayed in Table A2 in Appendix A. As with participants who completed the study, the most frequently endorsed symptom was being “super alert” or watchful. No participants reported someone indicating that they have changed since a stressful military experience. Again, this item had the lowest response rate (75%).

DETECT

Distributions for DETECT outcome measures were initially explored to check for normality before selecting descriptive statistics to display. For the target-tracking task, distributions were markedly skewed and are thus described with the median and interquartile range (IQR) using boxplots. Neuropsychological tests and NPB data distributions were approximately normally distributed and are summarized using the mean and standard deviation. Descriptive statistics were plotted for each DETECT outcome measure by week of the study and by those who experienced a head impact and those that did not. For the tracking task, target type (e.g., invisible fast, invisible slow) was plotted as an additional factor. For NPB data, test difficulty (easy, hard, seasick) was plotted as an additional factor.

Cognitive tasks.

Trends in tracking task performance metrics split by target type are displayed in Figure 4. The three participants who reported a head impact at baseline are excluded. As to be expected, participants showed better and more stable performance with visible targets than invisible targets. For invisible targets, the mean difference metric tended to decrease across the study weeks (i.e., values approaching zero), indicating a potential learning effect. Those experiencing a head impact tended to have slightly more mean absolute error for visible fast targets during Weeks 2 and 3 compared to those not experiencing a head impact. No other consistent patterns were evident.

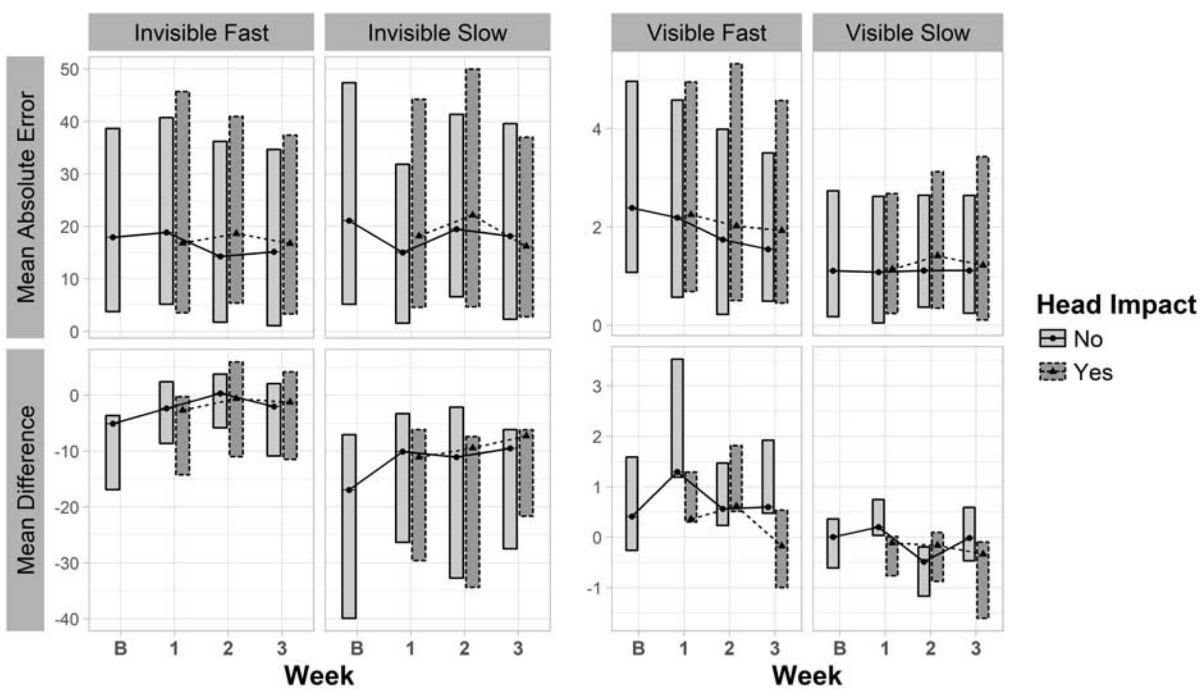

Figure 4. Boxplots for Airborne tracking task performance by training week, target type, and head impact status. B = Baseline. Those who reported a head impact at baseline are excluded.

Figure 5 displays trends in accuracy and reaction times for the four DETECT neuropsychological tests. Due to technical failures, 15 participants did not complete the delayed word recall task. Therefore, patterns for this test should be interpreted with caution due to a reduced sample size. The complex reaction time test demonstrated the most pronounced of change over time. Specifically, accuracy and reaction times tended to increase linearly across the testing weeks, indicating a speed-accuracy tradeoff. Reaction time variability for this task also tended to be high. For the arrow task, those experiencing a head impact at Week 3 tended to be less accurate but faster at responding than those not experiencing a head impact. Similar patterns were observed for the complex and delayed word recall task. Together, these results indicate a slight speed-accuracy tradeoff for those experiencing a head impact.

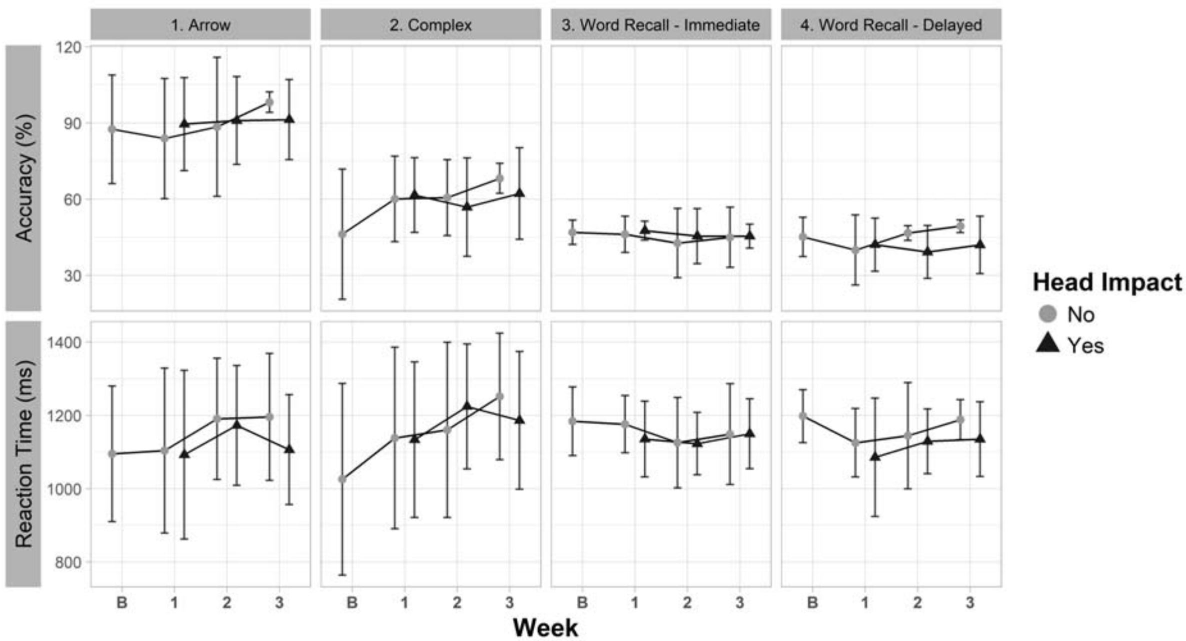

Figure 5. Airborne arrow, complex, immediate word recall, and delayed word recall performance by training week and head impact status. Values are mean ± 1 standard deviation. B = Baseline. Those who reported a head impact at baseline are excluded.

Non-postural balance (NPB).

Trends in NPB entropy measures are displayed in Figure 6. In general, groups demonstrated similar patterns of change over the course of the study. Measures of entropy were generally higher during the more difficult levels compared to the easy level, indicating more randomness in the position and acceleration. Moreover, entropy measures also tended to be more variable at higher difficulty levels. For the seasick difficulty level, entropy values tended to decrease over the testing weeks. Across the three entropy values, participants reporting a head impact exhibited higher entropy than those without a head impact during Week 3 of testing at the hard difficulty; however, this trend was very slight.

Figure 7 displays non-entropy NPB measures. In general, the correlation coefficient and JERK measures were the most sensitive the difficulty level, with both measures showing a decrease from easy to seasick. Participants reporting a head impact tended to have slightly greater X-axis acceleration (in either direction) across the training weeks. Moreover, participants reporting a head impact during Week 3 tended to have less total in gate time across the difficulty levels than participants not reporting a head impact.

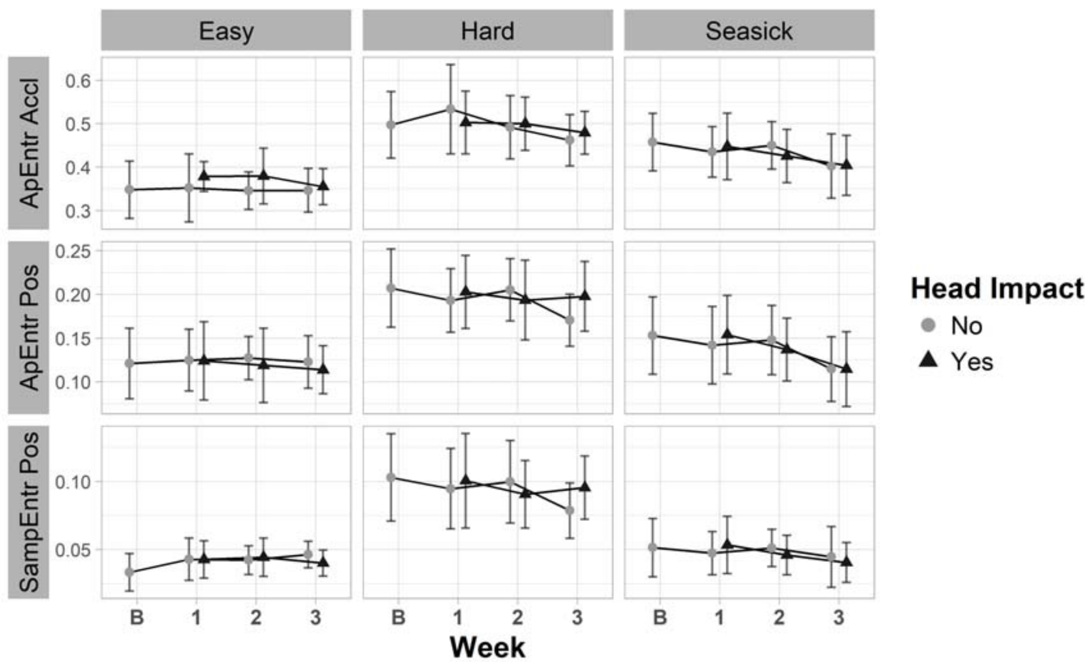

Figure 6. Airborne non-postural balance entropy measures by difficulty, training week, and head impact status. Values are mean ± 1 standard deviation. B = Baseline, SampEntr Pos = Sample Entropy of Position, ApEntr Pos = Approximate Entropy of Position, ApEntr Accl = Approximate Entropy of Acceleration. Those who reported a head impact at baseline are excluded.

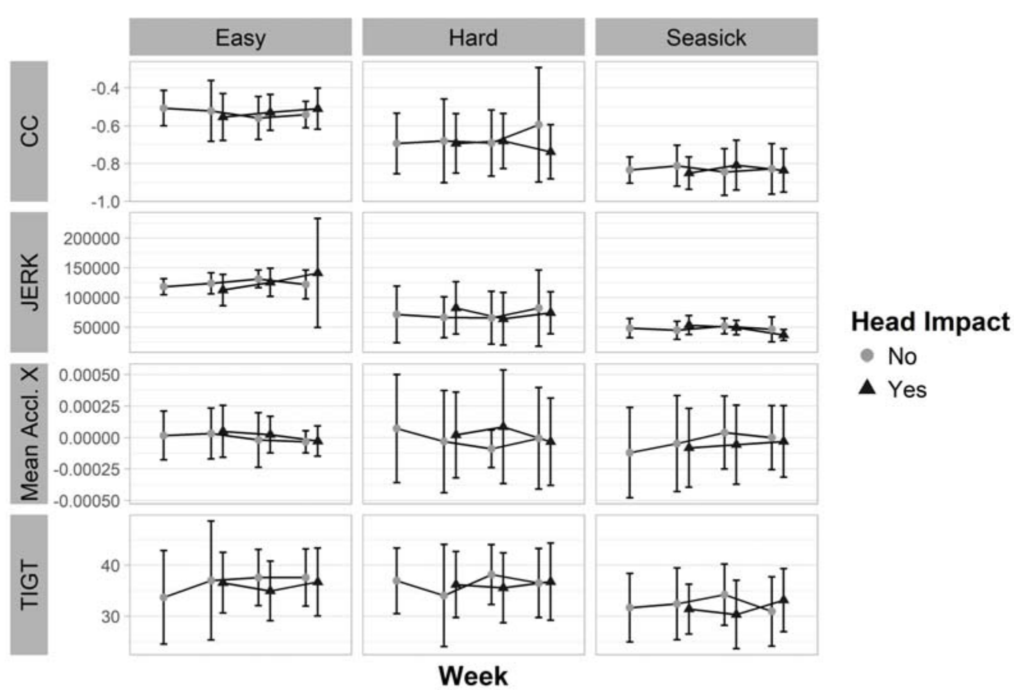

Figure 7. Airborne non-postural balance non-entropy measures by difficulty, training week, and head impact status. B = Baseline, TGIT = Total in Gate Time, Mean Accl. X = Mean Acceleration on the X-Axis, JERK = Jerkiness, CC = Correlation Coefficient. Values are mean ± 1 standard deviation. Those who reported a head impact at baseline are excluded.

Discussion

Overall, more than half of Airborne participants reported a head impact during Weeks 1-3 of training. Causes of these impacts were most frequently reported during parachute landing fall drills (e.g., lateral descent apparatus or swing landing trainer), or during combat jumps the last week of training. Some MACE responses were too vague to make a determination as to the cause of a head impact. Potentially, a supplemental questionnaire could be implemented in training environments that more specifically addresses the head injury cause to provide this information to cadre and/or leadership. There were no trends in symptoms across the training weeks; however, the most frequently reported symptom was headache for participants experiencing a head impact. Therefore, mitigating headache during training may be a focal point for improving training conditions for Soldiers.

LOC did not occur frequently. In total, three participants reported losing consciousness, one of which lost consciousness due to illness. The most extreme case was a participant who reported an LOC duration of 3-4 min. This participant did not complete the study. Results of the concussion history questionnaire for participants who completed the study revealed that only a minority (*n* = 7) had a history of head injury or concussion prior to training. Nine participants reported experiencing a head injury or concussion during training. However, no participants reported being evaluated by a doctor for a concussion during training.[*] PCLM results indicated that feeling "super alert" and watchful was the most commonly reported PTSD symptom.

DETECT results revealed that participants reporting a head impact appeared to exhibit more mean absolute error on the target tracking task than participants without a head impact. This effect was more pronounced for visible stimuli moving at a fast rate during Weeks 2 and 3. Participants reporting a head impact also tended to display a speed-accuracy tradeoff for the complex, arrow, and delayed word recall neuropsychological tasks. That is, those reporting a head impact tended to respond faster but less accurately. This type of trade-off is consistent with the existing literature (e.g., Fong, Chan, Ng, & Ng, 2009). However, given the descriptive nature of this study, the patterns presented here are tentative.

Patterns in NPB data were more equivocal. Participants experiencing a head impact tended to have higher measures of entropy for the hard difficulty of the balance task relative to those not experiencing a head impact. Studies have generally shown that entropy values decreased in individuals experiencing concussion (Cavanaugh et al., 2005). However, acceleration metrics did reveal that participants reporting a head impact tended to have greater acceleration in the X-axis direction. This may indicate reduced vestibular system information processing efficiency. Fatigue could have also played a role in confounding outcomes. Specifically, our research team observed high levels of fatigue for participants throughout training. In several instances, some participants had to be woken up while performing the DETECT. Therefore, fatigue may have also contributed to the variability in outcome measures.

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[*] The authors interpret this apparent discrepancy to have resulted from misinterpretation of what was meant by a "head injury."

Phase 2 - Combatives

Phase 2 of this study recruited participants completing the Modern Army Combatives Course (MACP). The MACP is an Army-wide Combatives program with multiple training sites. The MACP consists of several courses starting with an introduction to Combatives (Basic Combatives Course – BCC), followed by a more intensive course teaching tactical applications of Combatives (Tactical Combatives Course – TCC), and finally progressing to a master trainer certification (Combatives Master Trainer Course – CMTC). The BCC is a one-week course, taught at the local battalion level, during which students learn the basics of hand-to-hand combat including a drill providing instruction on how to immobilize an opponent. During this drill, probability of a mild head impact is increased. The TCC is a two-week course during which subjects learn the basics of striking and grappling. Finally, the CTMC is four weeks in duration and involves multiple sparring and grappling sessions where students practice striking and grappling skills. Mobile Training Teams (MTTs) will teach both the TCC and CMTC courses at selected Army posts.

Methods

Participants

Thirty-five Soldiers undergoing Combatives training at Fort Benning, GA, were participants in Phase 2. Inclusion criteria were the same as Phase 1.

Materials

Questionnaires, the DETECT system, and environmental sensors were identical to Phase 1 with the exception of adding the Karolinka Sleepiness Scale (KSS) (Akerstedt & Gillberg, 1990; Kaida et al., 2006). The KSS is a single item questionnaire that asks participants to rate how sleepy they feel at the moment. Higher scores indicate greater feelings of sleepiness. The KSS has been validated with electroencephalographic measures of sleepiness (Kaida et al., 2006)

Procedure

At the baseline testing session, participants completed the concussion history questionnaire, KSS, and PCLM (baseline testing occurred after sparring due to scheduling limitations). Environmental sensors were issued prior to each training session. Following a session, participants completed the MACE, KSS, and DETECT. At the end of the course, participants completed the MACE, DETECT, KSS, and concussion history questionnaire. Assessment order was counterbalanced and forms A, B, and C of the MACE were used.

Results

Only a minority (n = 6) of participants completed all possible testing sessions. Therefore, participants were classified as completing the study if they were tested after at least one sparring session. Because data were potentially collected at different time points across participants, results are reported for the baseline and last testing session completed. Thirty-two participants were retained for analysis of the MACE, PCLM, KSS, and Concussion History Questionnaire (three participants did not continue after baseline). Six participants were not evaluated with the DETECT system (e.g., did not have time to complete, medical attention required), resulting in a total sample size of 26 for these data. Data analytic procedures were the same as Phase 1.

MACE

Results for the MACE are displayed in Table 6. Overall, 59.38% (*n* = 19) and 53.13% (*n* = 18) of participants experienced an incident during baseline and the last recorded week, respectively. All participants experiencing an incident during baseline reported hitting their head and all but one reported hitting their head during the last training session. No participants reported amnesia or loss of consciousness due to an incident. Figure 8 displays MACE symptom frequency for participants experiencing a head impact. The most frequently endorsed symptom was headache and only one participant reported experiencing a symptom (headache) during the last recorded week of training. Causes of head impacts included the following: at baseline, 14 participants reported an unspecified sparring hit, one reported being kicked, three reported being punched, and one reported the head impact was due to a fall, while during the last training session, five participants reported an unspecified sparring hit, one reported being kicked, one reported being hit with an open hand, and 11 reported being punched.

Table 6. Combatives MACE Incident Responses by Training Week

	Training Week					
	Baseline			Last		
MACE Item	*N*	*Yes*	*No*	*N*	*Yes*	*No*
1. Was there an incident?	32	19	13	32	18	14
2. Dazed, Confused, Saw Stars	18†	4	14	17†	1	16
3. Hit head	19	19	0	18	17	1
4. Was a helmet worn?	19	15	4	18	16	2
5. Amnesia before incident	19	0	19	18	0	18
6. Amnesia after incident	19	0	19	18	0	18
7. Loss of consciousness	19	0	19	18	0	18

Note. †One participant did not respond.

Concussion History Questionnaire

Concussion history questionnaire results are displayed in Table 7. Previous head injuries or concussions were more prevalent than those in Airborne training, with half of Combatives participants reporting a previous head injury or concussion. Most participants (*n* = 8) with a history of injuries reported between 1-4 previous injuries/concussions with one participant reporting over 12. Moreover, approximately half of Combatives participants reported experiencing a previous blow to the head that caused confusion, headaches, or memory problems with 45.16% (*n* = 14) of participants reporting loss of consciousness. Prior to training, 37.50% (*n* = 12) of Combatives participants reported frequent headaches.

Twenty-seven participants completed the post-study concussion history questionnaire. During training, 19.23% (*n* = 5; note one participant failed to respond to this question) of Combatives participants reported sustaining a head injury or concussion. All five of these participants reported experiencing one injury. One participant reported losing consciousness and four participants reported being evaluated by a doctor for a concussion. Frequent headaches during training were reported by 22.22% (*n* = 6) of participants.

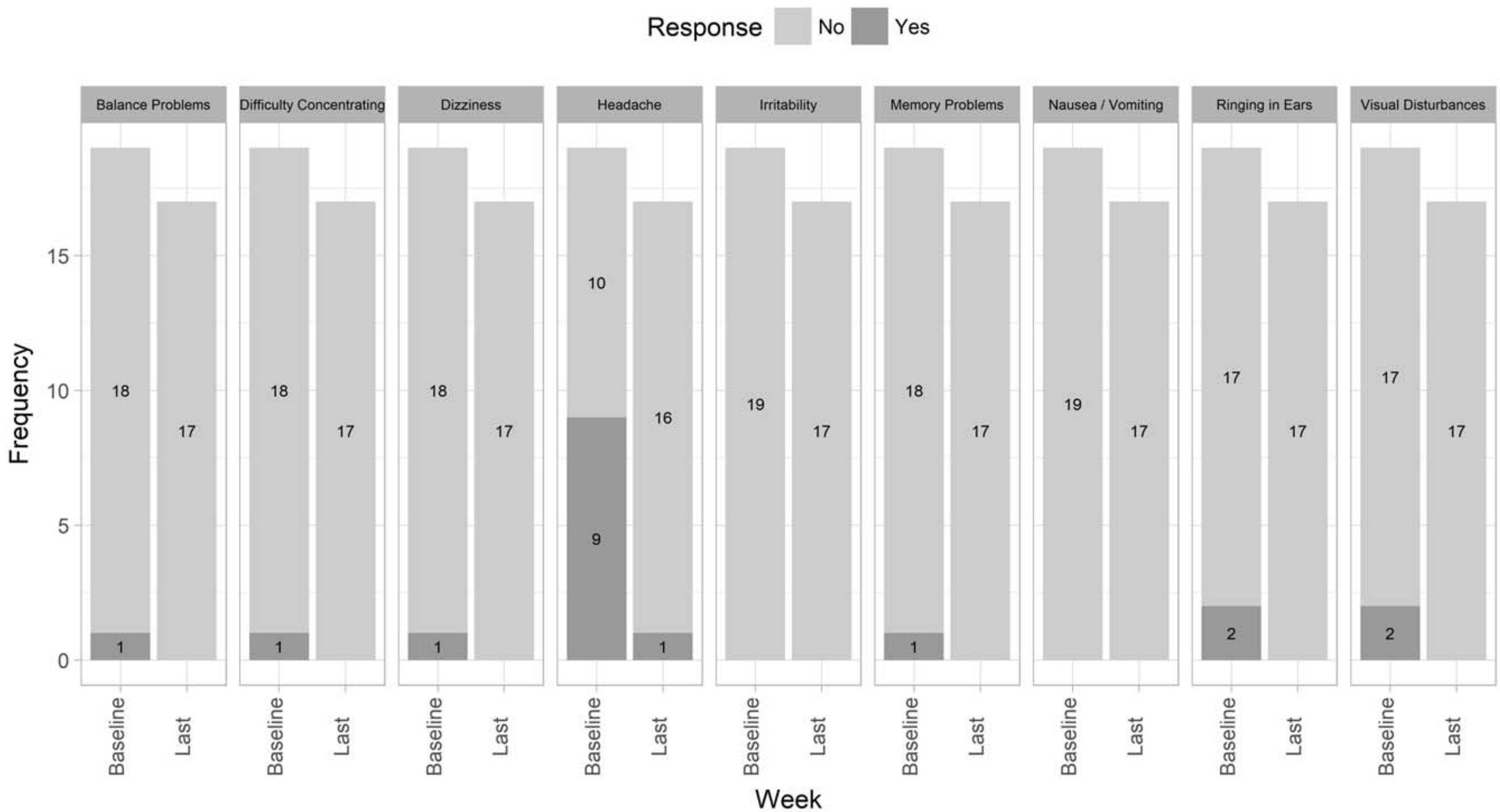

Figure 8. Combatives MACE symptom frequencies by training week for participants reporting a head impact.

Table 7. Combatives Concussion History Questionnaire Results by Training Week.

Question	Pre		Post	
	N	Frequency	*N*	Frequency
1. **Have you ever had a head injury or concussion?** (During training, did you experience a head injury or concussion?)	32	Yes = 16 No = 16	26	Yes = 5 No = 21
2. **If yes, how many head injuries or concussion have you had?** (If yes, how many head injuries or concussions did you experience?)	14▲	1-4 Injuries = 8 5-8 Injuries = 3 12+ Injuries = 1 Unsure = 2	4†	1 Injury = 4
3. **Have you ever had a hit or blow to the head that caused confusion, prolonged headaches, or memory problems?** (During training, did you experience a hit or blow to the head that caused confusion, prolonged headaches, or memory problems?)	32	Yes = 17 No = 15	27	Yes = 4 No = 23
4. **Have you ever been "knocked-out" or lost consciousness?** (During training, did you experience being "knocked-out or losing consciousness?)	31	Yes = 14 No = 17	27	Yes = 1 No = 26
5. **If yes, how long were you unconscious?**	12▲	< 1 min = 6 3-5 min = 2 15 min = 1 Unsure = 3	1	3 min = 1
6. **Have you ever been hospitalized or evaluated by a doctor for a concussion?** (During training, were you evaluated by a doctor for a concussion?)	32	Yes = 10 No = 22	27	Yes = 4 No = 23
7. **How long did it take you to fully recover from your concussion?** (If so, were you diagnosed with a concussion?)	10	< 1 week = 3 2 weeks = 1 1-3 months = 3 6 months = 1 Unsure = 2	4	Yes = 1 No = 3
8. **Do you get frequent headaches?** (During training, did you experience frequent headaches?)	32	Yes = 12 No = 20	27	Yes = 6 No = 21
9. **If yes, how frequently do** (did) **you get headaches?**	11†	Daily/every other day = 5 At least once weekly/biweekly = 4 During rainy weather = 1 With contact to head = 1 Once per month = 1	6	3-4 times = 1 Daily = 1 2 times per week = 2 Seldom = 1 Unsure = 1

Note. Bold-face type indicate pre-training question wording. Parenthetical text indicates post-training wording. †One participant did not respond. ▲Two participants did not respond.

Karolinska Sleepiness Scale (KSS)

Figure 9 displays boxplots for the distribution of KSS responses. For participants experiencing a head impact, KSS ratings were higher at baseline (*Mdn* = 5.0, *IQR* = 4.0) than the last testing session, (*Mdn* = 4.0, *IQR* = 3.0), indicating an increase in alertness. Similarly, KSS ratings for participants not experiencing a head impact decreased from baseline (*Mdn* = 6.0, *IQR* = 3.00) to the last testing session (*Mdn* = 4.0, *IQR* = 1.75). In general, alertness ratings were similar between participants with and without head impacts.

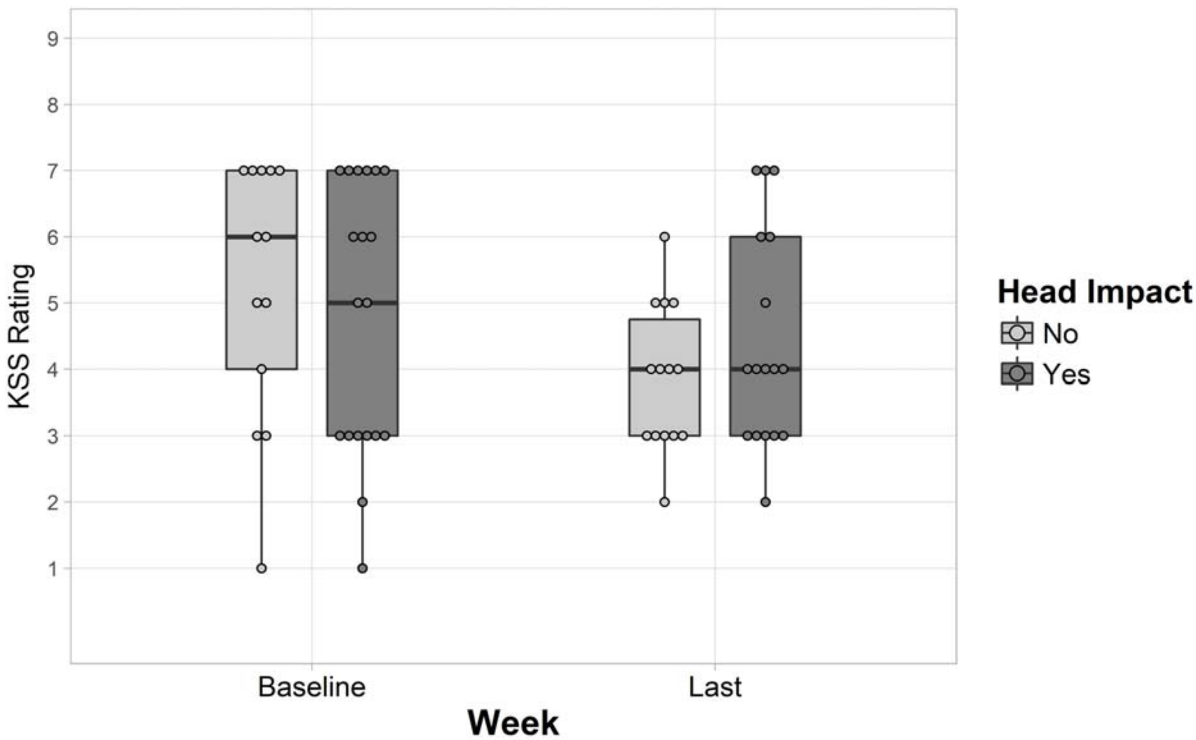

Figure 9. Boxplots for Combatives Karolinska Sleepiness Scale (KSS) responses by head impact status and training week. *Note*. One participant did not indicate head impact status at the last testing session.

PCLM

Frequencies for PCLM individual items are displayed in Table A3 in Appendix A. The average PCLM total score for Combatives training (*M* = 24.79, *SD* = 8.37) was higher than Airborne training. Participants endorsed the following symptoms the most: being "super alert" or watchful, difficulties concentrating, troubles falling asleep, feeling distant or cut off from other people, and feeling jumpy or easily startled. One participant reported that someone has indicated that they have changed due to a stressful military experience. It should be noted again that the response rate for this item (31%) was lowest of all the items.

DETECT

Cognitive tasks.

Figure 10 displays boxplots for tracking task performance. As with Airborne participants, participants performed better with visible targets compared to invisible targets. Participants with a head impact tended to exhibit better performance from baseline to the last session for invisible targets and more stable performance for visible targets. Those without a head impact tended to show improvements in performance for all measures besides invisible fast targets. Counterintuitively, participants who reported a head impact versus those who did not report such at baseline tended to have better performance except for invisible fast targets, for which the impact group performed worse.

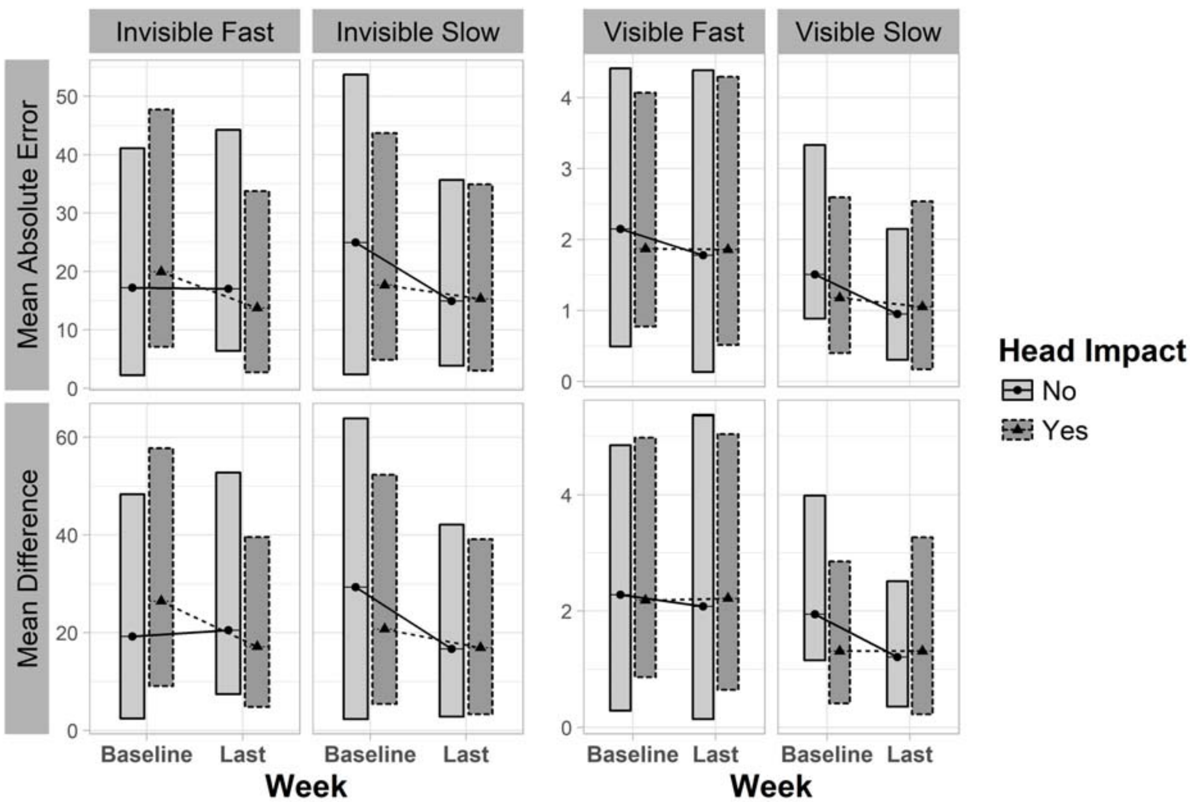

Figure 10. Boxplots for Combatives tracking task performance by stimulus type, training week, and head impact status.

Neuorpsychological task performance trends are displayed in Figure 11. For the arrow and complex choice tasks, accuracy tended to improve and reaction times tended to slow from baseline to the last week of training. Participants experiencing a head impact generally exhibited slower reaction times for the arrow task at both time periods compared to participants not experiencing a head impact. However, this pattern was reversed for the complex choice task. Participants reporting head impacts at baseline tended to be slower at responding to both the immediate and delayed word recall tasks.

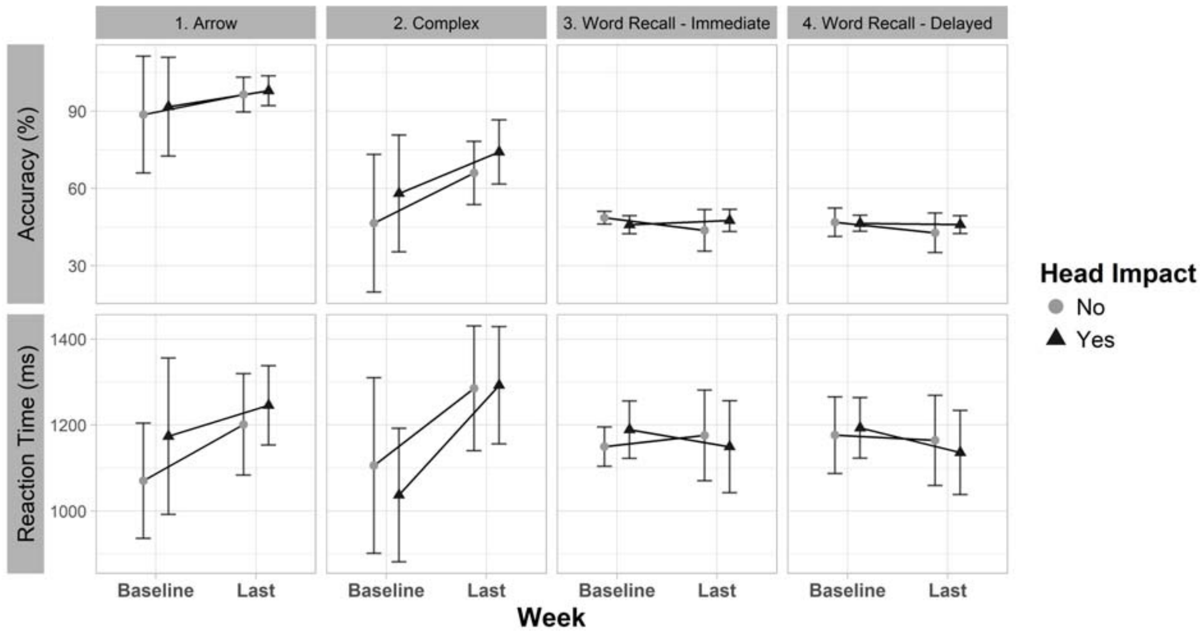

Figure 11. Combatives arrow, complex, immediate word recall, and delayed word recall task performance by training week and head impact status. Values are mean ±1 standard deviation.

Non-Postural Balance (NPB).

Trends in NPB task entropy measures are displayed in Figure 12. Participants reporting a head impact had lower approximate entropy of position and sample entropy of position for the hard difficulty comparted to participants not reporting a head impact at both time points. Over time, participants tended to show an overall decrease in entropy values, with the exception of approximate entropy of acceleration at the easy difficulty. Moreover, those reporting a head impact showed small increases in sample entropy of position at the easy difficulty and approximate entropy of acceleration at the hard difficulty from baseline to the last week of testing.

Non-entropy non-postural balance metrics are displayed in Figure 13. Mean acceleration in the X-axis direction tended to show the most consistent group differences. For the hard and seasick difficulties, participants reporting a head impact tended to have more acceleration (in either direction on the X-axis) at baseline and the last week of testing. Both groups tended to show increases in total in gate time from baseline to the last week of testing for all difficulty levels, potentially indicating a learning effect.

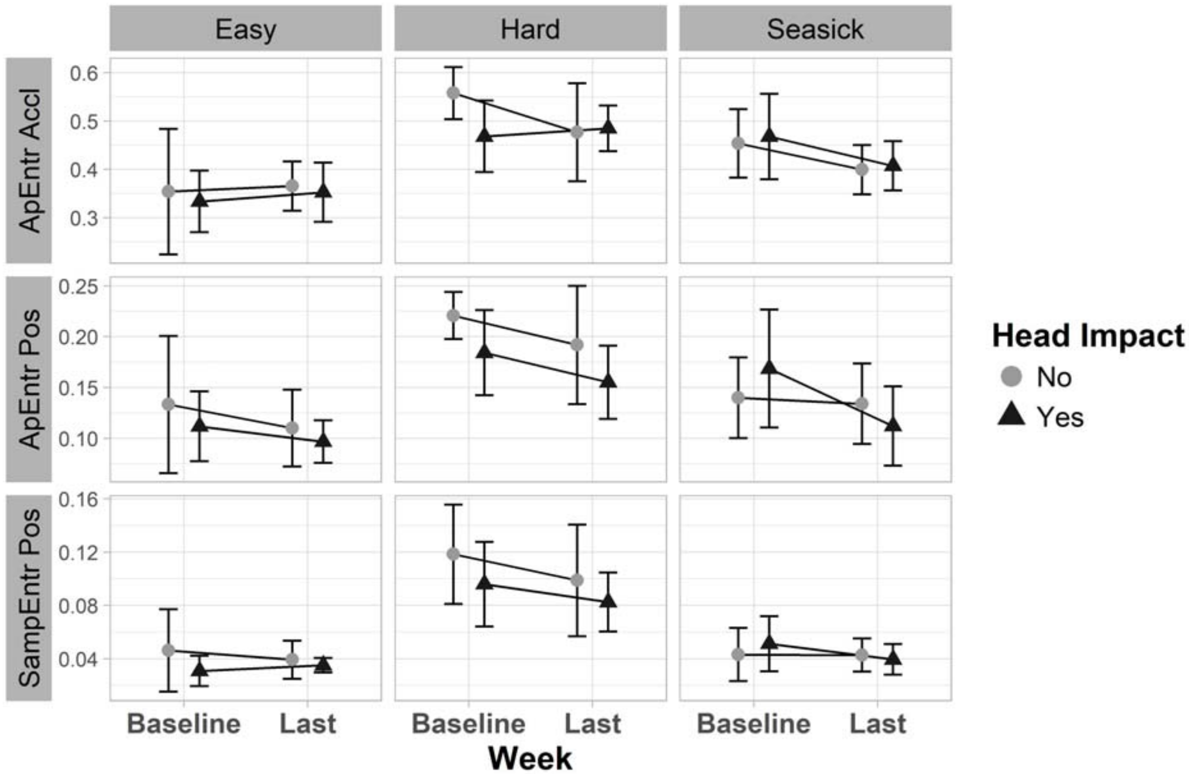

Figure 12. Combatives non-postural balance entropy measures by difficulty, training week, and head impact status. Values are mean ± 1 standard deviation.

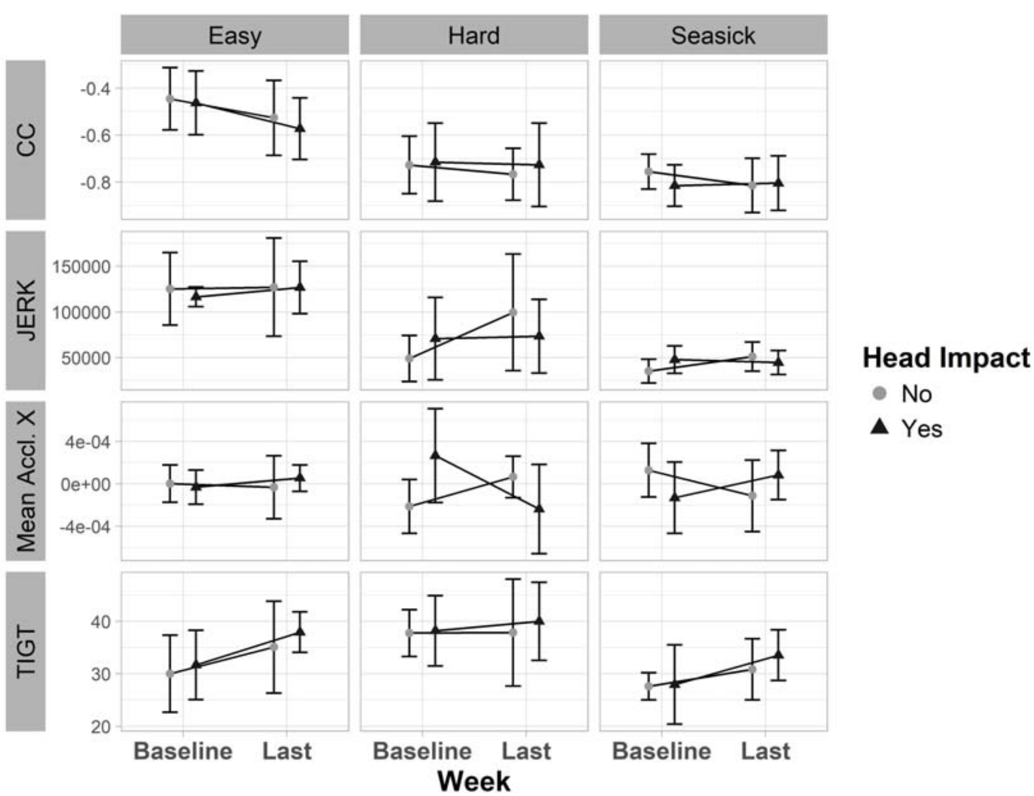

Figure 13. Combatives non-postural balance non-entropy measures by difficulty, training week, and head impact status. Values are mean ± 1 standard deviation

Discussion

Overall, more than half of Combatives participants experienced an incident resulting in a head impact during training. Of those reporting a head injury, headache was the most commonly reported symptom. Prior to training, half of participants reported a previous head injury or concussion. At some point during training, one participant reported losing consciousness, however, this did not occur during the first or last week of training. Four participants were evaluated for a concussion, with one participant ultimately being diagnosed with a concussion. The results of the concussion history questionnaire indicate that only a small fraction of participants reporting a head impact were evaluated by a doctor for a concussion. Results of the PCLM indicated that the most frequently endorsed PTSD symptom was feeling “super alert” and watchful.

DETECT results showed some differences between those reporting a head impact and those not reporting a head impact. Specifically, participants reporting a head impact tended to have slower reaction times for the arrow attention task, immediate word recall, and delayed word recall. Moreover, participants reporting a head impact tended to have lower approximate entropy of position, lower sample entropy of position, and more acceleration in the X-axis direction for the more difficult NPB trials. Other studies (e.g., Cavanaugh et al., 2005) also reported reduced entropy values for individuals experiencing a concussive injury. Furthermore, these results are likely not attributable to fatigue. KSS results indicate that participants in both group had similar ratings of alertness. Moreover, alertness tended to improve from baseline testing to the last week of testing.

General Discussion

The purpose of this report was to document the methodology used in the ESiT research program aimed at improving detection of concussive head injuries during training. This report also presented preliminary descriptive data on neurocognitive outcome measures. In both training courses, head impacts were prevalent with about 50% of Airborne and 60% of Combatives participants experiencing at least one head impact over the course of training. However, severe head impacts involving LOC or amnesia were rare. In both training groups, the most commonly reported MACE symptom for those experiencing head impacts was headache. Thus, headache may be a symptom that may need to be mitigated further in training environments.

The MACE was a useful tool in tracking head impacts and symptoms across training weeks. However, slight modifications may be needed to improve its utility. One critical aspect to reducing head impacts during training is to track during which training activities head impacts occur the most. Many of the responses given on the MACE asking participants to recall how their head impact occurred were vague, making it difficult to identify which training activities pose a greater risk for incurring a head impact. Therefore, researchers should consider implementing a supplemental set of specific probing questions regarding the actual cause of the injury, including during which drill the impact occurred. A separate list of probing questions could be developed specifically for training environments. These questions might include a listing of the drills trainees complete to better assist in tracking which drills are the most prone to head impacts.

The in-house developed concussion questionnaire aided in identifying participants who were evaluated during training for a concussion by a doctor. Moreover, the pre-training concussion history questionnaire revealed that previous head injuries were more common in the Combatives training group than the Airborne training group. This may indicate that Service members entering Combatives training have a higher pre-disposition for previous head injuries. Therefore, head injury mitigation during training for this population should be concerning because of the potentially higher rate of prior-head injury.

In terms of general patterns of DETECT performance measures, no formal conclusions can be made about differences between those with and without head impacts on any of the measures. However, general patterns in the NPB entropy measures suggest that these results are consistent with past literature regarding concussions and measures of postural entropy (Cavanaugh et al., 2005). Therefore, future analyses will likely focus on the relationships between environmental sensor outputs and DETECT NPB metrics.

Conclusions

This report provides detailed description of the methodology used for purposes of comparability to other studies as well as replicability. The environments chosen for testing head impacts proved sufficient with a slightly larger percentage of Combatives participants reporting a head injury than those from Airborne. The instruments and subsequent performance outcomes were appropriate in that they did not yield ceiling or floor effects and produced sufficient data for further analyses.

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Appendix A. PCLM Responses

Table A1. Airborne PCLM Response Frequencies for participants completing the study.

Question	*N*	Not at all (*n*)	A little bit (*n*)	Moderately (*n*)	Quite a bit (*n*)	Extremely (*n*)
1. Repeated, disturbing memories, thoughts, or images	34	30	4	0	0	0
2. Repeated, disturbing dreams	34	33	1	0	0	0
3. Reliving stressful experience	34	33	1	0	0	0
4. Feeling upset when something reminded you of stressful experience	34	33	1	0	0	0
5. Having physical reactions (e.g., heart pounding, trouble breathing, or sweating) when something reminded you of a stressful military experience?	34	30	4	0	0	0
6. Avoid thinking about or talking about a stressful military experience or avoid having feelings related to it?	34	29	5	0	0	0
7. Avoid activities or talking about a stressful military experience or avoid having feelings related to it?	34	32	2	0	0	0
8. Trouble remembering important parts of a stressful military experience?	34	33	1	0	0	0
9. Loss of interest in things that you used to enjoy?	34	28	6	0	0	0
10. Feeling distant or cut off from other people?	34	28	6	0	0	0
11. Feeling emotionally numb or being unable to have loving feelings for those close to you?	34	29	4	1	0	0
12. Feeling as if your future will somehow be cut short?	34	28	6	0	0	0
13. Trouble falling or staying asleep?	34	30	4	0	0	0
14. Feeling irritable or having angry outbursts?	34	31	2	1	0	0
15. Having difficulty concentrating?	34	24	8	2	0	0
16. Being "super alert" or watchful on guard?	34	20	9	4	1	0
17. Feeling jumpy or easily startled?	34	30	3	1	0	0
		Yes		No		
18. Has anyone indicated that you've changed since the stressful military experience?	24	2		23		

Table A2. Airborne PCLM Response Frequencies for Participants not Completing the Study.

	N	Not at all (*n*)	A little bit (*n*)	Moderately (*n*)	Quite a bit (*n*)	Extremely (*n*)
1. Repeated, disturbing memories, thoughts, or images	20	19	1	0	0	0
2. Repeated, disturbing dreams	20	20	0	0	0	0
3. Reliving stressful experience	20	20	0	0	0	0
4. Feeling upset when something reminded you of stressful experience	20	20	0	0	0	0
5. Having physical reactions (e.g., heart pounding, trouble breathing, or sweating) when something reminded you of a stressful military experience?	20	19	1	0	0	0
6. Avoid thinking about or talking about a stressful military experience or avoid having feelings related to it?	20	20	0	0	0	0
7. Avoid activities or talking about a stressful military experience or avoid having feelings related to it?	20	20	0	0	0	0
8. Trouble remembering important parts of a stressful military experience?	20	19	1	0	0	0
9. Loss of interest in things that you used to enjoy?	20	20	0	0	0	0
10. Feeling distant or cut off from other people?	20	18	2	0	0	0
11. Feeling emotionally numb or being unable to have loving feelings for those close to you?	20	19	1	0	0	0
12. Feeling as if your future will somehow be cut short?	20	20	0	0	0	0
13. Trouble falling or staying asleep?	20	19	1	0	0	0
14. Feeling irritable or having angry outbursts?	20	19	1	0	0	0
15. Having difficulty concentrating?	20	18	2	0	0	0
16. Being “super alert” or watchful on guard?	20	15	3	0	2	0
17. Feeling jumpy or easily startled?	20	18	2	0	0	0
		Yes		No		
18. Has anyone indicated that you’ve changed since the stressful military experience?	15	2		13		

Table A3. Combatives PCLM Response Frequencies.

	N	Not at all (*n*)	A little bit (*n*)	Moderately (*n*)	Quite a bit (*n*)	Extremely (*n*)
1. Repeated, disturbing memories, thoughts, or images	32	22	8	1	1	0
2. Repeated, disturbing dreams	32	22	9	0	1	0
3. Reliving stressful experience	32	28	3	0	1	0
4. Feeling upset when something reminded you of stressful experience	32	22	6	3	0	1
5. Having physical reactions (e.g., heart pounding, trouble breathing, or sweating) when something reminded you of a stressful military experience?	32	24	5	1	2	0
6. Avoid thinking about or talking about a stressful military experience or avoid having feelings related to it?	31	25	4	1	0	1
7. Avoid activities or talking about a stressful military experience or avoid having feelings related to it?	31	23	6	2	0	0
8. Trouble remembering important parts of a stressful military experience?	31	23	6	1	0	1
9. Loss of interest in things that you used to enjoy?	32	21	9	0	2	0
10. Feeling distant or cut off from other people?	32	20	9	1	2	0
11. Feeling emotionally numb or being unable to have loving feelings for those close to you?	32	26	3	3	0	0
12. Feeling as if your future will somehow be cut short?	30	24	4	1	1	0
13. Trouble falling or staying asleep?	31	14	5	4	6	2
14. Feeling irritable or having angry outbursts?	32	18	5	9	0	0
15. Having difficulty concentrating?	32	20	4	3	3	2
16. Being "super alert" or watchful on guard?	32	14	9	6	2	1
17. Feeling jumpy or easily startled?	32	20	9	1	2	0
		Yes		No		
18. Has anyone indicated that you've changed since the stressful military experience?	10	1		9		

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