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# On-Body Measure of Reaction Time Provides Real-Time Triage of Impairment

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**ABSTRACT**

There is an urgent need for accurate, cost-effective tools to aid the timely triage of cognitive impairment in field-forward settings. Neurocognitive assessments are used to evaluate individuals after suspected head trauma, and reaction time in particular is a measure identified as a sensitive, robust metric of performance changes. Standard reaction-time tests used in clinics are not practical in the field and mobile touchscreen tests can vary from trial to trial by tens of milliseconds, masking alterations that represent cognitive impairment. Pison has developed and commercialized a wrist-worn technology that enables on-body measurement of reaction time. The Pison device contains surface electromyography sensors that measure electrical activity associated with motion, as well as accelerometers and gyroscopes that measure actual motion. Reaction times are calculated on-device, not on-phone, removing sources of variability. This manuscript describes the Pison wearable technology and details the field-based measurements from 2 military demonstrations: breaching training and a special operations competition. The Pison wearable is not intended to be diagnostic, but informs users of changes in reaction time from baseline performance, which may be indicative of impairment, such as sub-concussive impact and fatigue. Although the cause of impairment is not specified, the easy-to-use Pison cognitive tests empower users to track their own operational readiness and to seek medical guidance if changes from baseline performance persist.

## INTRODUCTION

The timely triage of cognitive impairment in field-forward settings is critical, as it aids in the evaluation of an individual's operational readiness. Early triage is especially critical in sub-concussive trauma, as a majority of blunt force-induced concussions are never identified,[1] due in part to the challenge of assessing subtle and transient effects of repeated exposure to low-level blast overpressure.[2] Detection of cognitive impairment is also important in the context of fatigue[3] and intoxication.[4] Multiple studies have found that increases in reaction time measures are robust and sensitive metrics of performance changes,[5,6] and imaging research has demonstrated that performance on psychomotor vigilance tests, which include a measure of reaction time, relies on the activation of the sustained attention system and the motor system.[7] This paper describes the current landscape of reaction-time tests, the unmet need in reaction-time testing, the Pison wearable device as a solution to that unmet need, and 2 field-based data collections that demonstrate the ability of the Pison device to quantitatively assess cognitive impairment.

### *Current Reaction-Time Tests*

Objective measures of attention and coordination are standard evaluation tools to detect readiness. Examples of such assessments include the Automated Neuropsychological Assessment Metrics (ANAM) tool, and subsets of the ANAM such as the Windows Spaceflight Cognitive Assessment Tool (WinSCAT) and the Automated Neuropsychological Assessment Metrics-4 Traumatic Brain Injury (ANAM4-TBI) battery, as well as the psychomotor vigilance test (PVT).

The ANAM is a computer-based testing system that was developed by the Department of Defense to assess both human performance and psychological function, and it was specifically designed for repeated measures.[8] It consists of a library of over 30 neuropsychological test modules used to establish cognitive baseline and track cognitive function over time. ANAM testing is administered on a computer or tablet and consists of a variety of subtests that measure different cognitive abilities, such as simple reaction time (SRT) and complex problem-solving tasks.[5] The ANAM is particularly favored for its versatility in different settings.

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The WinSCAT is a limited subset of ANAM tests developed by NASA to specifically assess astronaut cognitive function during space missions. The WinSCAT assesses cognitive domains such as working memory, executive function, and processing speed.[9] The WinSCAT is a computer-based, self-administered battery of 5 cognitive assessment subsets. The WinSCAT is routinely completed 3 times: prior to mission start, during the mission, and within 30 days of completing a mission. It is considered the current standard for cognitive assessment in space operations, as it has been shown to detect differences in reaction time and accuracy in studies of crewmembers during spaceflight.[10]

The ANAM4-TBI battery is a subset of the ANAM, which was built upon data derived from patients with TBI.[11] The battery consists of demographics, a TBI history questionnaire, and 8 tests: sleepiness scale, SRT, code substitution-learning, procedural reaction time, mathematical processing, matching to sample, code substitution-delayed, and repeat SRT.

The PVT is a cognitive assay that focuses on sustained attention and reaction time and often involves a simple task in which participants respond to visual stimuli as quickly as possible, with results providing insight into an individual's alertness and cognitive fatigue.[8,12]

### *Unmet Need in Reaction-Time Testing*

Although there are well-established reaction-time tests that are routinely used to monitor cognitive impairment, they are not optimized for deployment in a mobile or field-forward setting. Standard reaction-time tests use either a tablet or a computer monitor to present stimuli and use peripherals to measure responses. The currently available reaction-time tests are administered on consumer-grade computers, which are inherently designed to favor cost and convenience, whereas professional-grade technology is often designed for performance and durability. The operating software, choice of peripherals, as well as the speed and robustness of the technology employed has a direct impact on the testing output. For example, in a study of response time variability, touchscreen responses were found to vary by as much as ±40 ms and computer mouse responses by as much as ±20 ms.[13] Another study of a mobile version of ANAM across different tablet devices found both that there was considerable variability between devices and that the reaction times recorded on tablets were slower than laptops.[14] These studies highlight the difficulty of adapting sensitive tests to consumer-grade technology and of scaling it to a mobile setting. In the context of assessing cognitive impairment, the demonstrated variability of response times attributable to the technology are clinically meaningful. A margin of error of ±40 ms could mask a change in response time caused by cognitive impairment. For example, the mean response time increased by 29.5 ms in a group exposed to pressures above 5 psi when compared to a group exposed to pressures less than or equal to 5 psi.[5] Also, reaction time increases of 40-60 ms have been documented after chronic sleep deprivation.[12]

### *Pison Solution*

Pison has developed a wrist-worn sensor that uses multi-channel surface electromyography (EMG) and other sensors to extract insights from the peripheral nervous system. The Pison wearable, shown in Figure 1, includes sensors that measure EMG, motion, photoplethysmography, electrocardiography, galvanic skin response, and temperature. The collected data is transmitted wirelessly to a client device (e.g., mobile phone) over Bluetooth Low Energy. The EMG and motion sensors are used for active tests, described below. The device also collects data passively for monitoring sleep, heart rate variability, steps, and strain.

The Pison wearable offers 3 types of active tests: a "Readiness Test" that measures SRT, an "Agility Test" that presents a Go/No-Go test, and a "Focus Test" that presents a 3-minute PVT. The primary sensors used in reaction-time tests are the EMG, sampled at 800 Hz, and the inertial measurement unit sensor, sampled at 200 Hz.

The Readiness Test is modeled after a SRT test in which subjects are instructed to respond as quickly as possible to a visual, auditory, tactile, or multi-modal stimulus. The SRT test has been used since the late 19th century[15] and is one of the simplest ways of measuring processing speed. The Readiness Test uses a visual cue, specifically a white light-emitting diode (LED), to prompt users to extend their fingers. The measured time represents sensory perception and transmission to the brain and central processing. The device's EMG sensors measure electrical activity associated with motion and are used to calculate premotor time (PMT), defined as the time it takes between presentation of the visual stimulus and when a threshold EMG signal is


**Figure 1.** The Pison wearable sensor platform uses patented sensing technology to acquire biopotential, motion, and other physiological signals.

measured. The device's accelerometer and gyroscope sensors are used to measure motion and to calculate SRT, defined as the time between the visual stimulus and when a threshold motion is measured. The time series of these events is shown in Figure 2, alongside the average latencies for commercial touchscreen measures of visual reaction time. Users are instructed to react as quickly as possible and are not penalized for false starts (i.e., responding before the visual cue is presented). The standard Readiness Test is ~30 seconds and averages results for 9 consecutive trials. The output of these tests is a quantitative score representing the average PMT that can be compared to the individual's baseline.

The Agility Test is based on the Go/No-Go test, a common behavioral task used to measure response inhibition.[16] The Pison test uses 2 visual cues: a white LED for the "go" cue and an orange LED for a "no-go" cue. Users are instructed to respond as quickly and accurately as possible to the 2 different stimuli. During a "go" cue, users are instructed to extend their fingers, but during a "no-go" cue, users must withhold a response. Unlike the Readiness Test, in which a user responds to all stimuli as quickly as possible, the Agility Test requires judgment by the user based on the color of the LED. The user's score incorporates response speed, errors of omission (failing to respond to a "go" stimulus), and errors of commission (incorrectly responding to a "no-go" stimulus).

The Focus test is modeled after the brief 3-minute psychomotor vigilance test (PVT-B), which has been validated as an objective measure of changes in alertness associated with sleep loss, and shown to track the performance of the standard 10-minute PVT when the lapse threshold is reduced from 500 to 355 ms.[17] The Pison Focus test presents a red LED to users at a randomized interstimulus interval of 1-4 seconds and tracks average response time, false starts, lapses, and misses. These metrics have been demonstrated to objectively assess changes in alertness and cognitive readiness associated with extended wakefulness, circadian misalignment, and time on task.[17] The PVT-B test was chosen because it is a valid tool to assess behavioral alertness and vigilant attention in a more acceptable duration to participants and to consumers than the 10-minute version. In addition, the PVT-B has been reported to be free of practice effects and to not be modified by the test administration interval.[18] While both the Readiness and Focus Tests instruct users to respond to the visual cue as quickly as possible, the Focus Test provides the additional metrics of the number of false starts, lapses, and misses. The Focus Test also more closely mimics the PVT by providing feedback to the user after each response, conveying that a response has been received and displaying the measured PMT. The short length of the Readiness Test is sufficient to ascertain a snapshot of the user's average reaction time but is not long enough to assess attention. The Focus Test lasts 3 minutes and is sufficient to assess both reaction time and attention.

The Pison technology platform, which includes the wearable, signal conditioning, and machine-learning classifiers, has been demonstrated in field settings for several

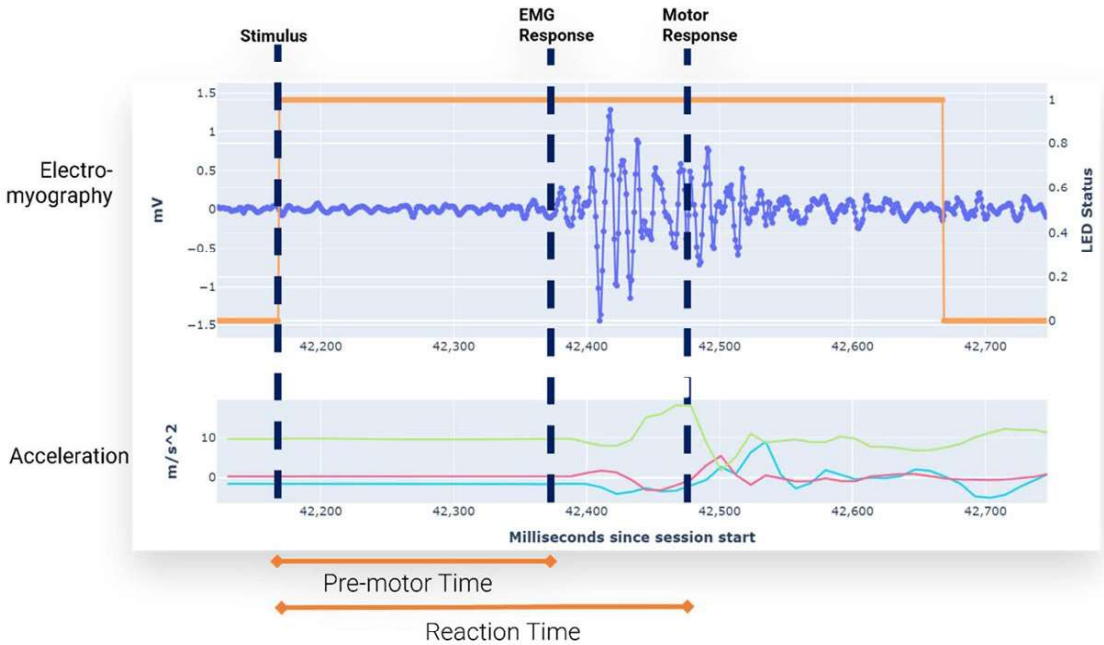


**Figure 2.** Pison's wrist-worn sensor is a self-contained assessment of reaction time calculated by presenting a visual stimulus on-device, measuring premotor time through its electromyography sensors and simple reaction time through its inertial measurement unit. The top graph plots the electromyography time course; the bottom, the inertial measurement unit. AQ14

application areas, including measuring cognitive performance and impairment. Pison's wearable device facilitates on-body measurement of SRT and PMT, which are metrics for monitoring cognitive readiness. SRT is one of the cognitive tests of the ANAM and specifically 1 of the 8 tests included in the ANAM4 TBI battery, where it is used to evaluate the domain of basic neural processing (speed efficiency).[11] SRT is included in other ANAM batteries, such as the ANAM Sports Medicine Battery (ASMB) for concussion surveillance, because statistically significant decrements in SRT performance were observed between pre- and post-concussion injury assessments.[19] SRT can then be broken down into its component parts, the first of which is PMT, the time between the stimulus and EMG detection of electromyographic response, the second of which is the motor time, the time between EMG response and physical movement response. While PMT and SRT have been shown to be highly correlated with comparable variations, motor time is poorly correlated with SRT.[20]

The Botwinick finding[20] was spurred by the observation in the 1960s that reaction time varies with the preparatory interval inserted between a "warning" cue and the stimulus to which healthy participants are instructed to respond. The PMT and SRT both varied with the duration of the preparatory interval, but the motor time did not. This distinction motivates the use of PMT to investigate changes in the preparatory set or readiness of individuals, although it is much more common to measure full reaction time than PMT in cognitive studies. Because motor time is shown to be consistent and not change with stimulus presentation in the 1966 study, as motor time represents the mechanical process of initiating movement after muscle firing, PMT is as relevant a metric as SRT. More recent studies have measured PMT to assess cognitive load[21] and cognitive biases[22] using surface EMG sensors. As surface EMG technology improves and becomes more portable, PMT will be a more viable metric for cognitive studies in real-world settings.

Pison's device does not suffer from software or peripheral delays seen with current reaction-time tests that rely upon consumer-grade touchscreens, keyboards, or other inputs to measure a user's response time. Independent testing of the measurement accuracy and repeatability of the Pison wearable has been performed by the Timex Performance Testing Team. The Timex team constructed a test rig consisting of an LED driven by a power supply and a microcontroller that reads the output from a light sensor. Once the LED illumination is detected, the microcontroller inserts a pre-programmed delay before supplying a digital-to-analog converter with a 10 Hz square wave to simulate the opening of a hand. This voltage signal was input to the EMG contacts on the Pison wearable device. Four programmed delays were used to represent simulated reaction times and included 90, 100, 140, and 180 ms and were tested in 3 Pison devices for 10 consecutive Readiness Tests. At all 4 reaction times, the 4 devices had a maximum range of 4 ms, which is within the rounded range of the measurement error of the test fixture (data provided by Timex). These tests show that the Pison devices have high measurement accuracy and are consistent among devices.

Although the Pison device is not intended to be diagnostic, it informs users of changes from baseline performance, which may be indicative of new-onset cognitive impairment and may prompt further evaluation by a medical specialist. The Pison device is thus well-suited to fit the unmet need for robust and reliable reaction-time testing in field-forward settings for the real-time triage of TBI or other cognitive impairments. This paper reviews the value of the Pison wearable device for 2 military proof of concept demonstrations during training events, one looking at reaction time changes during breacher training and another looking at reaction time as an indicator of performance during an international special operations skills competition.

## *Field Data Collections Using the Pison Wearable*

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### Sub-concussive impact: reaction time changes after blast overpressure exposure

In October 2023, a proof-of-concept demonstration was conducted at Hunter Army Airfield in Savannah, GA. Three instructors led 16 students through outdoor and indoor explosive breaching training. During breaching, all instructors and trainees wore Blast Gauge sensors (BlackBox Biometrics) placed on their left shoulder, helmet, and torso as well as Combo Impact monitoring devices (Prevent Biometrics) placed both on the inside and outside of their helmets. Before and after each round of breaching, instructors and trainees performed 3-minute focus tests using the wrist-worn Pison device. This duration was deemed by investigators and instructors as not too burdensome on participants, whose priority was breaching instruction. For this initial demonstration, changes in reaction time before and after breaching were chosen to investigate the "slow thinking" that has been described as a subjective complaint from service members exposed to blast overpressure.[5] Participants were instructed to extend their fingers as quickly as possible when a light on the Pison wearable was activated. All participants provided verbal consent to collect data in this voluntary demonstration.

Understanding the clinical symptoms associated with blast peak and impulse pressure, duration, and cumulative exposure is an area of active research. Limited data suggest exposures equaling or exceeding 4 psi may cause injury and that exposures to 6-8 psi have been associated with a measurable decline in cognitive function lasting 3-4 days.[23] In this demonstration, trainees experienced between 1 and 5 blasts; instructors experienced 13-16 blasts. For the trainees, the Blast Gauge sensors read a maximum peak of 2.4 psi and a maximum impulse of 2.76 psi-ms. The Combo Impact sensors measured a maximum peak of 6.77 psi and a maximum impulse of 10 psi-ms. For the instructors, the Blast Gauge sensors read a maximum peak of 2.79 psi and a

maximum impulse of 3.77 psi-ms. The Combo Impact sensors measured a maximum peak of 4.1 psi and a maximum impulse of 6.1 psi-ms. Changes in reaction time were plotted for each individual as a function of the total peak pressure and total impulse pressure and are shown in Figure 3. Values are plotted for the Combo Impact sensors placed inside the helmets, as those sensor readings were consistently greater, presumably due to pressure amplification by the helmet, and may reflect a greater change in cognitive function. A correlation coefficient of 3.966 ($P < .005$) was calculated for the total peak overpressure and a correlation coefficient of 3.065 ($P < .005$) was calculated for the total impulse overpressure.

Although the small sample size limits the statistical power and generalizability of findings, this demonstration highlights the capabilities of the Pison wearable device to identify changes in premotor times in a field-forward setting, on individual events and in aggregate. In addition, an ongoing study led by the Uniformed Services University of the Health Sciences is using the Pison wearable and its Readiness and Agility tests as outcome measures of a larger study of explosive ordnance disposal specialists. This externally led study will further examine how reaction time changes after exposure to blast overpressure.

### Reaction time as a predictor of performance

Another meaningful use for the Pison device in mobile and field-forward settings is for a quantified readiness assessment. To evaluate this capability, Pison partnered with the Fuerzas Comando premier special operations skills competition in August 2025, in El Salvador to longitudinally evaluate participants' reaction times over the course of the 10-day competition. Each competing country sends top operators to the competition, which tests mental and physical stamina, marksmanship, and tactical proficiency. Verbal consent was obtained from each of 115 participants (16 teams, 7-8 members per team). Instructions were given to participants, sometimes through a Spanish-speaking translator, to open their hands quickly when the light on the Pison device becomes active. The length of the test was described and that reaction time would be measured. Participants agreed to take 2 self-administered Readiness Tests on the Pison device each morning and evening. The average and fastest PMT for each measurement were reported and cognitive variability calculated as the coefficient of variation. The fastest reaction time was used as an estimate of peak performance; average reaction time, as a measure of overall processing speed; variability in reaction time, as a measure of reliability.

A total of 925 testing sessions was collected from the 115 participants across 10 days, representing 62% user compliance of the maximum 1,498 sessions. The average PMT by team was calculated for all 16 teams and ranges between 143 and 189 ms, with a median of 167.5 ms. As the Readiness Test is a SRT test that does not include a speed–accuracy tradeoff, slower responses reflect slower sensorimotor processing. The winning team of the event was Colombia, and their team measured the second-fastest average PMT.

Data may also be analyzed for individuals, and PMT scores for members of the Colombia and Belize teams are shown in Figure 4. Members of the Colombia team displayed some of the fastest PMT (3 were in the top 10) and had consistent performance, as assessed by the average variability of PMT. All but one of the Colombia team had PMT variabilities in the top 25% (lowest variability). In contrast, 3 members of the Belize team had PMTs in the bottom 25% of all individuals ranked in the second highest quartile for PMT variability. Qualitative analysis of the longitudinal individual data revealed that: (1) many teams have one team member with slower PMTs; (2) some participants improved PMT scores over the exercise, suggesting an acclimation to environment; and (3) some participants had an acute degradation (average 25% deviation) on the last assessment day, after a heavier load day.

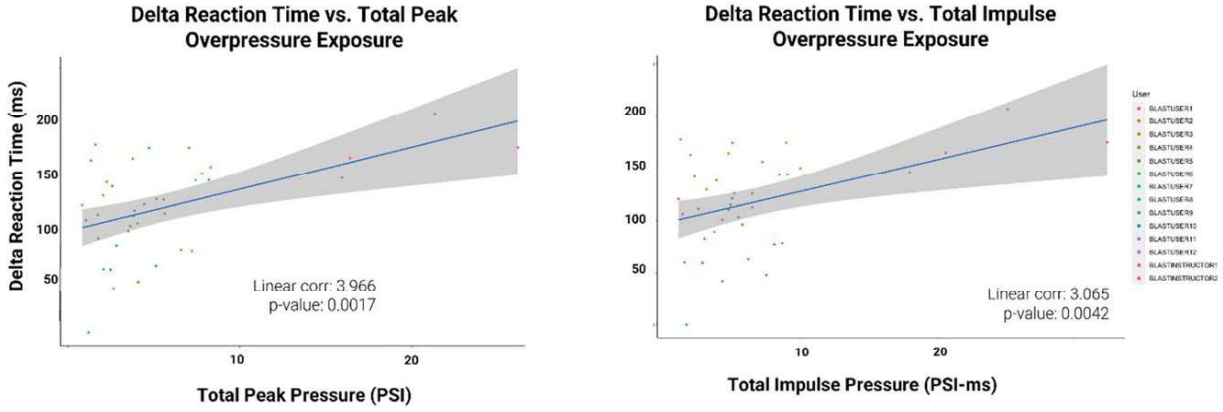


**Figure 3.** Changes in reaction time are plotted for each individual as a function of the total peak pressure (left) and the total impulse pressure (right). Values are plotted for the Combo Impact Sensors placed inside the helmets. A correlation coefficient of 3.966 ($P < .0017$) was calculated for the total peak overpressure and a correlation coefficient of 3.065 ($P < .0042$) was calculated for the total impulse overpressure.

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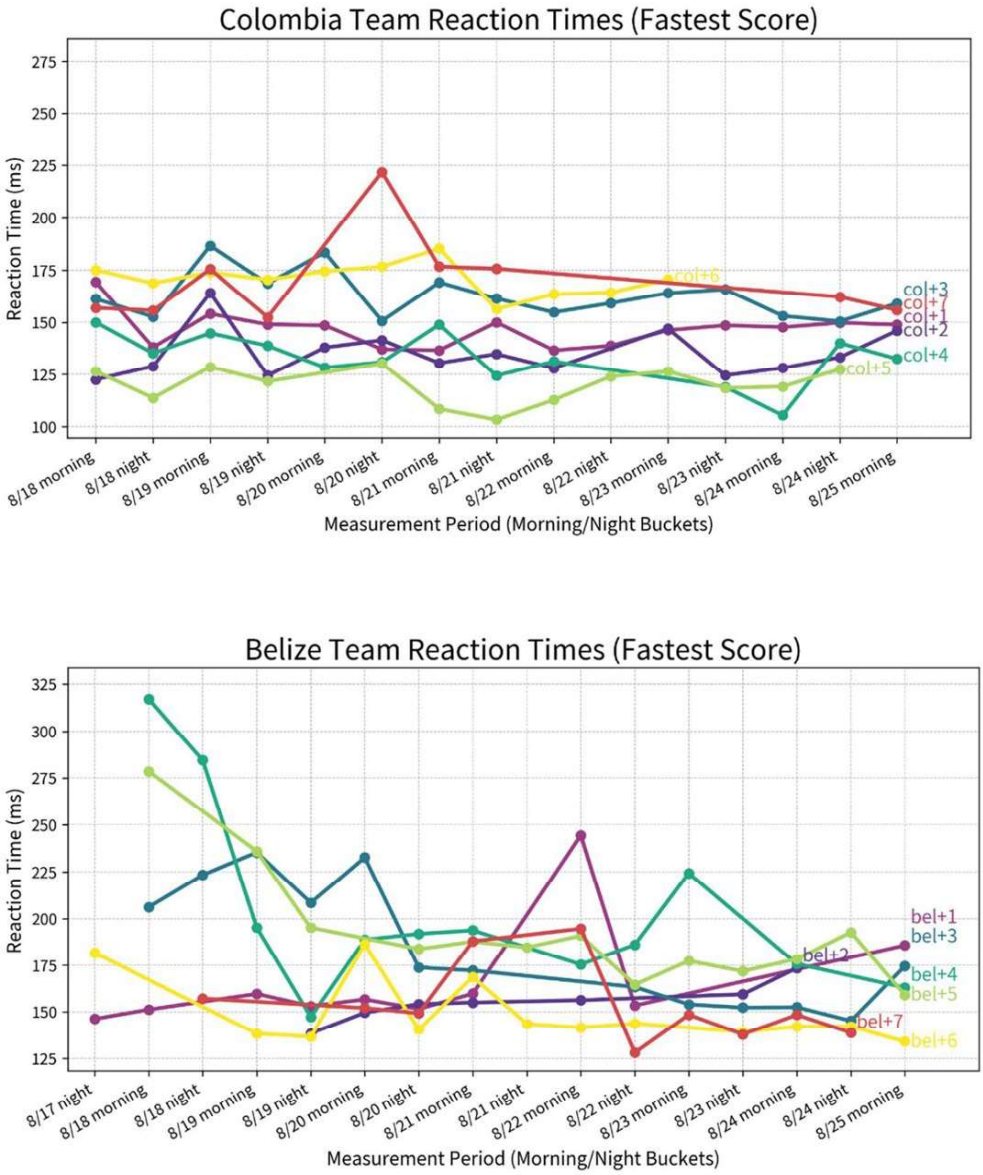


**Figure 4.** Individual reaction time scores for members of the Colombia and Belize teams in the 2025 Fuerzas Comando premier special operations skills competition are shown below. Members of the Colombia team (top figure) displayed some of the fastest reaction times and had consistent performance. Members of the Belize team (bottom figure) were initially much slower.

It is not surprising that the winning team demonstrated a fast average PMT, some of the fastest individual PMTs, and consistent PMTs. Reaction time measures raw neural processing speed—how fast the brain can detect and initiate a response. Winning a multi-stage assault and sniper competition requires converting that speed into accurate shots, sound tactical decisions, and coordinated team execution. Readiness is a multidimensional construct, and no single metric captures it fully.

These results provide a proof-of-concept that the Pison device can robustly capture reaction time tests as quantifiable readiness assessments in a military field setting. Larger, follow-on studies should be performed, and the study design would be improved if a gold-standard test were used for comparison.

## DISCUSSION

Neurocognitive performance has recently been highlighted as critical to individual performance and physical readiness. This manuscript describes an on-body, real-time, quantitative, cognitive assessment based on individual reaction times measured using next-generation surface EMG. The capacity of the Pison wearable device to identify cognitive

impairment is presented in 2 settings in which operational readiness was assessed in military personnel. These field data collections demonstrate the capability of on-body surface EMG to identify changes in reaction time via PMT and provide insight into impairment that is difficult to assess using current SRT modalities.

In the space of sub-concussive TBI, a study of 3 instructors who led 16 students through outdoor and indoor explosive breaching training found a statistically significant correlation between decrease in PMT and exposure to overpressure as measured inside of the participants' helmets. Unlike a concussion, exposure to one or more sub-concussive events may not lead to an immediate medical diagnosis because the symptoms are not as severe. Subtle changes in reaction time have previously been measured following sub-concussive exposure to blast overpressure.[5] The pilot data collected with the Pison wearable are promising and demonstrate that significant changes in reaction time can be measured by users themselves using a watch-based test. The importance of the ability to identify and quantify a clinically silent injury that can lead to significant long-term cognitive impairment cannot be overstated. This is especially important when there is growing evidence linking sub-concussive injury and long-term mental health problems. The use of a wearable device for real-time, in-field neurophysiologic assessment enhances the value of these findings, particularly regarding deployment and scalability.

The second demonstration detailed in this manuscript involved military exercises in which a total of 115 participants were exposed to physical and cognitive challenges under fatigue-inducing conditions. The conclusion of that demonstration suggests that measuring PMT with a wearable can help inform a user's readiness by measuring changes from baseline. The ability to identify performance decline is critical in managing both the use of recovery techniques as well as appropriate selection of personnel to carry out mission-critical tasks.

The military has long sought a solution for the problem of real-time identification of factors that predispose personnel to cognitive decline, whether this is in the form of TBI or fatigue. Currently, there has been reliance on self-reports, pressure gauges, and hours of work to help with this issue. However, none of these solutions actually measures the impact that these factors have on the neurocognitive function of the soldier. The Pison device delivers on this goal by measuring in real time, with an on-body assessment of cognitive impairment. In one envisioned concept of operations, a user would take tests using the Pison wearable at regular intervals and after exposure to potential sub-concussive events (e.g., breaching, use of ordnance). Results are stored on the Pison wearable and can be transferred to a software application installed on a phone or other Bluetooth- or WiFi-enabled system when convenient and safe to do so. In this way, the Bluetooth transmission used by the Pison device would not jeopardize a team's operational security.

The Pison wearable, which may be purchased with an annual membership fee of $299 or a lifetime membership for a one-time fee of $499, is comparable in price to an Apple Watch SE ($249), Apple Watch Series 11 ($399), or a mid-range Garmin Venu 3S ($349) or Garmin Instinct 2 ($279). Neither the Apple Watch nor the Garmin watches presently include EMG sensors.

This manuscript details real-time assessments for the areas of sub-concussive head injury and fatigue. The Pison on-body EMG holds promise to deliver the long-term goal of an individualized, mobile assessment of real-time cognitive impairment, agnostic as to the cause of that impairment.

## FUTURE WORK

These findings represent significant progress in the field of cognitive impairment assessments. Follow-on studies are needed with larger sample sizes and controls for sub-concussive exposure, and for different forms of cognitive impairment. The data presented herein does, however, identify a viable, scalable solution for both military and civilian use of any and all cognitive impairment monitoring.

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## FUNDING

AQ7

No federal funding was used in the execution of this effort.

## CONFLICT OF INTEREST STATEMENT

MB and WG hold options in the Pison Technology company. AQ8

## DATA AVAILABILITY

The data reviewed in this paper are available on request from the corresponding author. All data are freely accessible.

## INSTITUTIONAL REVIEW BOARD

The data referenced in this paper were collected under protocols 20234024 and 20230644 approved by the Western-Copernicus Group (WCG) Institutional Review Board.

## INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE

Not applicable. AQ9

## INSTITUTIONAL CLEARANCE

Not applicable.

## INDIVIDUAL AUTHOR CONTRIBUTION STATEMENT

T.B.D.

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