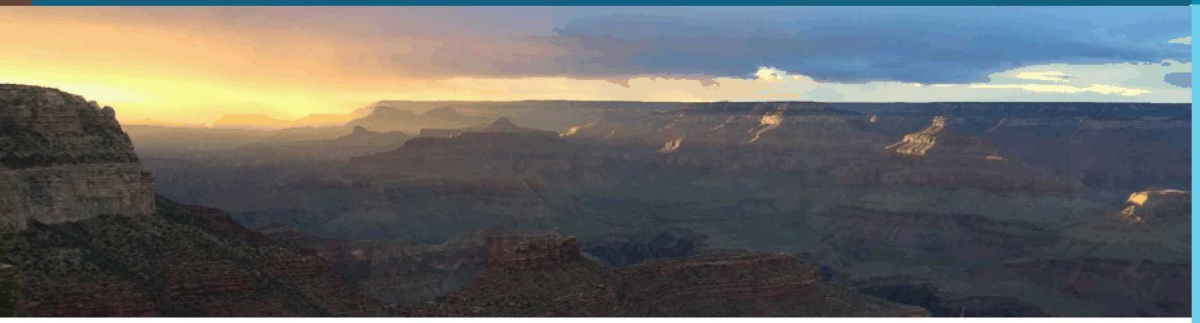
SAND2018-12191C

UNM SCHOOL OF MEDICINE
DEPARTMENT OF EMERGENCY MEDICINE

Wearables at the Canyon for Health (WATCH)

Quantifying Physical and Cognitive Fatigue in Extreme Environments



Austin Silva, Principal Investigator

PRESENTED BY Sandia National Laboratories

Dept. of Scalable Analysis & Visualization

Funding for Wearables At The Canyon for Health is provided by the Defense Threat Reduction Agency (CB10359).

Ooh Aah Point

Photo credit: WATCH team member, Rob Abbott

0.7mi; 790ft Down
20 miles to go!

Purpose of the Study

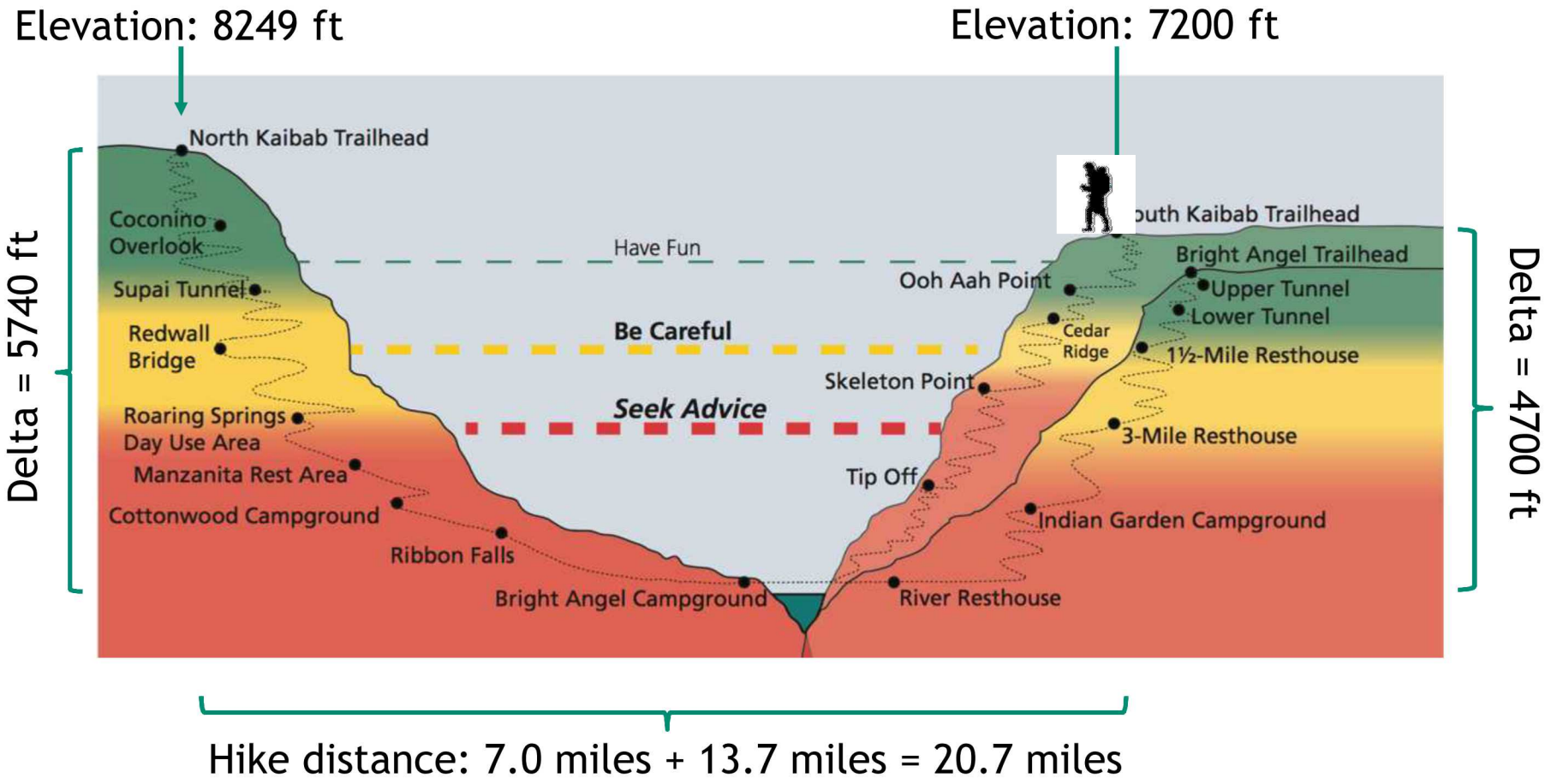
1) Markers for Health:
- Identify physiological, cognitive markers most related to health and task performance

2) Wearable Devices:
- Identify which commercial off-the-shelf (COTS) wearable devices are best for measurement and in rugged environments

3) Health Events:
- Use statistical analyses on collected data to identify which markers are most predictive of benign vs. traumatic health events

Two populations of interest: Military & Civilian

The Rim-to-Rim Hike



Source: “Hiking into Grand Canyon” – National Park Service

Average Conditions Throughout the Year

Location	Summer	Winter	Spring/Fall
Avg Top Min	48˚F	19˚F	32˚F
Avg Top Max	83˚F	45˚F	63˚F
Avg River Min	74˚F	38˚F	56˚F
Avg River Max	104˚F*	59˚F	82˚F

*Temperatures can feel like 140°F in the sun and reach 115°F in the shade in Summer.

Source: “Hiking into Grand Canyon” – National Park Service

Devices Used

LifeBeam SmartHat

Garmin eTrex 10

Equivital EQ02

Garmin Tempe

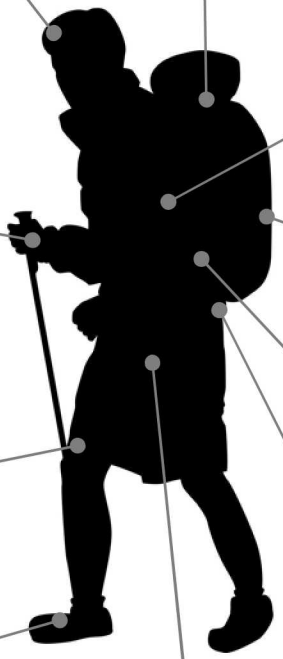
Wahoo Tickr-X

Suunto Smart Sensor

Suunto Spartan Ultra

Garmin Vivoactive HR

Fitbit Charge HR



Empatica E4

Garmin Fenix 3 HR

Garmin Fenix 5 HR

iPod Touch 6 BrainBaseline

Pre / Post Weigh-in (participant & pack)

Omron bio-impedance

Polar Foot Pod

Garmin Foot Pod

Myontec Mbody Shorts

SensorPush

September 2018 Data Collection Package

iPod Touch

Garmin Fenix 3 or 5

SensorPusl

Equivital (Primary HR)

OR

Wahoo TICKR-X & Garmin Tempe (Secondary HR)*

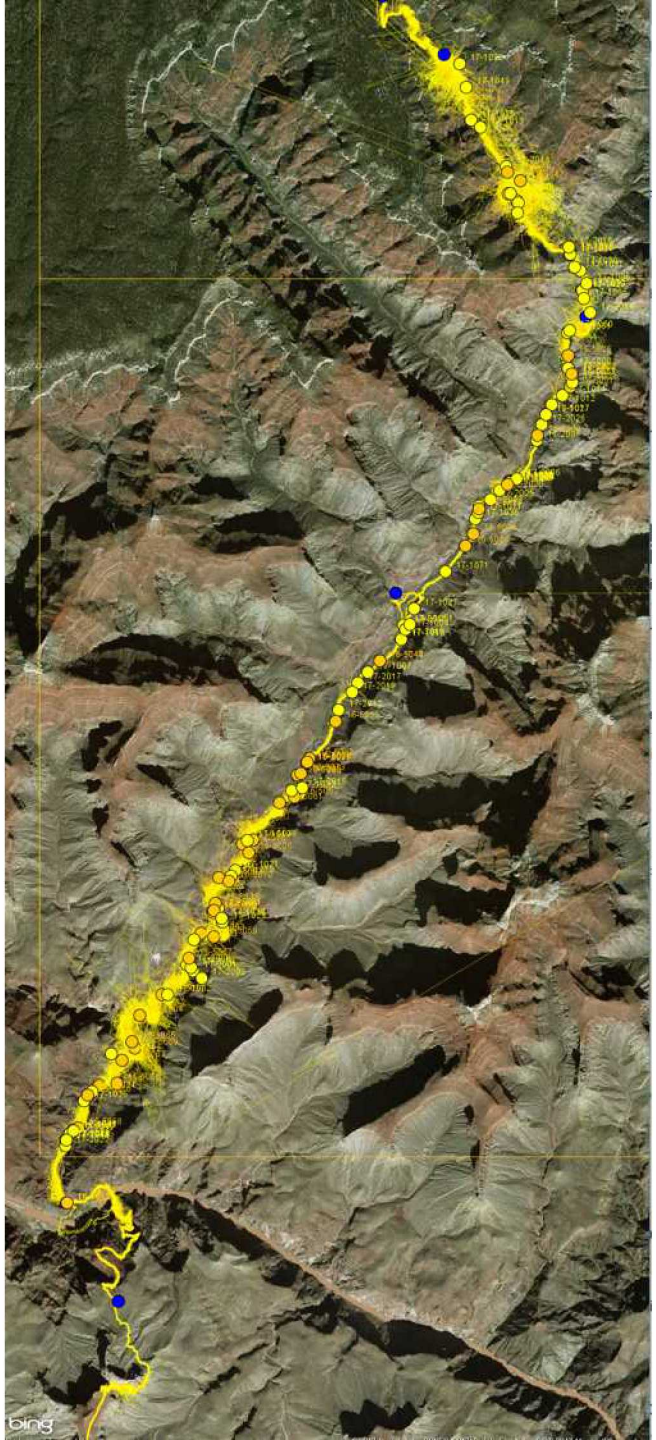
Garmin Foot Pod

Data Collected

- Heart rate
  - HRV
  - ECG (Intervals, QRS)
- Distance & Cadence
- GPS
  - Location
  - Elevation
- Body Temperature
- Environmental Temp & Humidity
- Cognitive Battery
  - VSTM
  - Go/No-go
  - BART
  - Subjective Mental/Physical fatigue
- Survey Data
  - Pre-hike
    - Personality
    - Pack weight
    - Sleep Quality
    - Home elevation
    - Start Time
  - Post-hike
    - Fatigue
    - End Time
  - Recovery (one-week)
- Blood data
  - Delta CK
  - Lactate
  - …
- Observation notes

Data Collected to Date

	Wearables	Cognitive	Bloodwork	Surveys
TOTAL	174	162	179	452
Sep 2018	38	38	37	38
Oct 2017	27	27	24	27
May 2017	59	57	67	99
Oct 2016	50	40	51	288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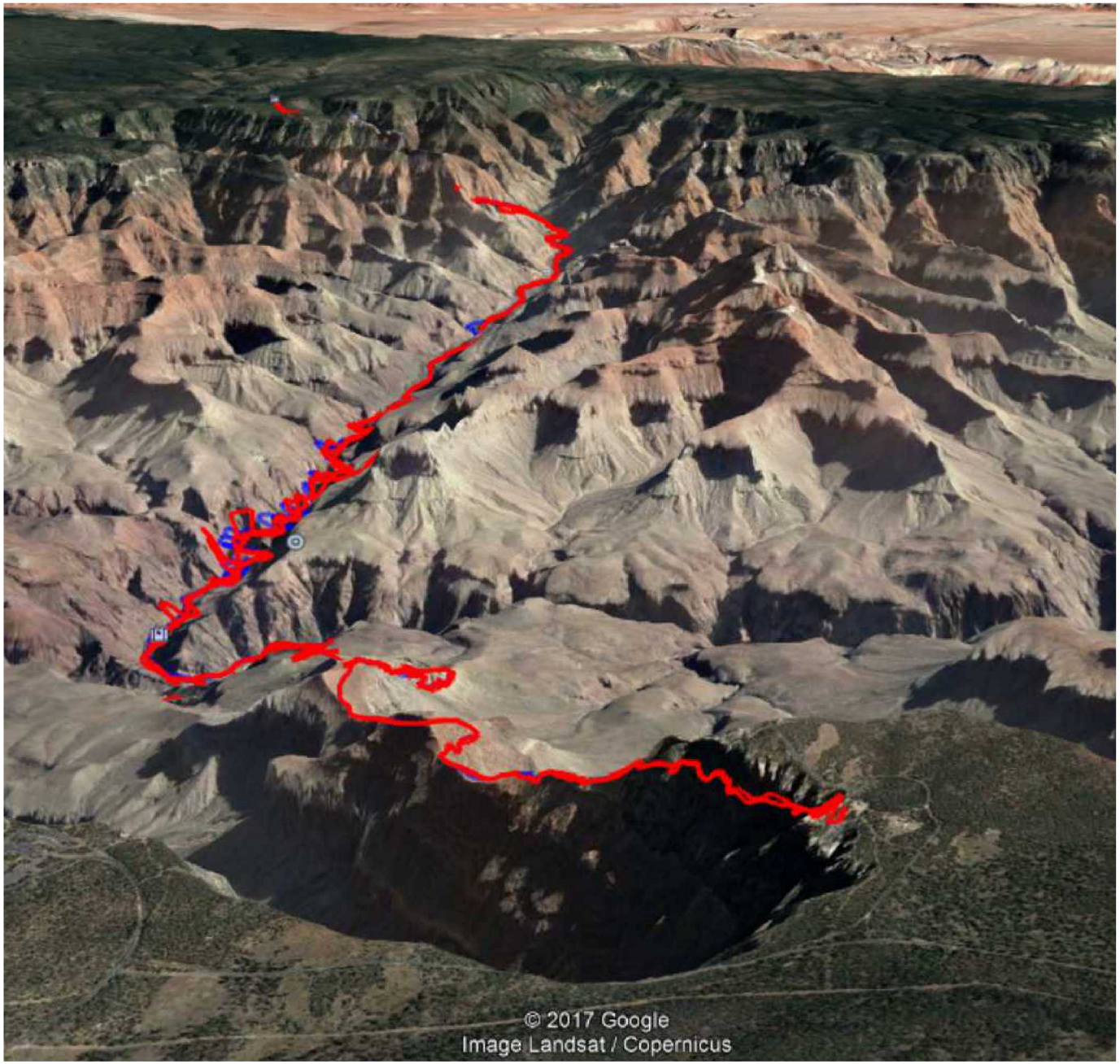
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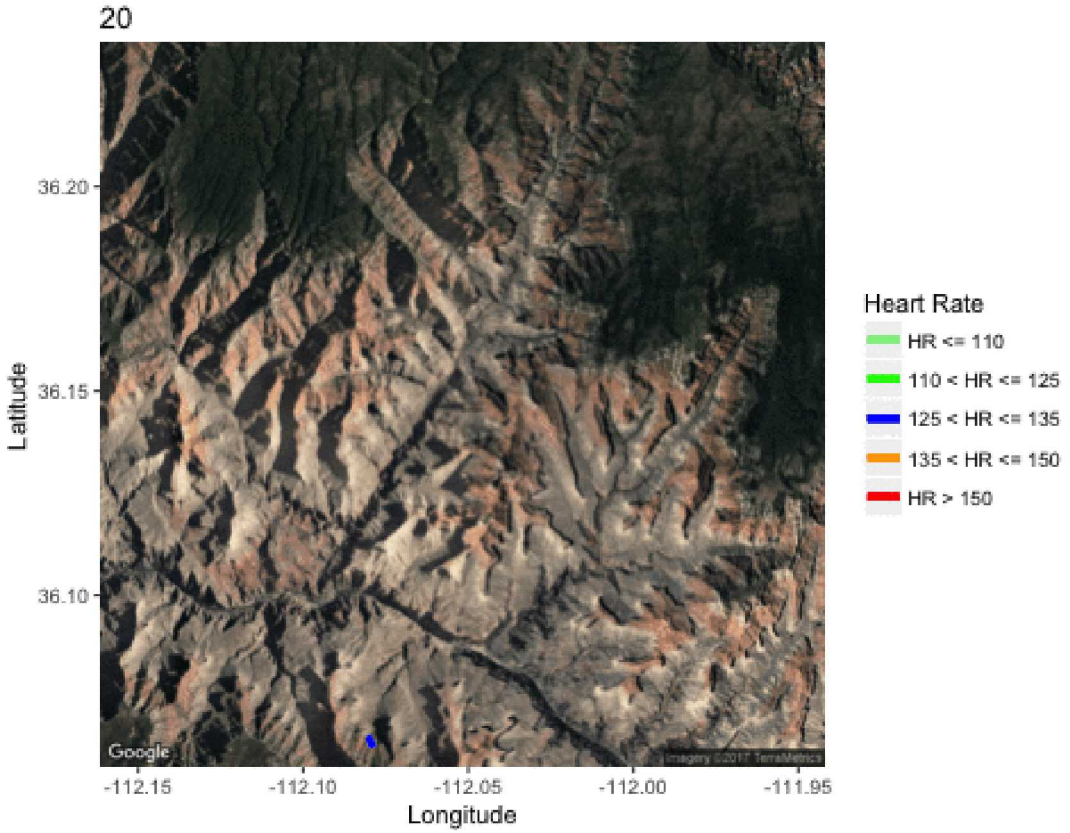
Image Landsat / Copernicus

Comparing Heart Rates Across Subjects

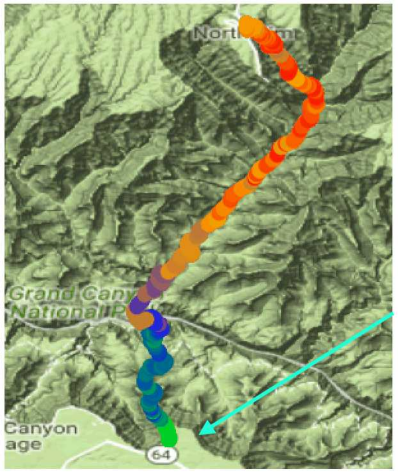


(Longitude shifted for visibility)

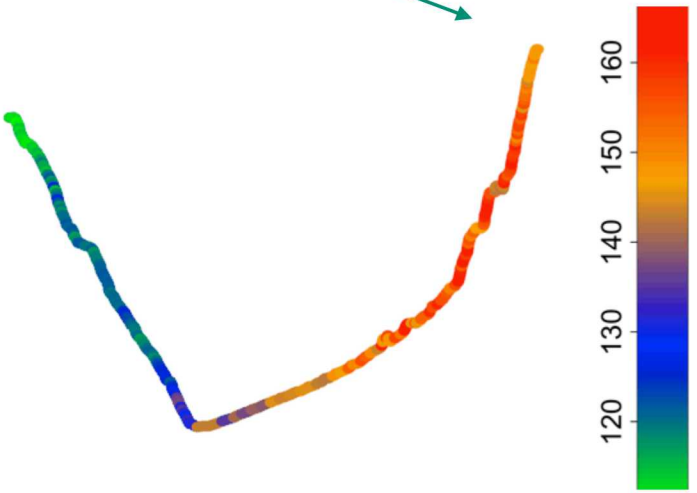
Intensity of Hike

Average Heart Rate (military)

North Rim (finish)



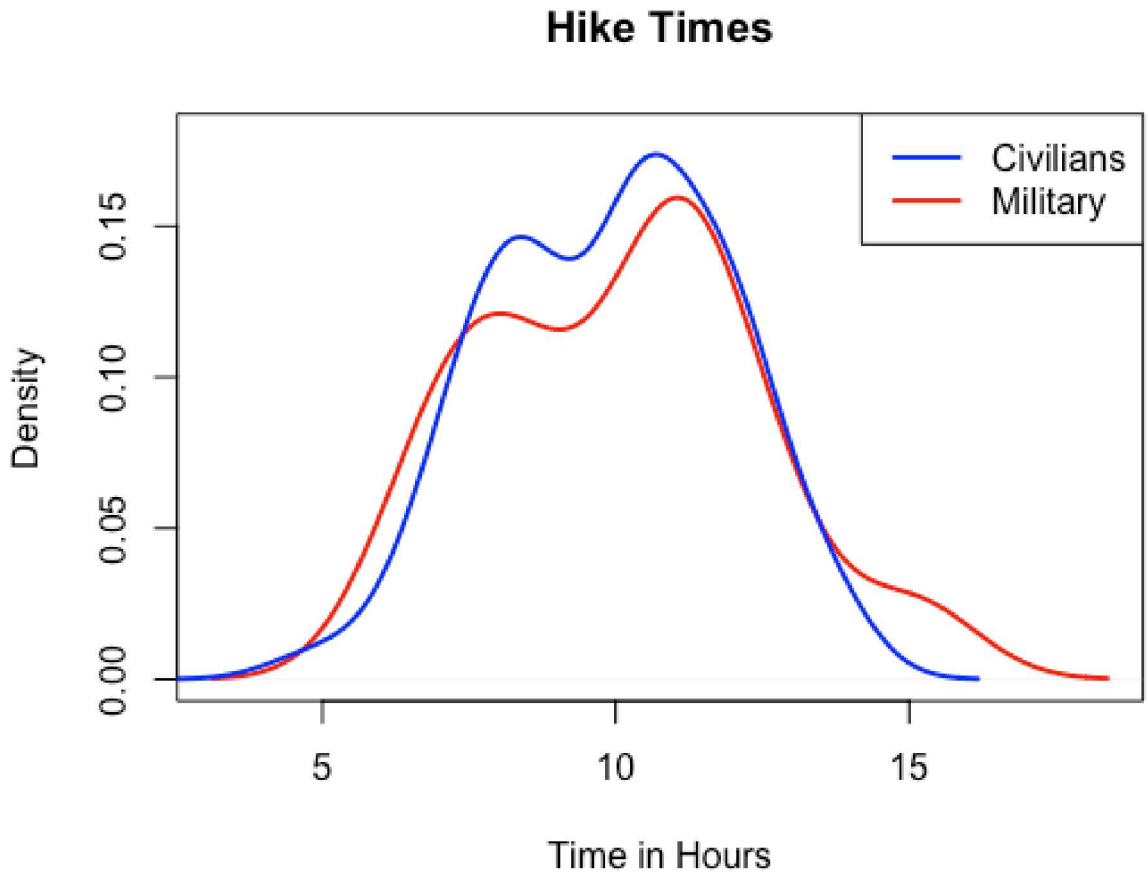
South Kaibab (start)



By GPS coordinates

By elevation

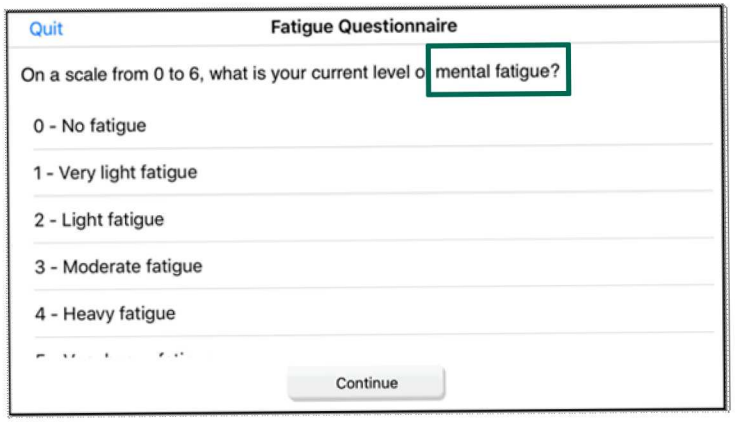
Hike Times

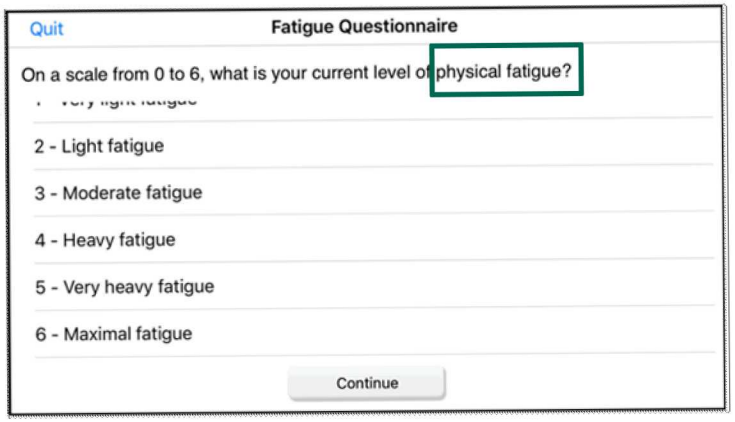

Hike Times
Civilians
Military
Density
0.00
0.05
0.10
0.15
5
10
15
Time in Hours

Cognitive Assessments

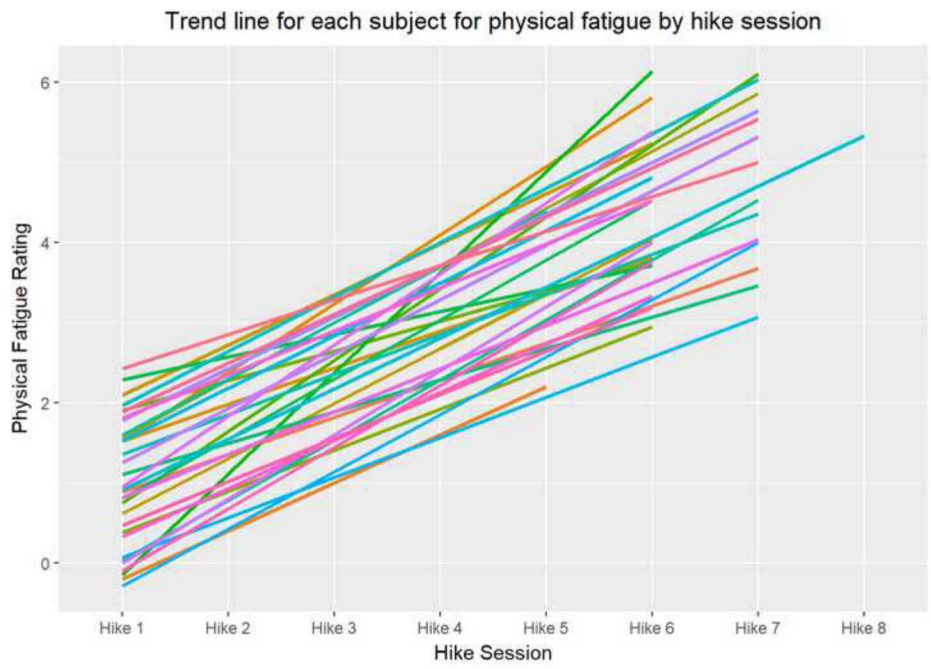
- Subjective Fatigue
- Visual Short Term Memory (VTSM)
- Go/No-Go
- Balloon Analogue Risk Task (BART)

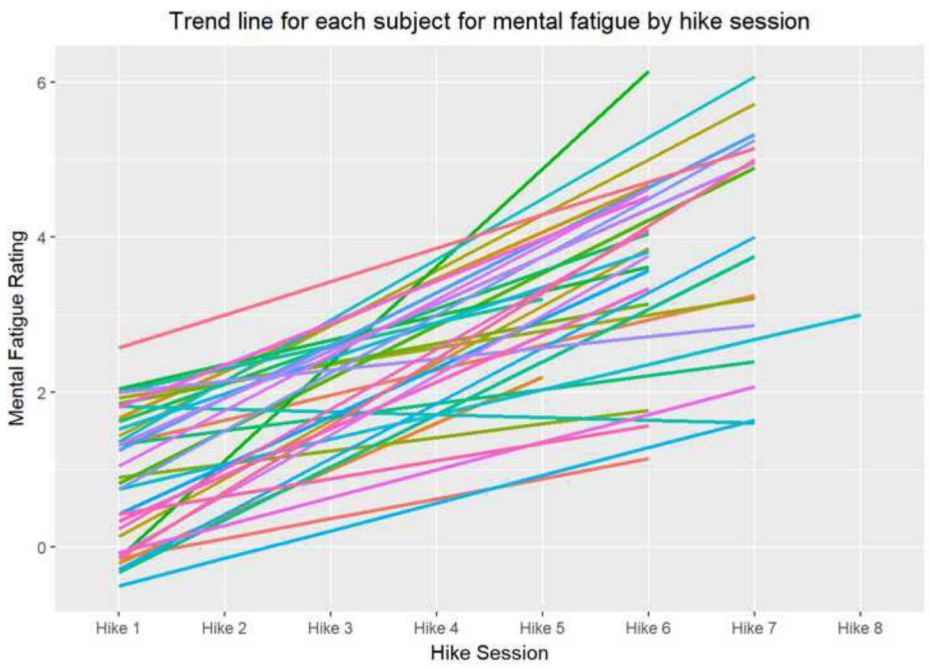
Cognitive Assessments – Subjective Fatigue



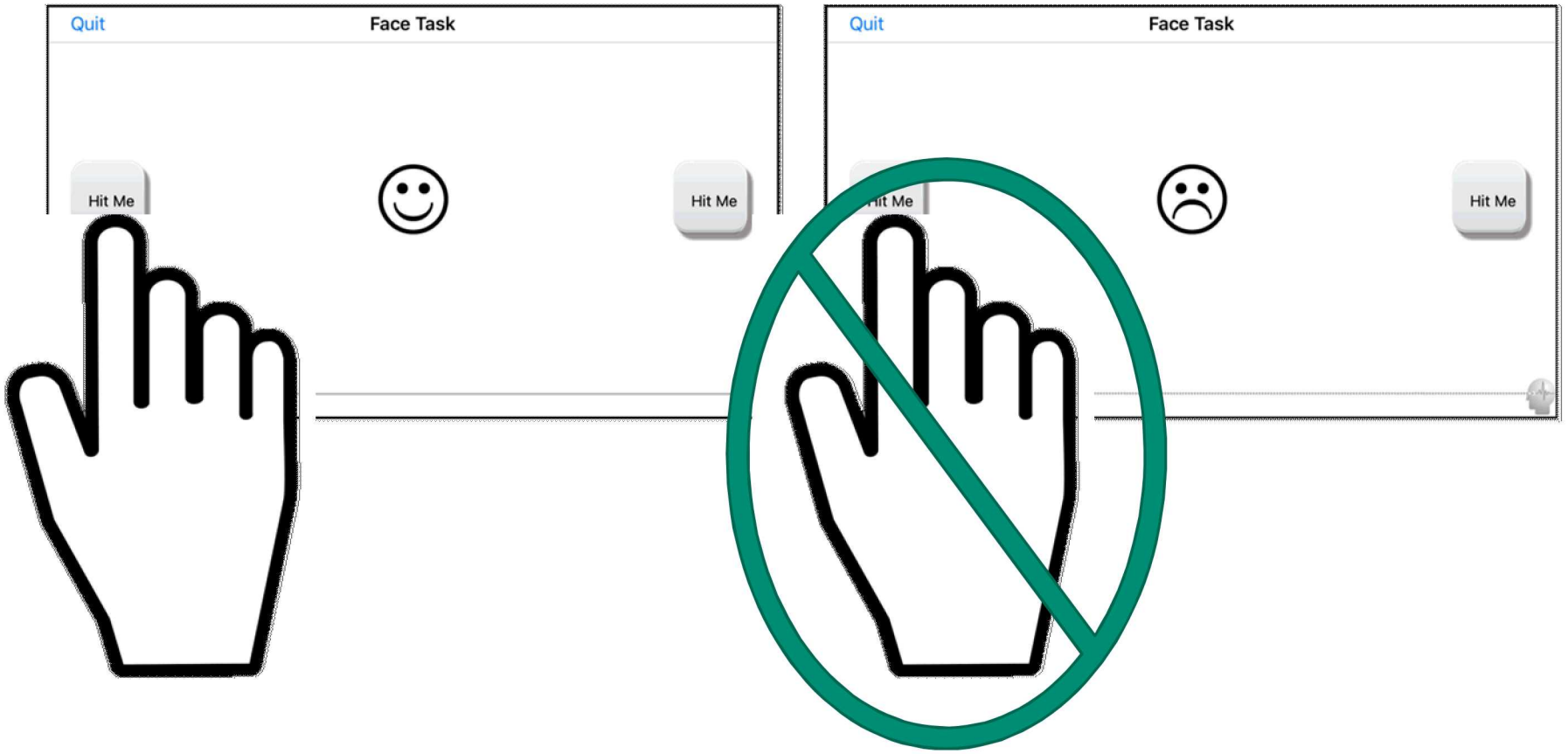


Fatigue

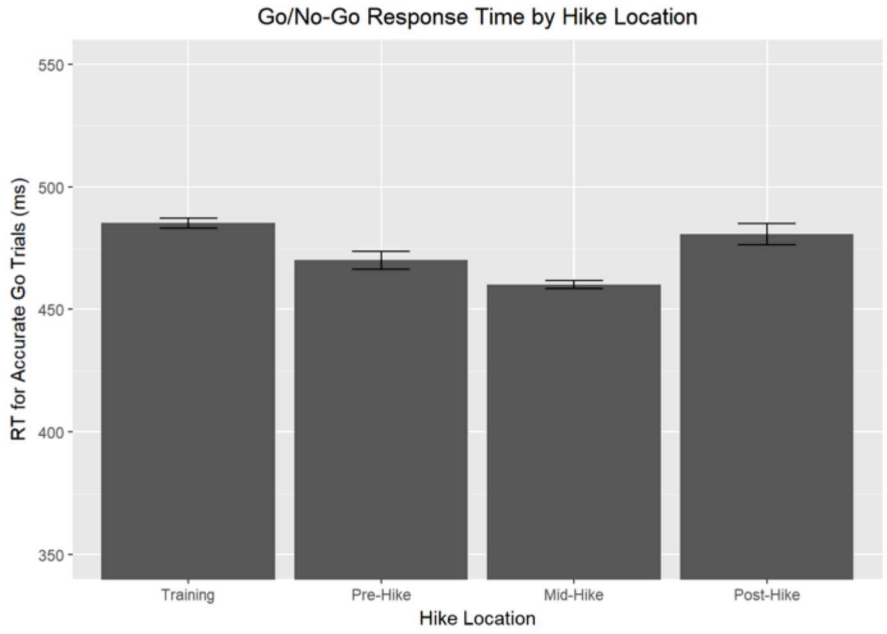

Trend line for each subject for physical fatigue by hike session
Physical Fatigue Rating
0
2
4
6
Hike 1
Hike 2
Hike 3
Hike 4
Hike 5
Hike 6
Hike 7
Hike 8
Hike Session

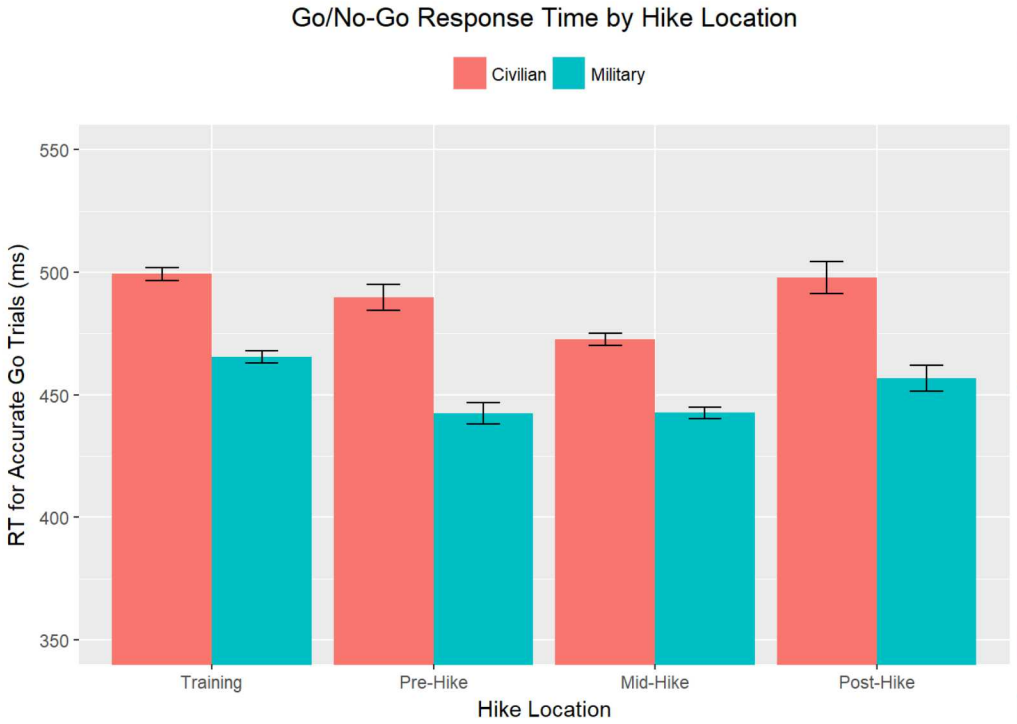

Trend line for each subject for mental fatigue by hike session
Mental Fatigue Rating
0
2
4
6
Hike 1
Hike 2
Hike 3
Hike 4
Hike 5
Hike 6
Hike 7
Hike 8
Hike Session

Cognitive Assessments – Go/No-Go



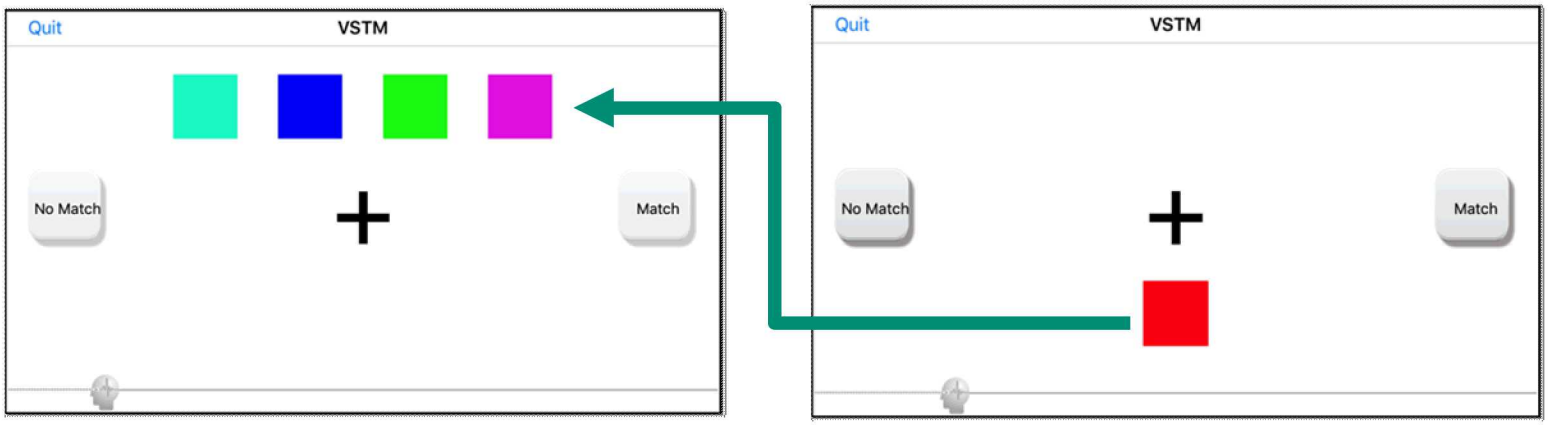
Go/No-Go


Go/No-Go Response Time by Hike Location
RT for Accurate Go Trials (ms)
550
500
450
400
350
Training
Pre-Hike
Mid-Hike
Post-Hike
Hike Location

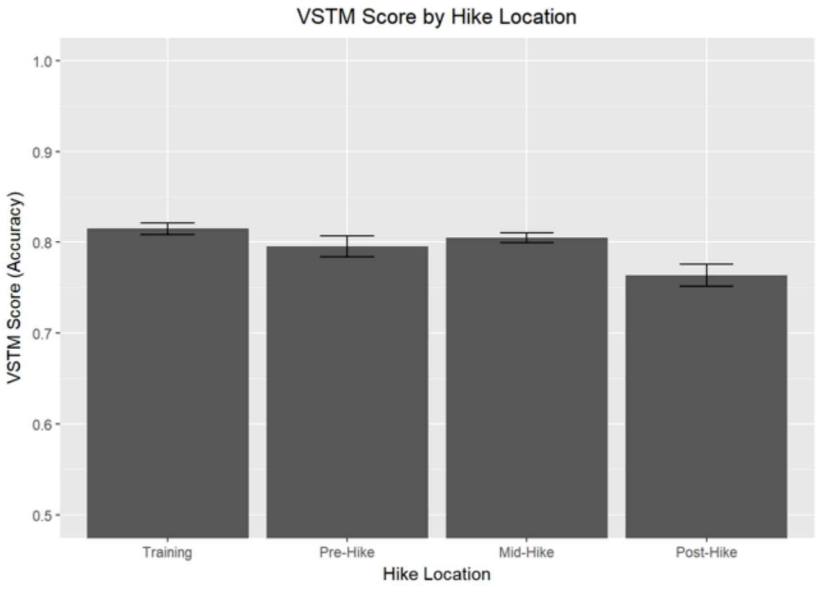

Go/No-Go Response Time by Hike Location
Civilian
Military
RT for Accurate Go Trials (ms)
550
500
450
400
350
Training
Pre-Hike
Mid-Hike
Post-Hike
Hike Location

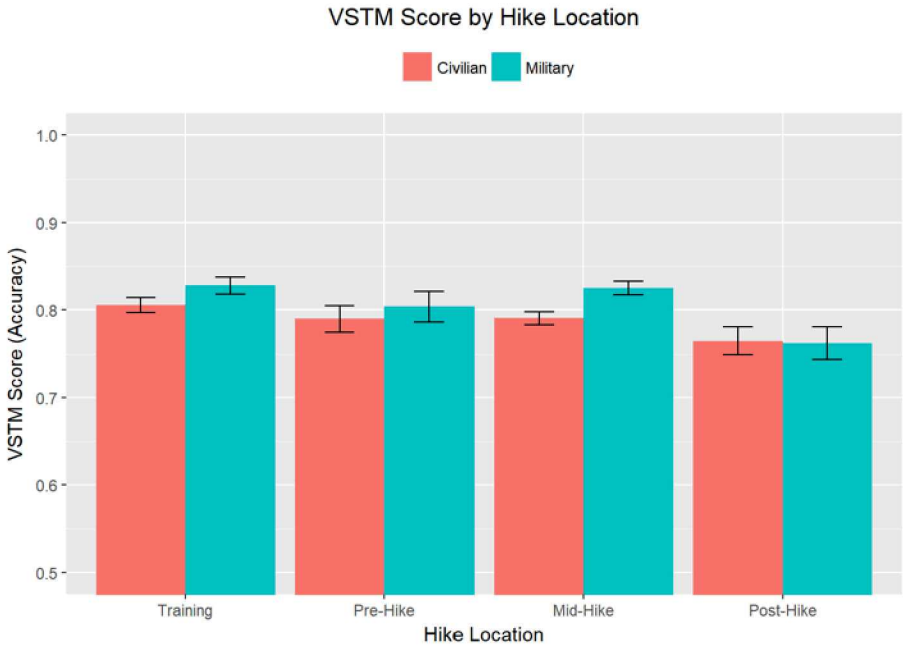
Cognitive Assessments – VSTM

Visual Short Term Memory (VSTM) task

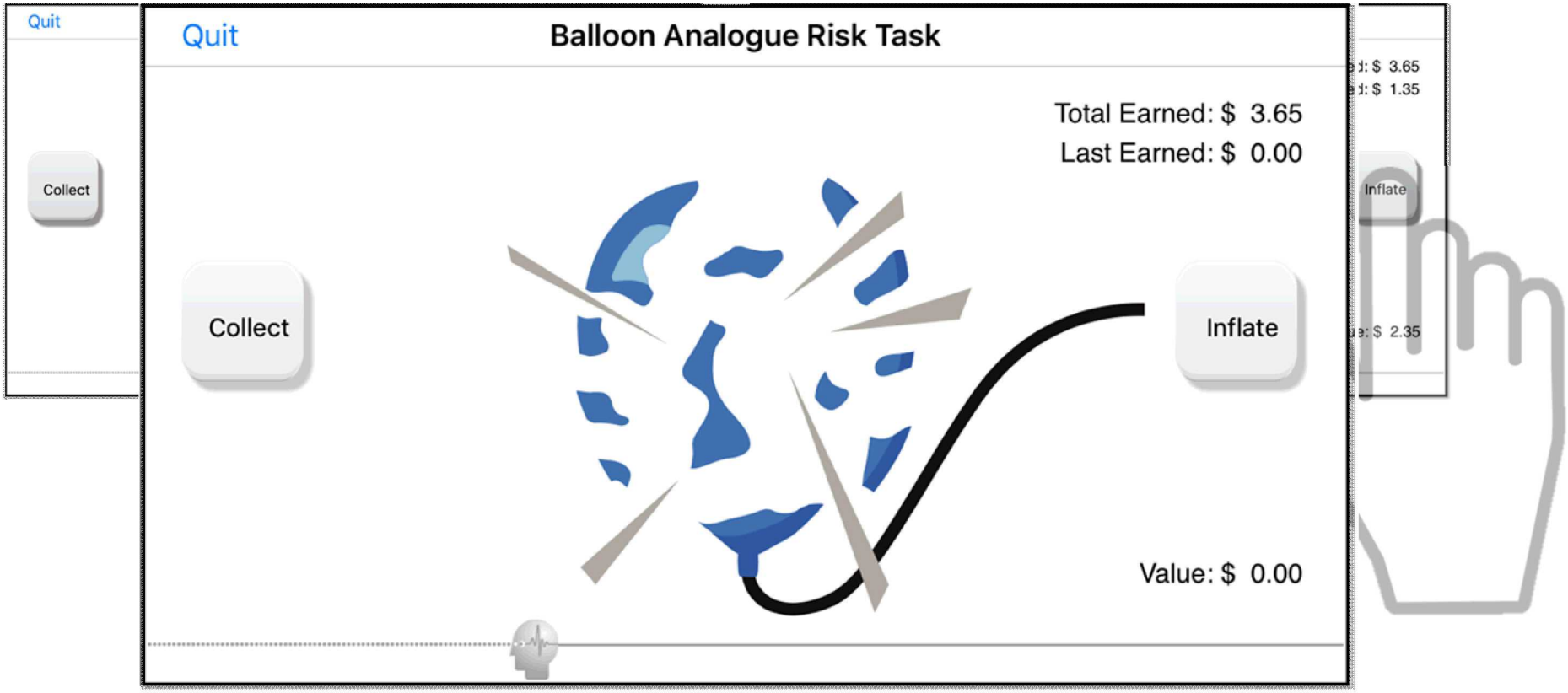


VSTM

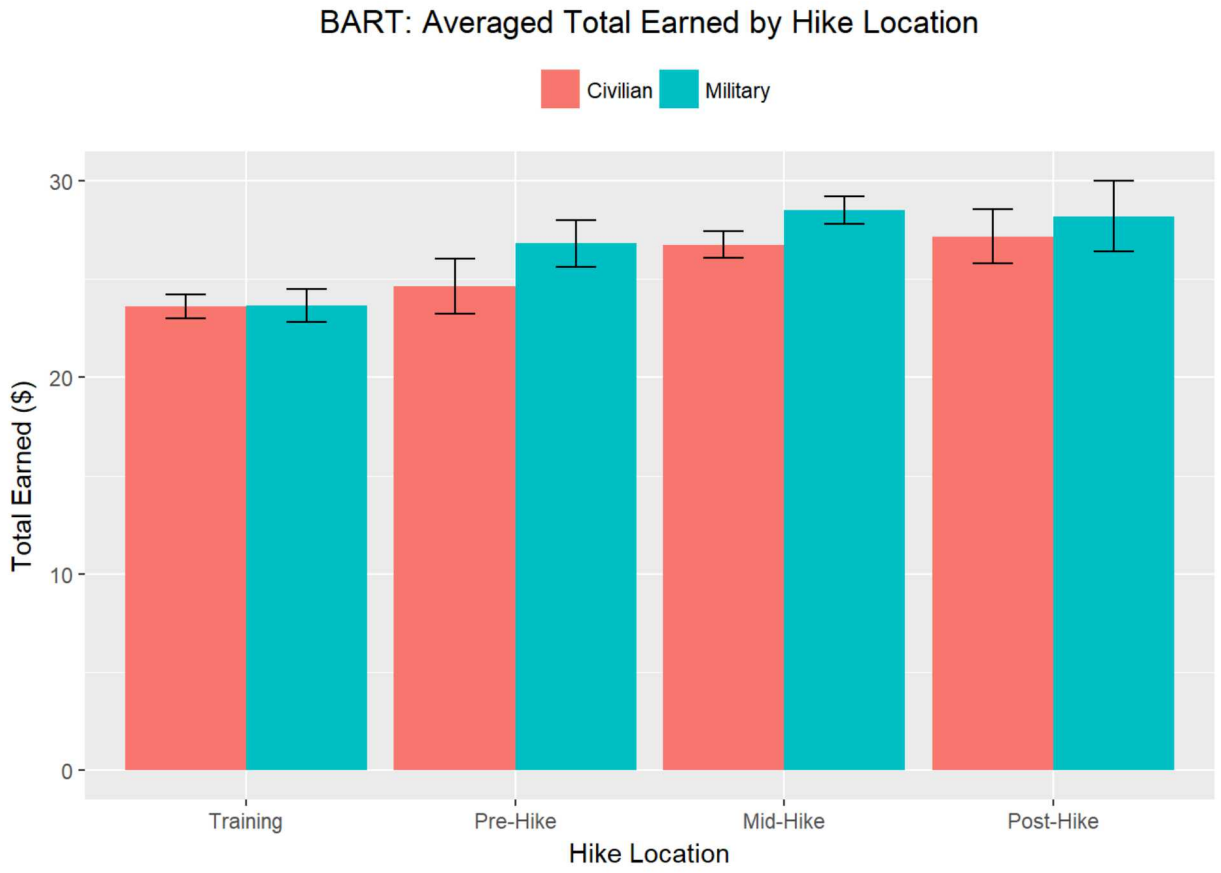

VSTM Score by Hike Location
VSTM Score (Accuracy)
1.0
0.9
0.8
0.7
0.6
0.5
Training
Pre-Hike
Mid-Hike
Post-Hike
Hike Location


VSTM Score by Hike Location
Civilian
Military
VSTM Score (Accuracy)
1.0
0.9
0.8
0.7
0.6
0.5
Training
Pre-Hike
Mid-Hike
Post-Hike
Hike Location

Cognitive Assessments – BART



BART

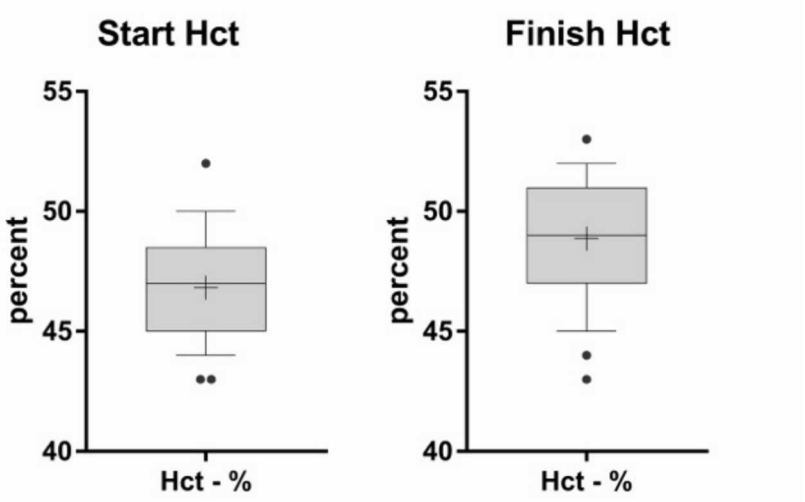


More risks are taken throughout the course of the hike.

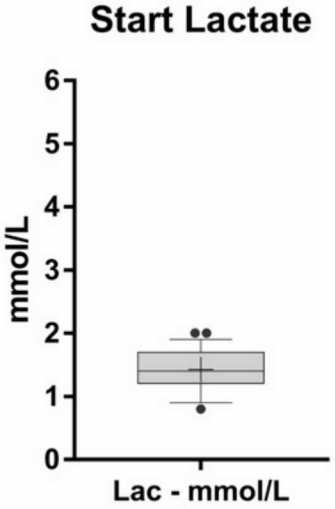
Blood Data

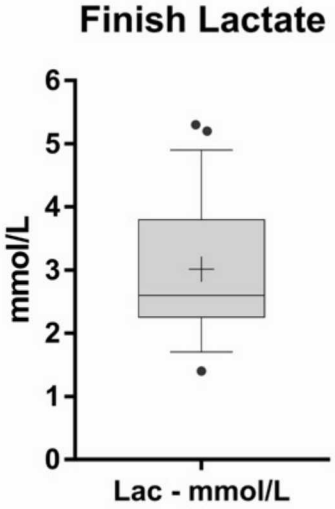
- Creatine Kinase (CK)
  - An enzyme used as a marker for muscle damage
  - Used to detect various health events such as myocardial infarction or rhabdomyolysis.
- Hematocrit
  - Measure of % of red blood cells
  - One of the best measures of dehydration
- Blood lactate
  - Lactic acid in the blood is linked to deficient oxygen to tissue during high levels of activity
  - Can be used as a measure of muscle breakdown
- pCO_2 – partial pressure of carbon dioxide in blood
  - Can be used to understand respiration rate
  - Decrease can be caused by hypoxia and hyperventilation
- pH
  - Blood is modulated around 7.4
  - Changes can result from respiration changes and lactate

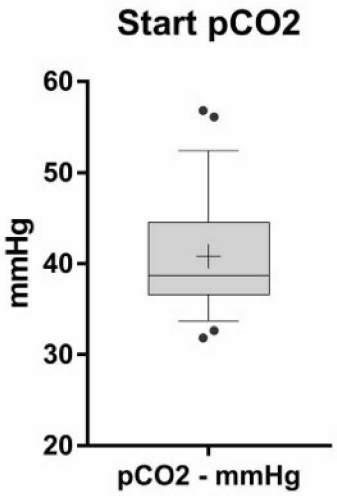
Blood Data

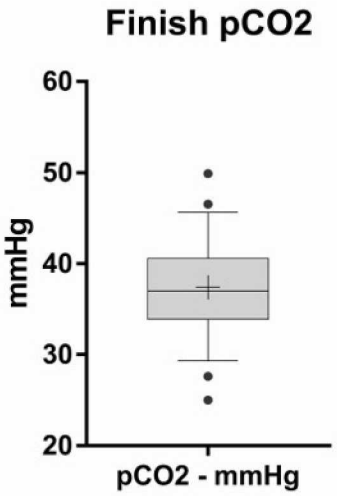

Start Hct
percent
55
50
45
40
Hct - %

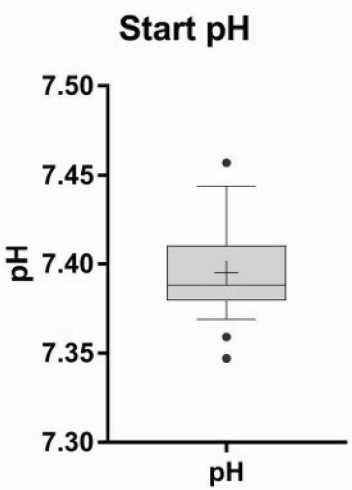
Finish Hct
percent
55
50
45
40
Hct - %

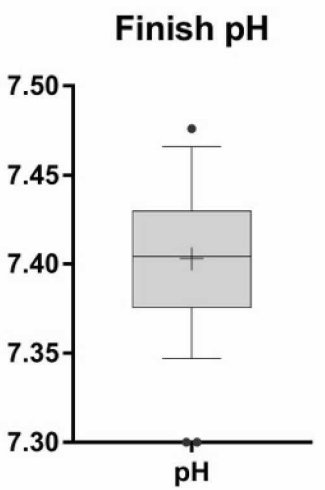

Start Lactate
mmol/L
6
5
4
3
2
1
0
Lac - mmol/L


Finish Lactate
mmol/L
6
5
4
3
2
1
0
Lac - mmol/L

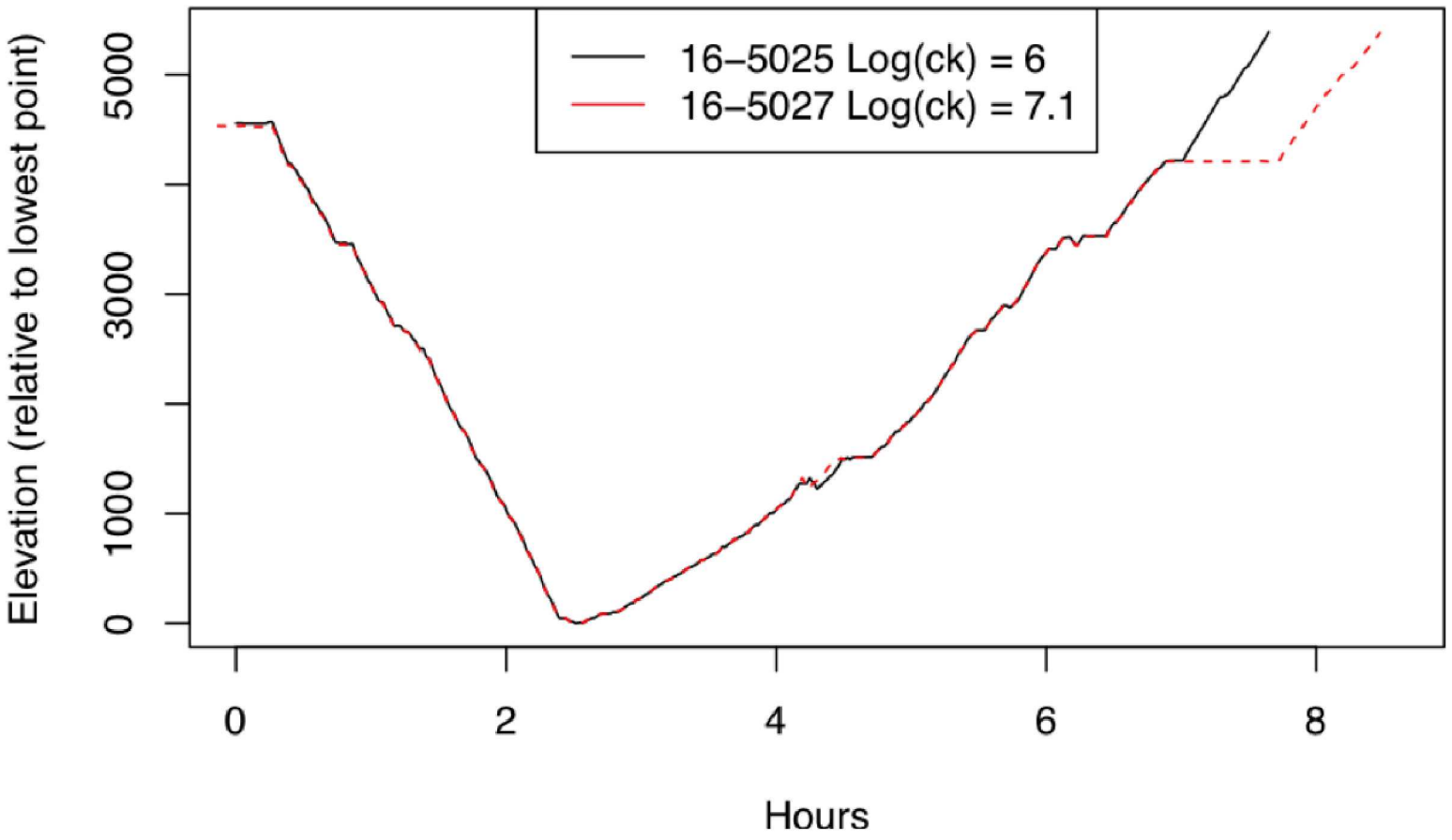

Start pCO2
mmHg
60
50
40
30
20
pCO2 - mmHg


Finish pCO2
mmHg
60
50
40
30
20
pCO2 - mmHg

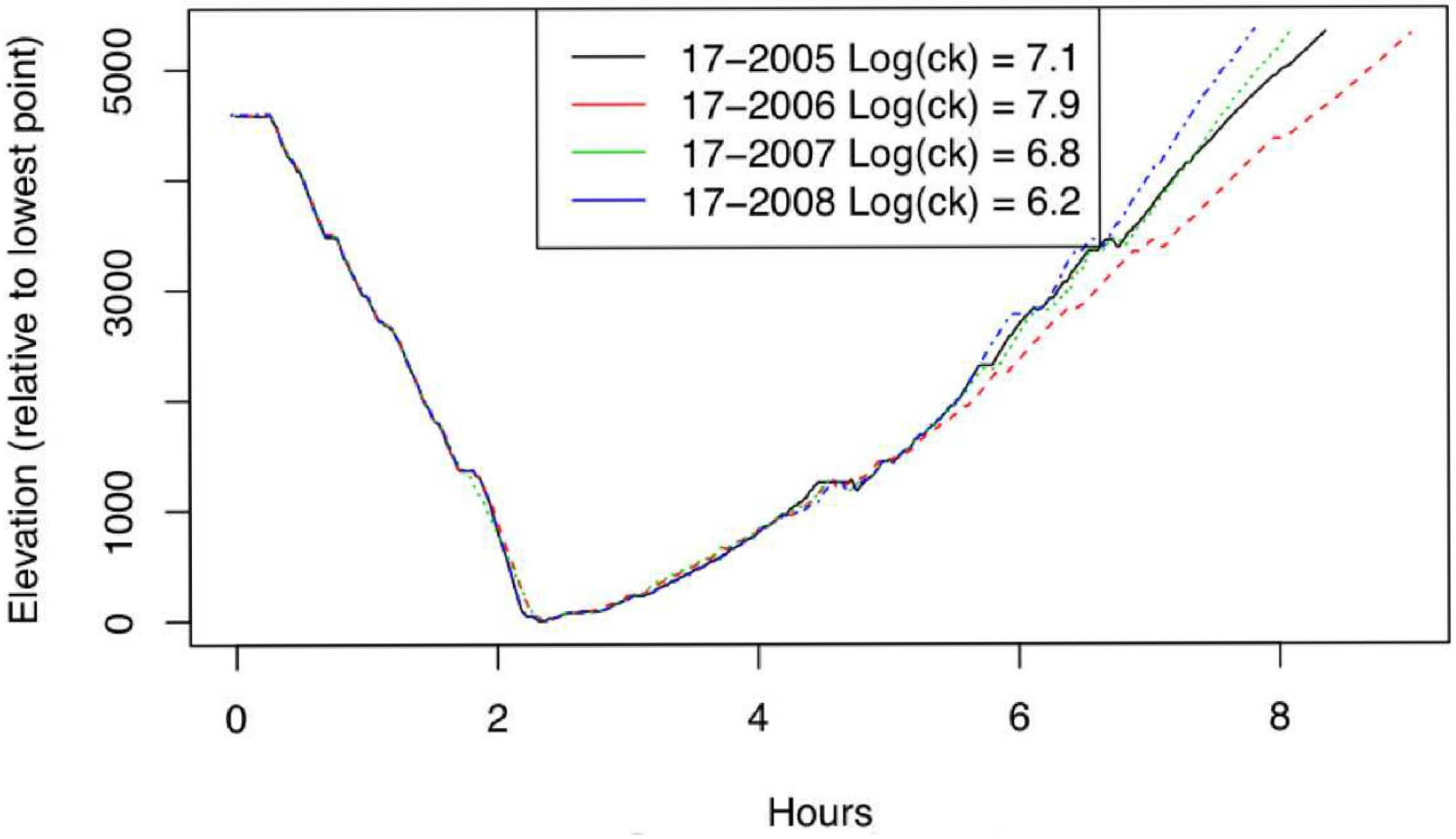

Start pH
pH
7.50
7.45
7.40
7.35
7.30
pH


Finish pH
pH
7.50
7.45
7.40
7.35
7.30
pH

Identifying "Droppers"



Identifying "Droppers"



Wearables at the Z-Machine (WAZE)

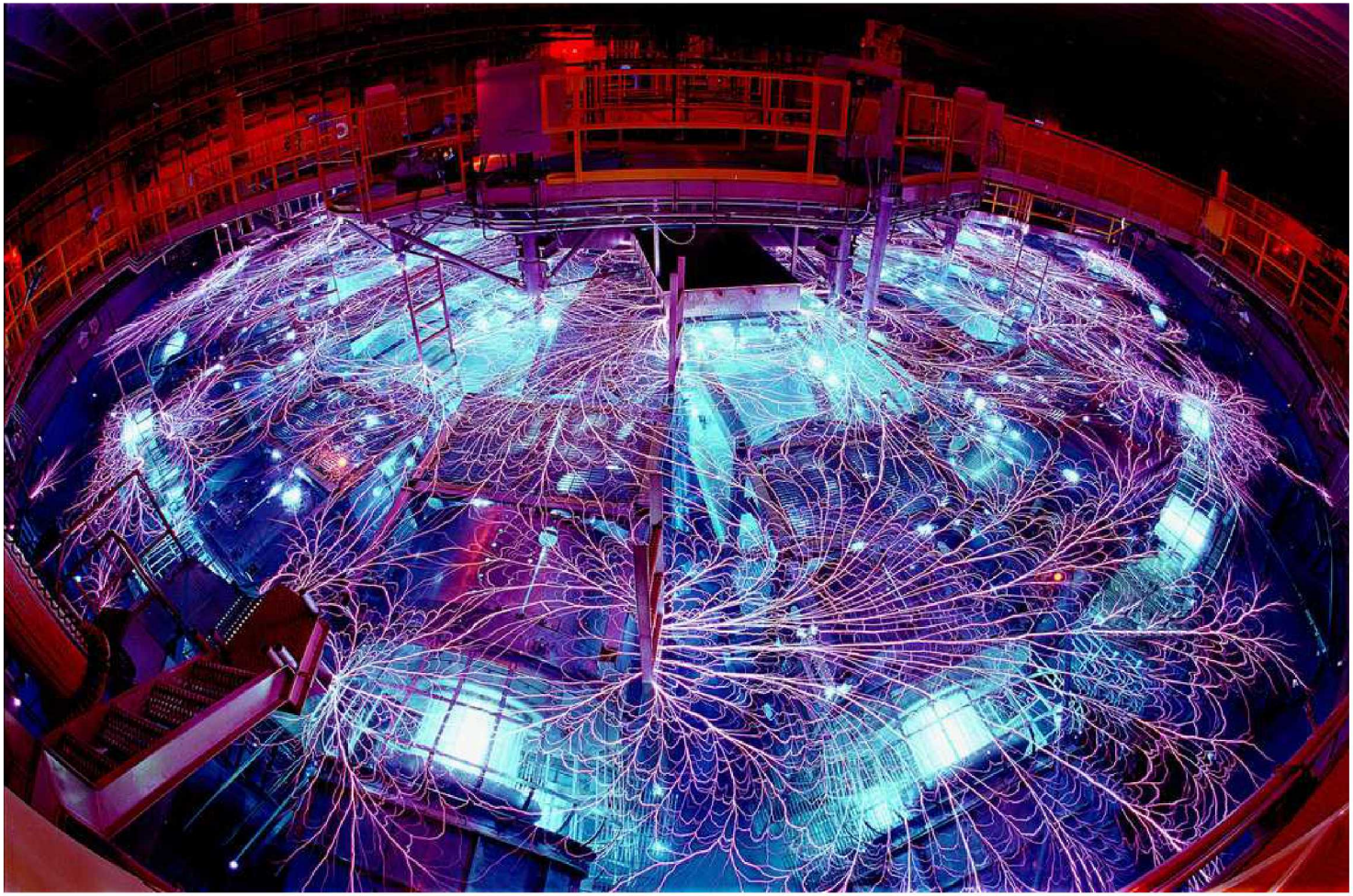


Photo Credit: Randy Montoya

Photo Credit: Randy Montoya

Additional Considerations for WAZE

- Observations
- Sleep journals
- More environmental condition measures
- No blood draw
- Activity logs
  - Including task and equipment & PPE used

Conclusions

- Several data streams are necessary to predict health events. It is difficult to do it in real-time.
- Individual variability is key to understand – outliers can often reveal interesting insights.
- Fatigue is not just physical – you can also observe cognitive decline.
- COTS devices are good enough to use for fatigue analysis and performance prediction, but not all are created equally.
- You must understand the nature of the task as much as possible before you can start to apply a research paradigm.

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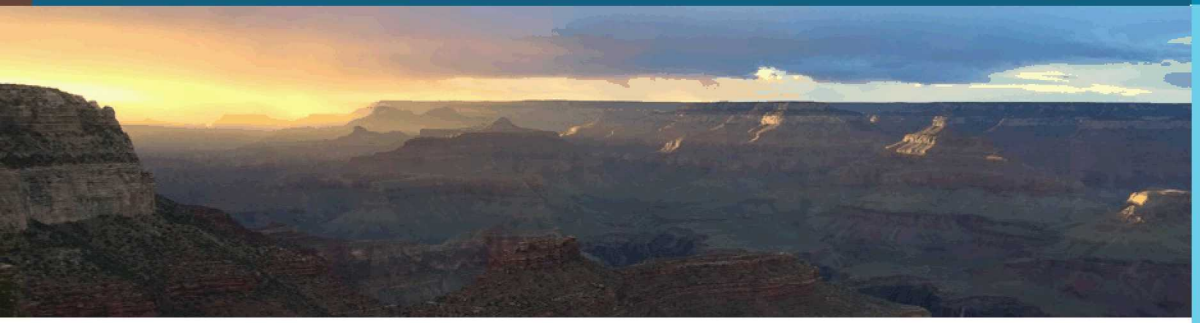

PRESENTED BY

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