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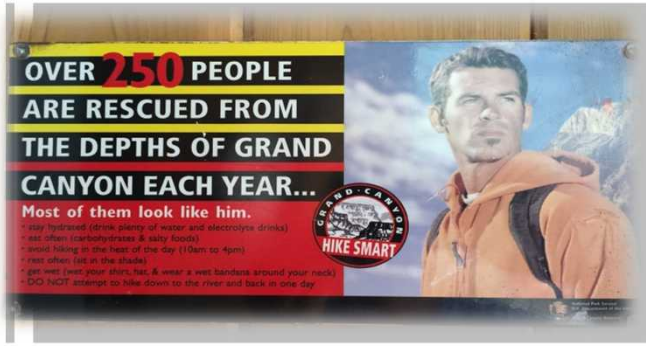

RIM-TO-RIM WEARABLES AT THE CANYON FOR HEALTH
R2R WATCH STUDY

Wearables At The Canyon for Health (WATCH)

Principal Investigator: Glory Aviña, PhD MBA

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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Introduction

- Subjects hike Grand Canyon wearing various wearable fitness devices that monitor physical activity
- Subjects take cognitive tests intermittently during hike
- Metabolic panel + demographic data collected before and after hike
- Two cohorts
  - Civilian volunteers
  - Military personnel

Purpose of this Study

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

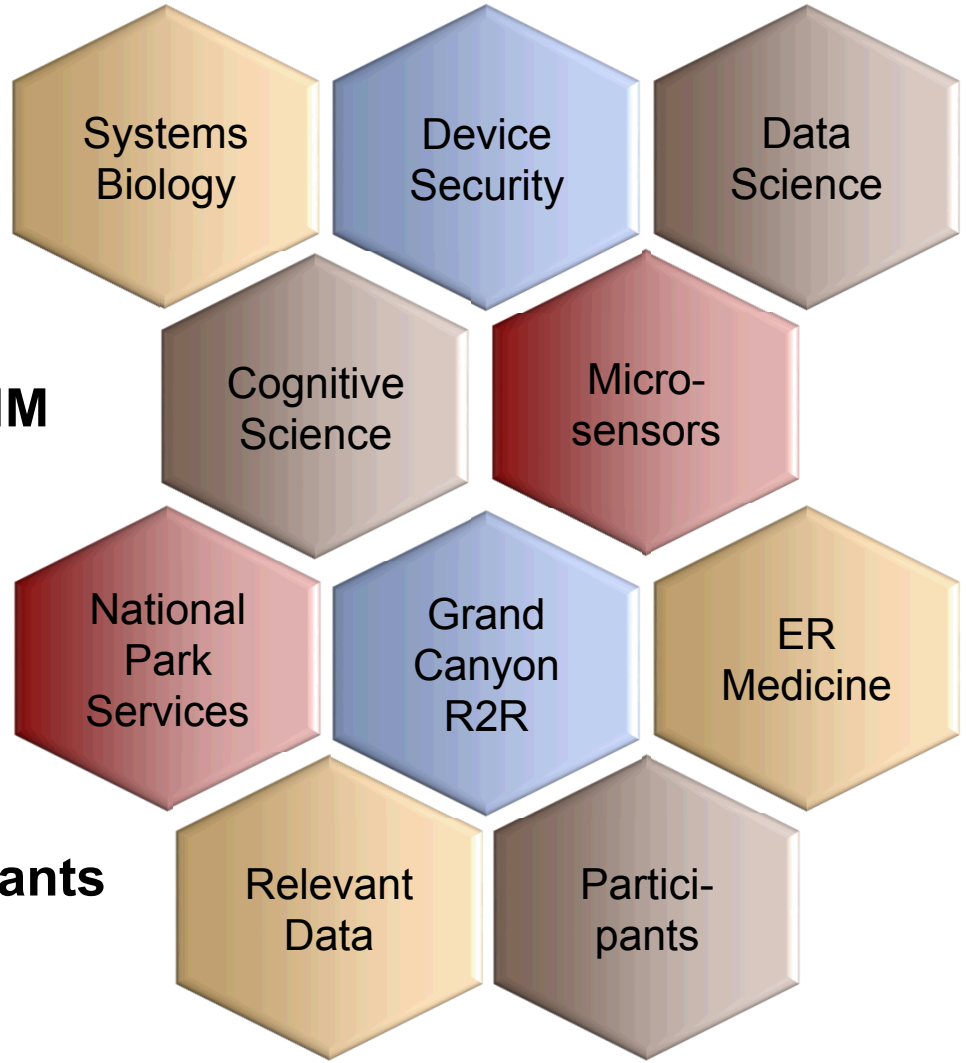
2) **Wearable Devices:**
   identify which COTS wearable devices are best for measurement and in rugged environments

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

Experimental Design

Proposed 3 year project

Interdisciplinary Approach



Sandia- CA

Sandia- NM

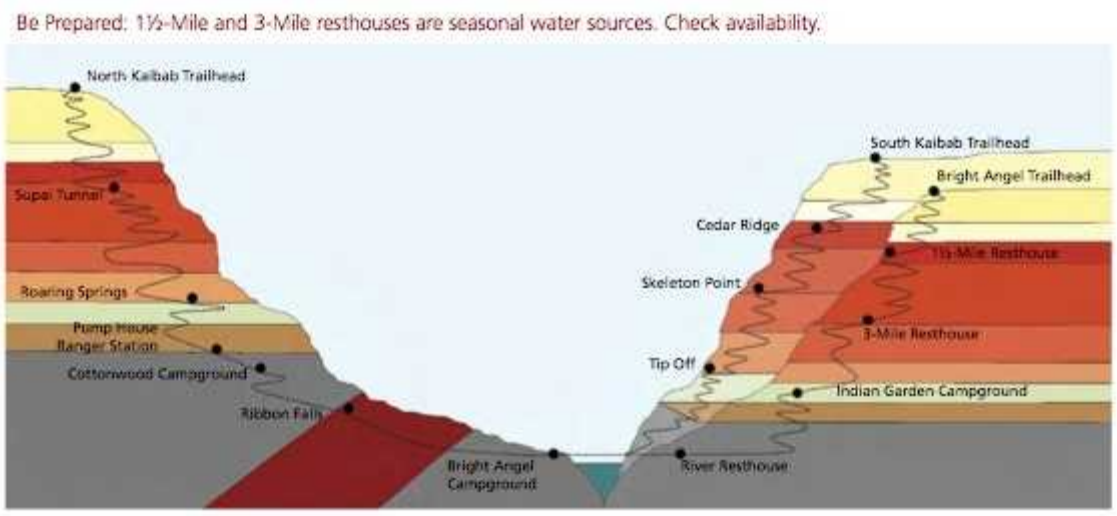
University of New Mexico

Military Participants

Grand Canyon Rim-2-Rim Hike

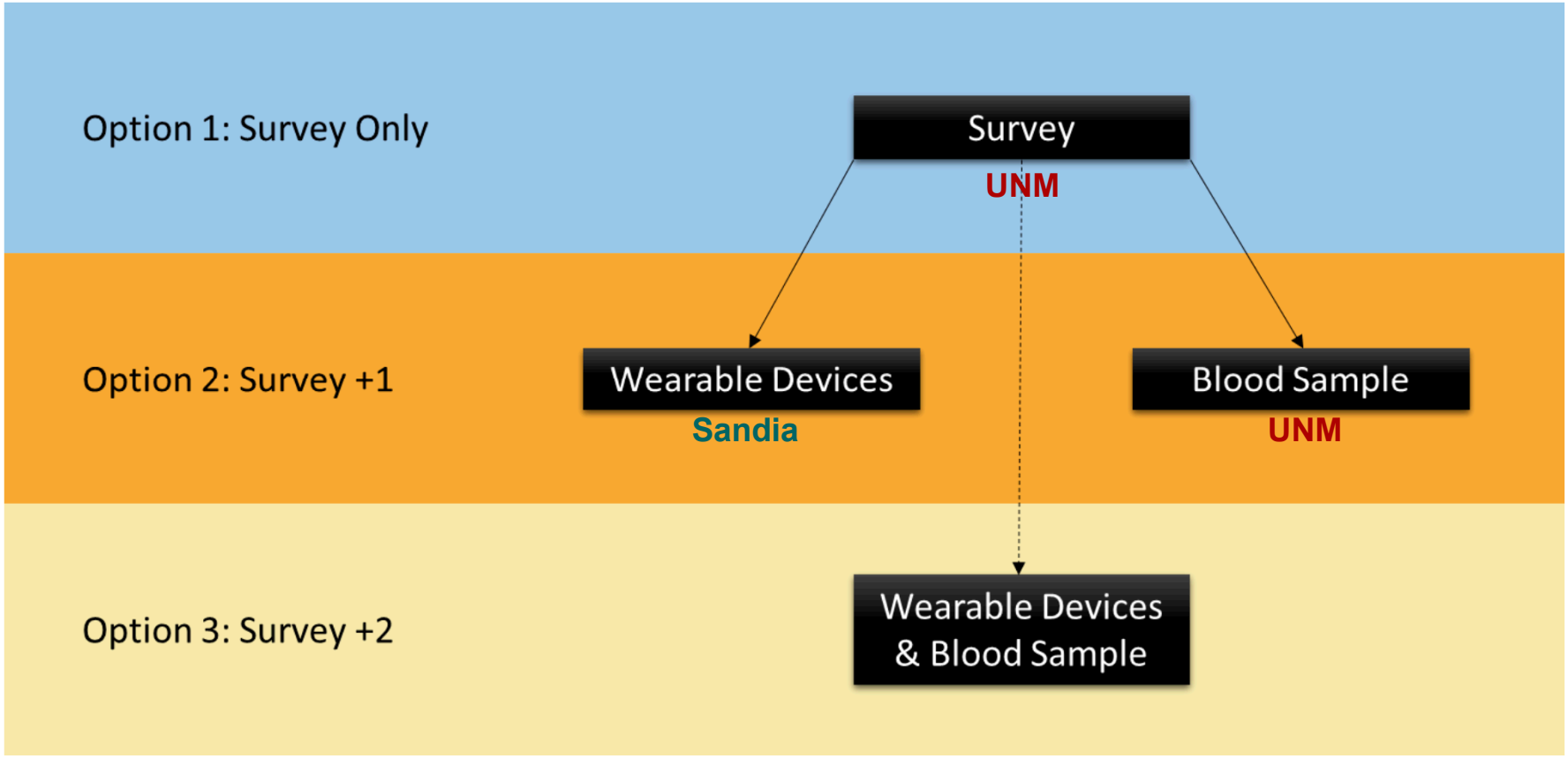
- Altitude and Temperature Change
- Extreme Environment
- Physical Strain
- 14.3 miles, 6,000 feet to the bottom
- 9.6 miles, 4,500 feet back to the South Rim

Figure 1. Signage at Bright Angel Trailhead, October 2015.



Source: https://www.nps.gov/grca/index.htm

Three tiers for R2R WATCH



Collecting Physiological and Cognitive Data

Sandia National Laboratories

Package	Cognitve Tests	GPS	Elevation	Heart rate (ECG)	Heart rate (Wrist)	Heart rate (Forehead)	Cadence (Wrist)	Cadence (Torso)	Temperature (Ambient)	Temperature (Direct Sun)	Temperature (Skin)	Humidity	Total	Qty
Advanced 1	iPod Touch 6	Fenix 3 HR	Fenix 3 HR	Wahoo TickrX	Fenix 3 HR	LifeBeam SmartHat	Fenix 3 HR	Wahoo TickrX	SensorPush	SensorPush	Tempe	SensorPush	**$1,115**	10
Advanced 2	iPod Touch 6	Spartan Ultra	Spartan Ultra	Smart Sensor	(None)	LifeBeam SmartHat	Spartan Ultra	(None)	SensorPush	SensorPush	(None)	SensorPush	**$1,165**	10
Basic 1	iPod Touch 6	Vivoactive HR	Vivoactive HR	(None)	Vivoactive HR	(None)	Vivoactive HR	(None)	SensorPush	(None)	(None)	SensorPush	**$515**	35
Basic 2	iPod Touch 6	eTrex 10 + 2AA	(None - 'floors')	(None)	Fitbit Charge HR	(None)	Fitbit Charge HR	(None)	SensorPush	(None)	(None)	SensorPush	**$485**	15

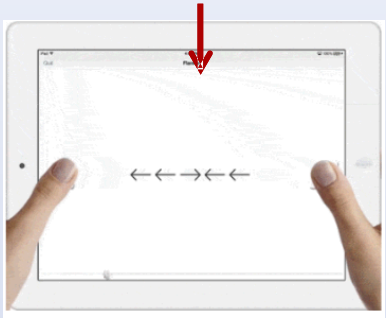
Continuous Variables Collected

Sandia National Laboratories

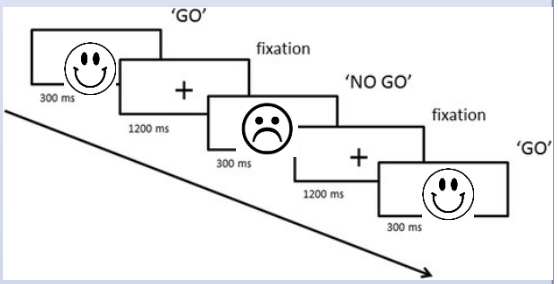
- Heart rate
- Heart rate variability (new to May 2017 data collection)
- Breathing rate (new to Oct 2017 data collection)
- GPS position
- Cadence
- Elevation
- Temperature (ambient + skin)
- Relative humidity
- Cognitive tests

Collecting Physiological and Cognitive Data

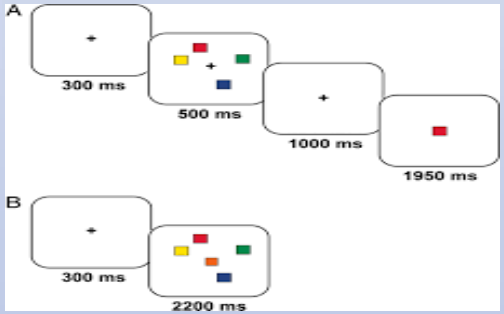
Flanker



Go/No-go



VSTM



Brain Baseline

- Attentional Blink
- Digit Span
- Digit Symbol Substitution
- Flanker
- N-Back
- Go/No-Go
- Posner Cueing
- Speed
- Spatial Working Memory
- Stroop
- Task Switching
- Trails A & B
- Visual Search
- Visual Short-Term Memory

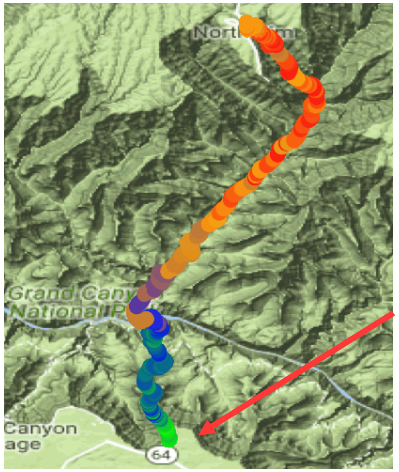
PRELIMINARY RESULTS
OCT 2016 + MAY 2017

(Data collected for Oct 2017)

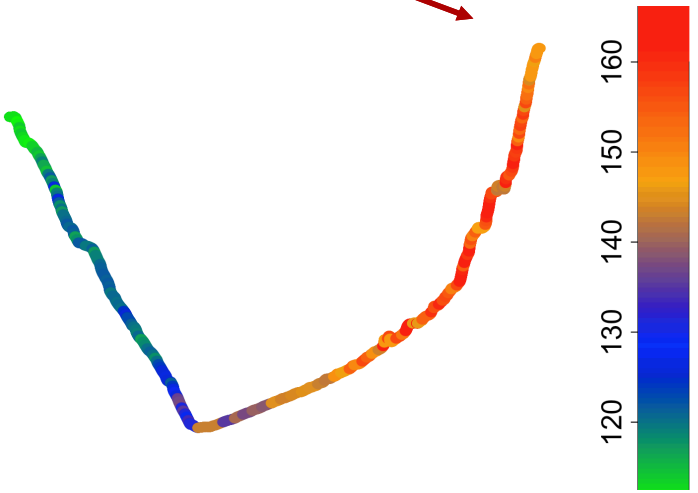
Intensity of Hike

Average Heart Rate (military)

North Rim (finish)



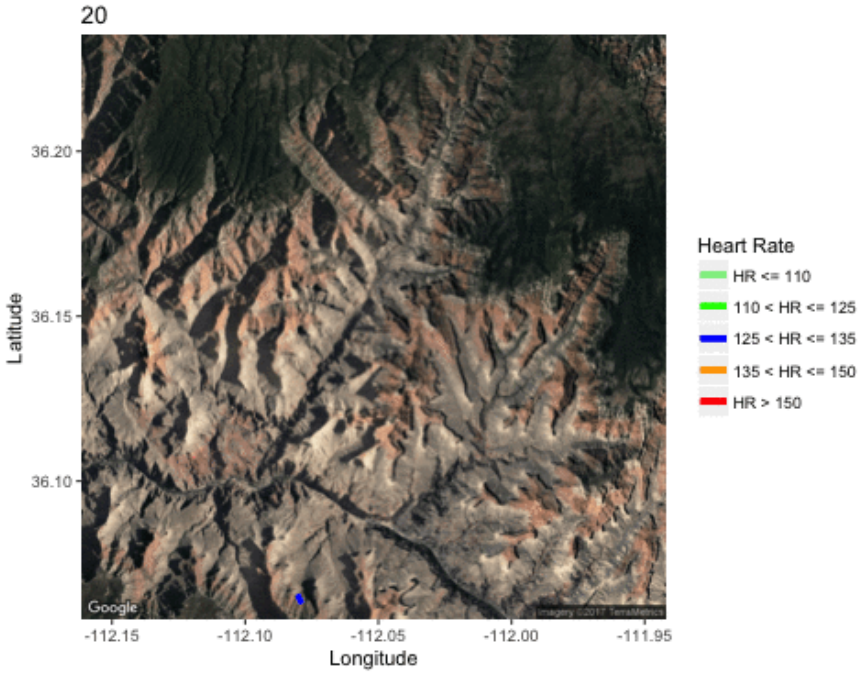
South Kaibab (start)



By GPS coordinates

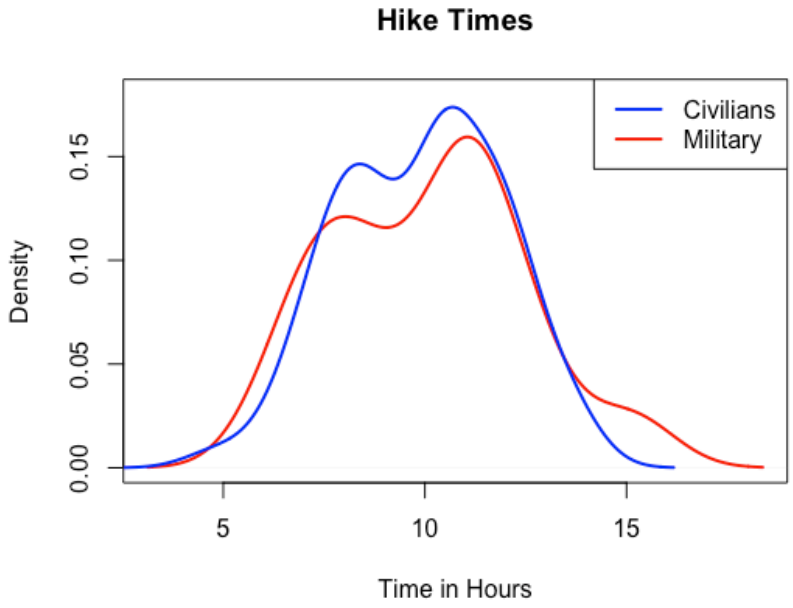
By elevation

Heart Rates: Side by Side Samples



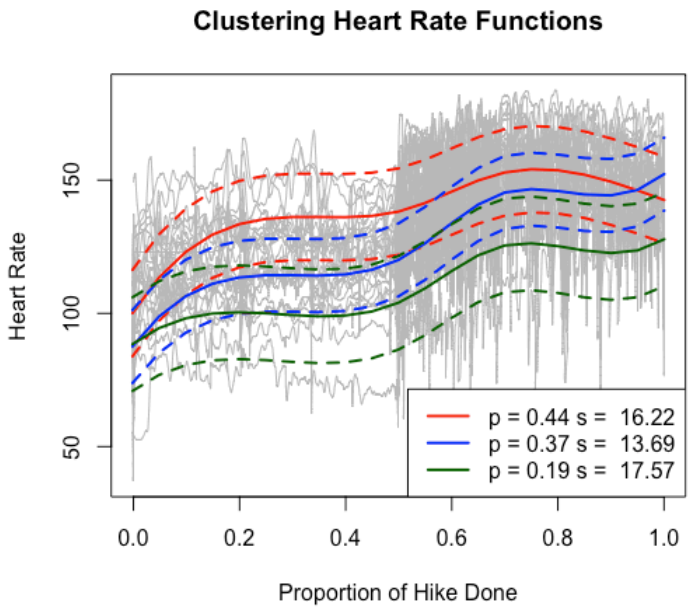
(Longitude shifted for visibility)

Distribution of Hike Times



- Distribution of hike times very similar between two groups
- Hypothesis for bimodality: competitive and leisure hikers

Functional Clustering of Heart Rate



Hypotheses suggested from clustering:

1. At least two distinct profiles:
    - All out from beginning (red)
    - More leisurely (blue + green)
2. All out group working hard throughout entire hike
3. Leisure group not working hard on descent but almost as hard on ascent

Military vs Civilian: Cognitive Differences

First Test		Military	Civilian
Go/No-go:	Time	527 ms (sd = 66)	554 ms (sd = 87)
	Accuracy	0.964 (sd = 0.061)	0.957 (sd = 0.070)
Flanker:	Time	594 ms (sd = 109)	592 ms (sd = 98)
	Accuracy	0.935 (sd = 0.140)	0.943 (sd = 0.107)
VSTM:	Time	1012 ms (sd = 206)	1139 ms (sd = 309)
	Accuracy	0.779 (sd = 0.082)	0.732 (sd = 0.093)
Last Test		**Military**	**Civilian**
Go/No-go:	Time	488 ms (sd = 92)	530 ms (sd = 71)
	Accuracy	0.940 (sd = 0.060)	0.949 (0.070)
Flanker:	Time	496 ms (sd = 64)	559 ms (sd = 71)
	Accuracy	0.975 (sd = 0.026)	0.956 (sd = 0.098)
VSTM:	Time	978 ms (sd = 411)	1088 (sd = 343)
	Accuracy	0.779 (sd = 0.082)	0.702 (sd = 0.106)

Military performed better in 10 / 12 measures

Military's advantage increased in later trials, especially with response time: Could be less fatigue or better learning

Cognitive-HR Connection to examine fatigue

- Goal of Model: validate that BrainBaseline captures fatigue effect
- Take advantage of structure of experiment for robust measures
  - Know subjects start experiencing light fatigue hiking down the Canyon, heavy fatigue hiking back up the Canyon
  - Capture this in two variables: Percent descended, percent ascended
- Important to validate, but results do not extend to a non-controlled environment

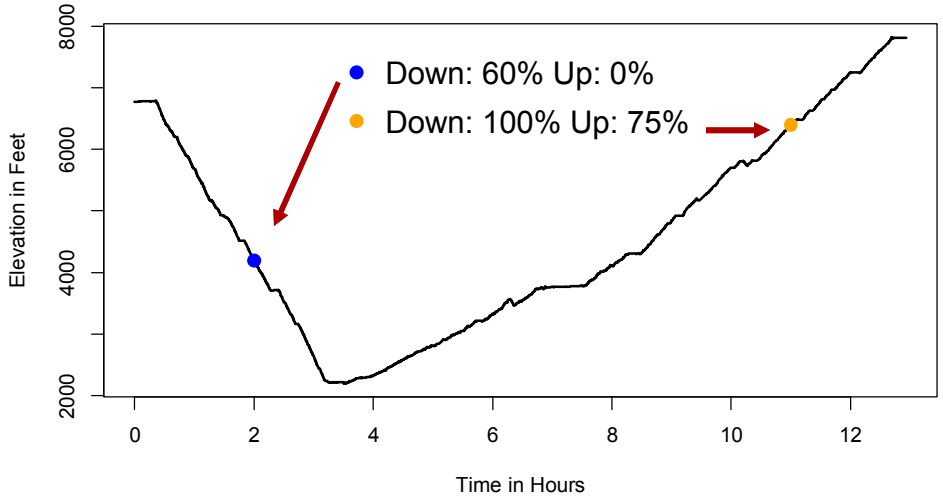


Table 2.

Estimated Effects on Response Time			
	Estimate	95% CI	P value
Flanker-congruent: Proportion up	72.1	(23.7, 120.6)	0.004
Flanker-congruent: Proportion down	-8.0	(-69.1, 53.1)	0.797
Flanker-incongruent: Proportion up	49.8	(-8.2, 107.9)	0.093
Flanker-incongruent: Proportion down	6.5	(-67.7, 80.8)	0.863
Go/no-go: Proportion up	27.7	(-23.6, 78.9)	0.290
Go/no-go: Proportion down	32.9	(-22.7, 88.5)	0.247
VSTM: Proportion up	206.8	(10.8, 402.9)	0.039
VSTM: Proportion down	225.2	(-33, 483.4)	0.087

Response time effects for the cognitive battery as a function of proportion up and down the canyon.

Table 3.

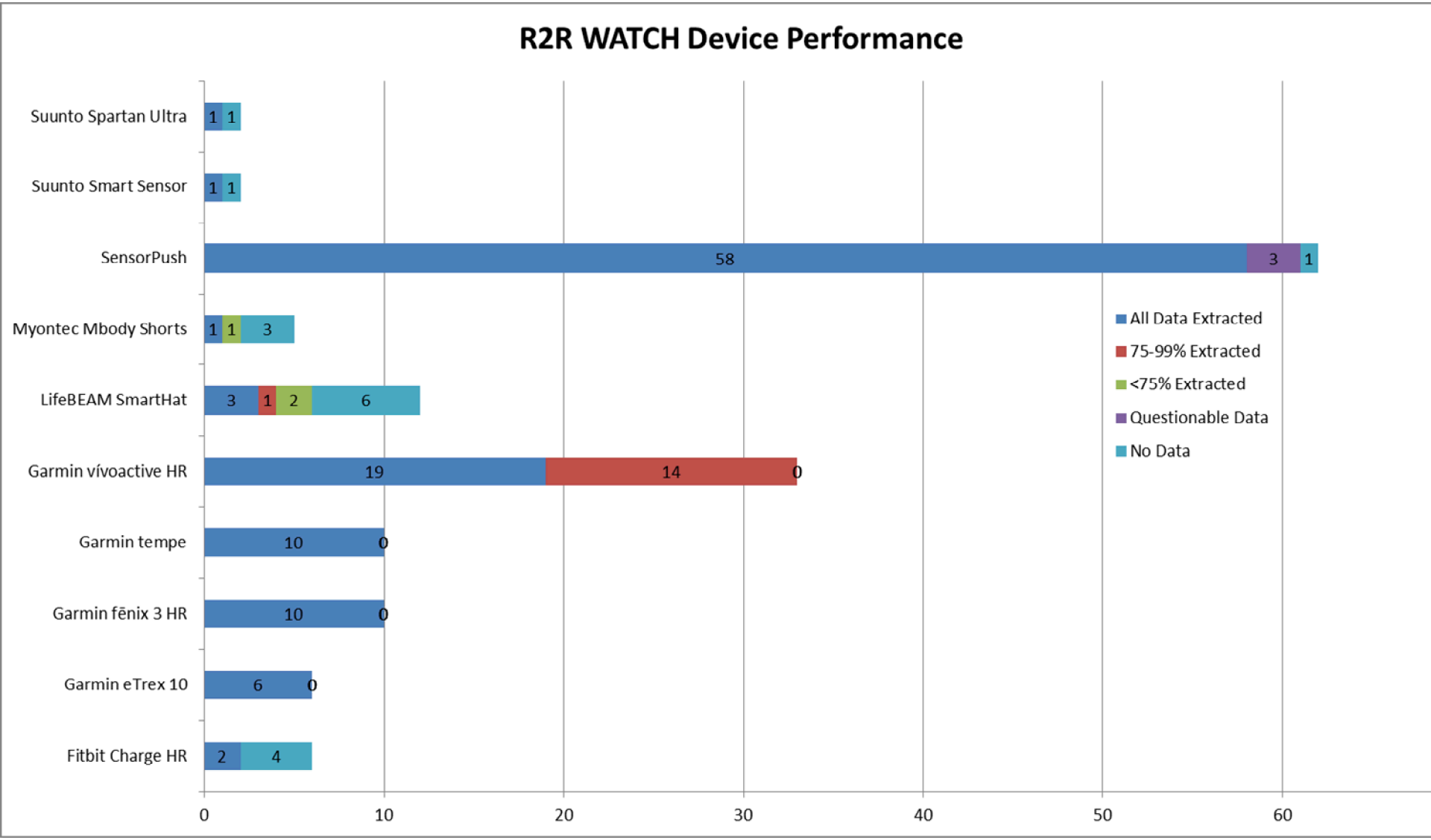
Estimated Effects on Accuracy			
	Estimate	95% CI	P value
Flanker: Proportion up	-0.003	(-0.052, 0.046)	0.9102
Flanker: Proportion down	-0.002	(-0.067, 0.063)	0.9562
Go/no-go: Proportion up	-0.047	(-0.088, -0.007)	0.0229
Go/no-go: Proportion down	-0.030	(-0.074, 0.015)	0.1878
VSTM: Proportion up	-0.124	(-0.184, -0.064)	0.0001
VSTM: Proportion down	-0.098	(-0.178, -0.019)	0.0155

Accuracy effects for the cognitive battery as a function of proportion up and down the canyon.

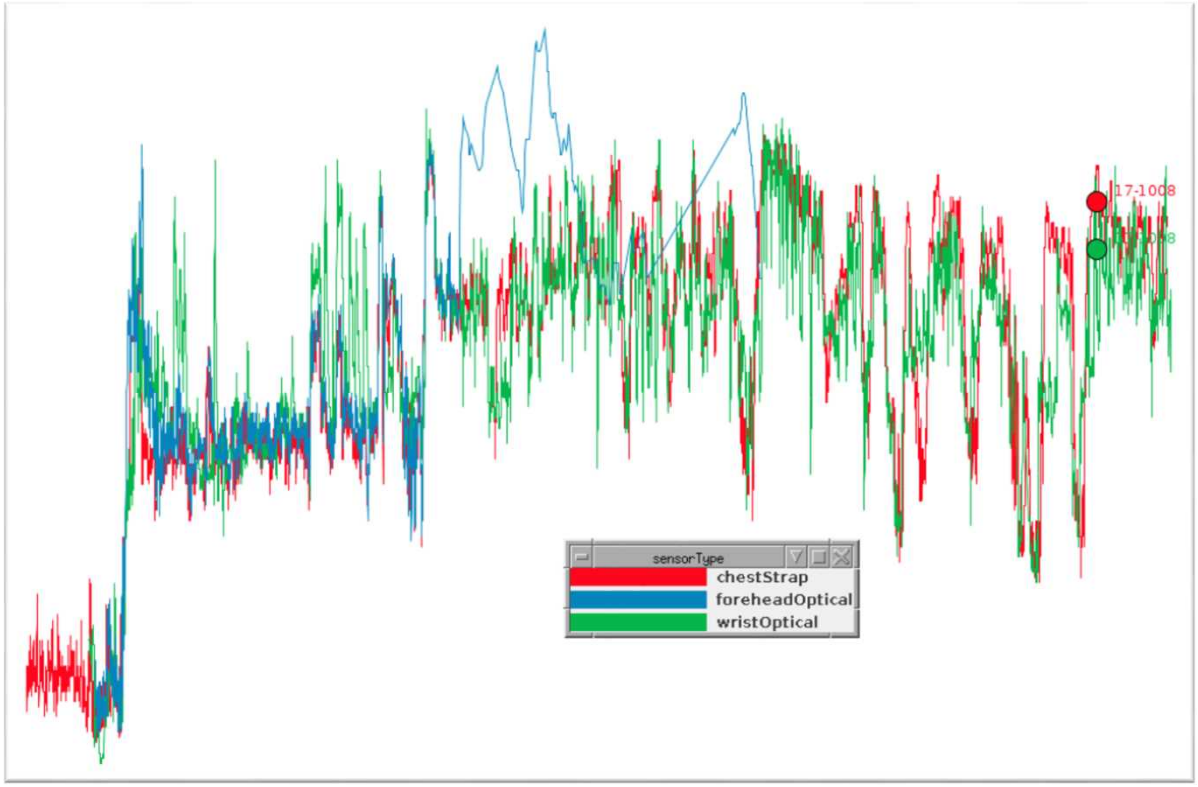
Hypotheses

- Fatigue would have a positive effect on response time (increase)
- Fatigue would have a negative effect on accuracy (decrease)
- In 13/14 estimated effects, this trend was observed (p-value from sign test: 0.0009).
- **Brain Baseline scores decline as fatigue increases**
- **Still would like to sharpen signal**

Overall Device Performance

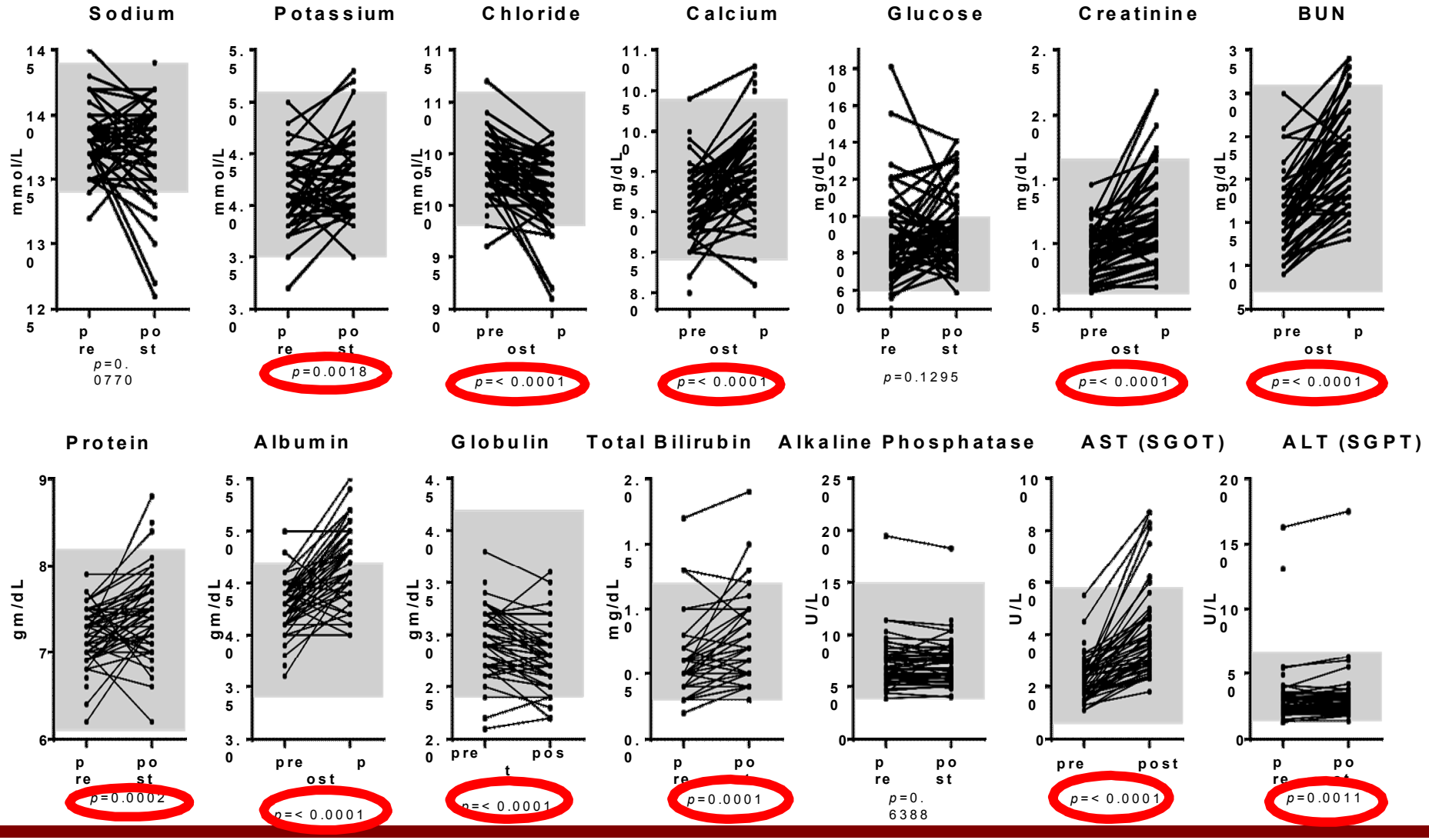


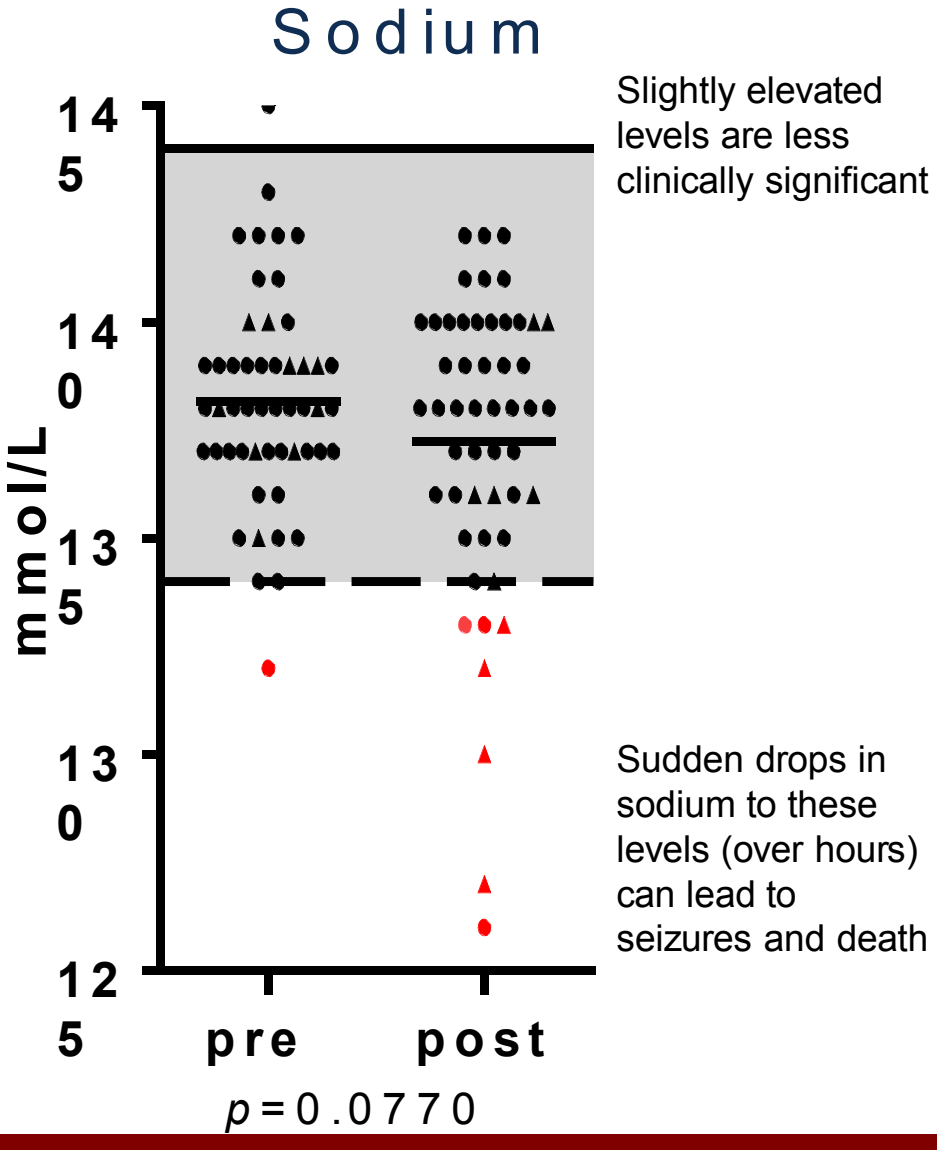
Example of Heart Rate Full Capture



- Forehead Optical starts well, but then drifts, then disappears. This is typical.
- Wrist optical is consistently fairly close but biased low. This is also typical.

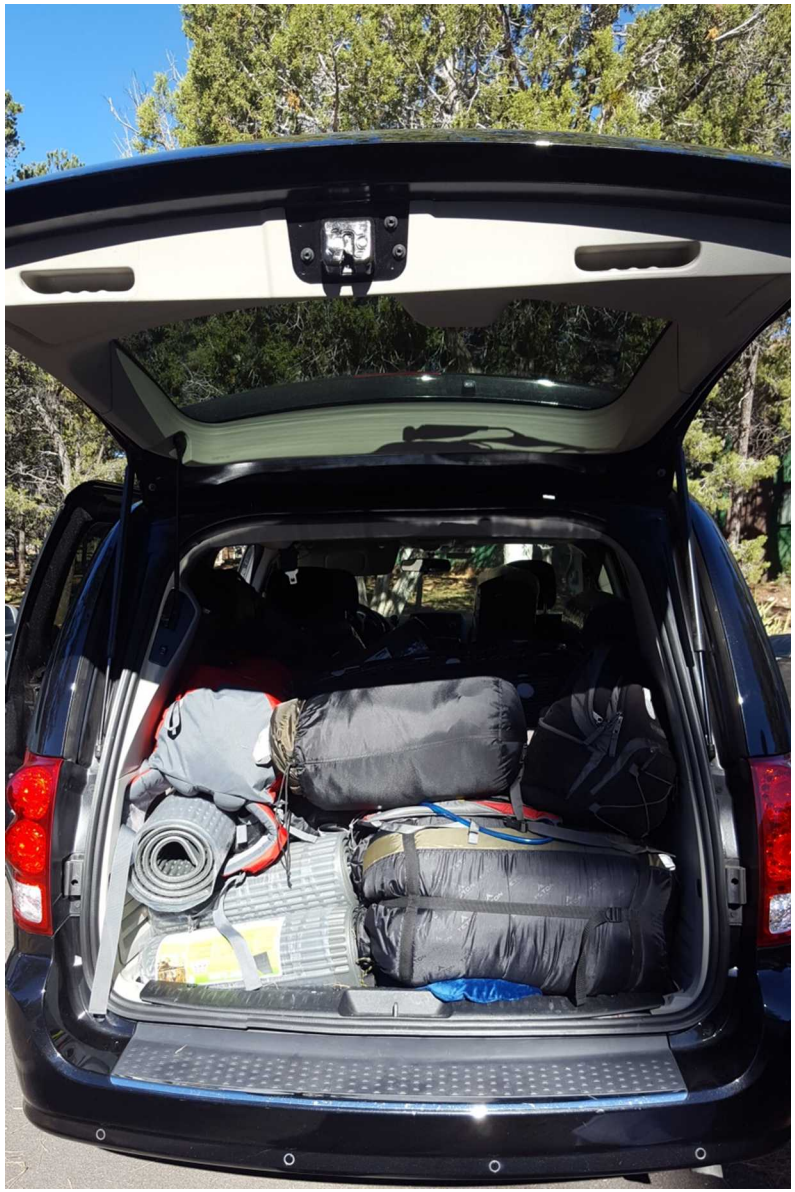
Complete Metabolic Panel: Before and After





Sodium levels did not change significantly as a population. This is in part because half of the subjects sodium concentrations increased, while the other half decreased. This is has important implications as decreases in sodium can lead to catastrophic outcomes including seizure, coma, and death. In less severe cases it can lead to nausea and declines in performance.

Previous literature implicates human behavioral factors like amounts of food and water ingestion as significant predictors. Molecular mechanisms through Arginine Vasopressin have also been implicated.

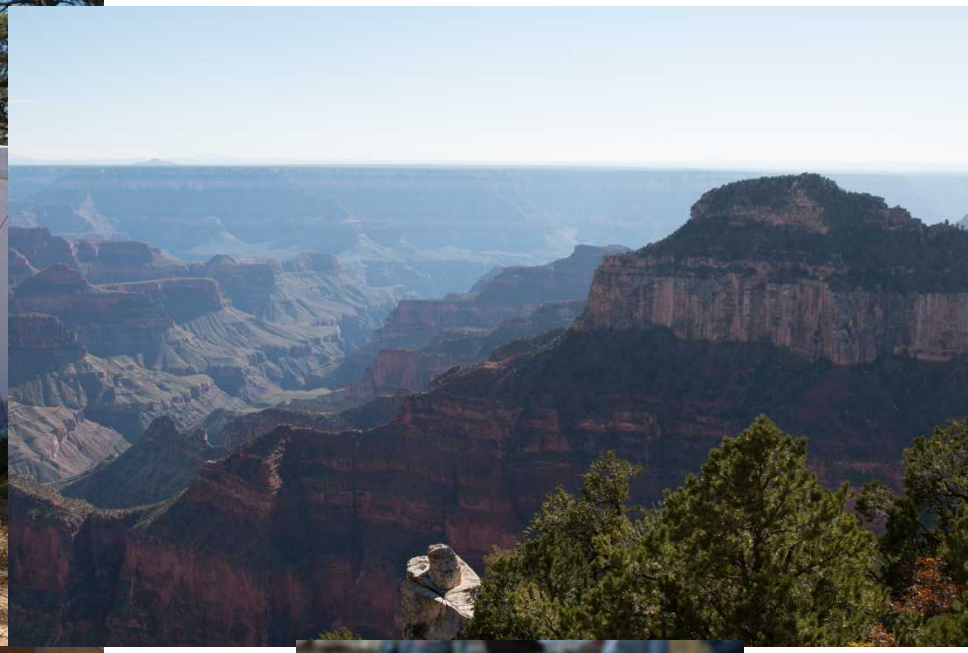


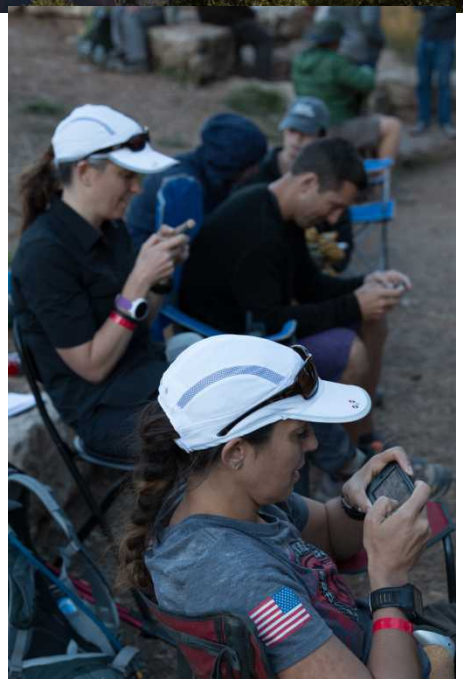
75 wearable devices packages
300+ wearable devices

Sandia National Laboratories Team

The University of New Mexico Emergency Medicine


UNM
GRAND CANYON






Post-Hike Basic Package 1 - per


08:24
26:06:21.53

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

Thank you

- **Glory Emmanuel Aviña,**
  - Principle Investigator
    - 925.294.2478

gremman@sandia.gov

Clifford Anderson-Bergman,
Lead statistician/Acting PI
925.294.4665
ciande@sandia.gov

Catherine Branda,
Program Manager
925.294.6833
cbranda@sandia.gov

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