WEARABLES FOR PHYSICAL AND COGNITIVE PERFORMANCE MEASURES

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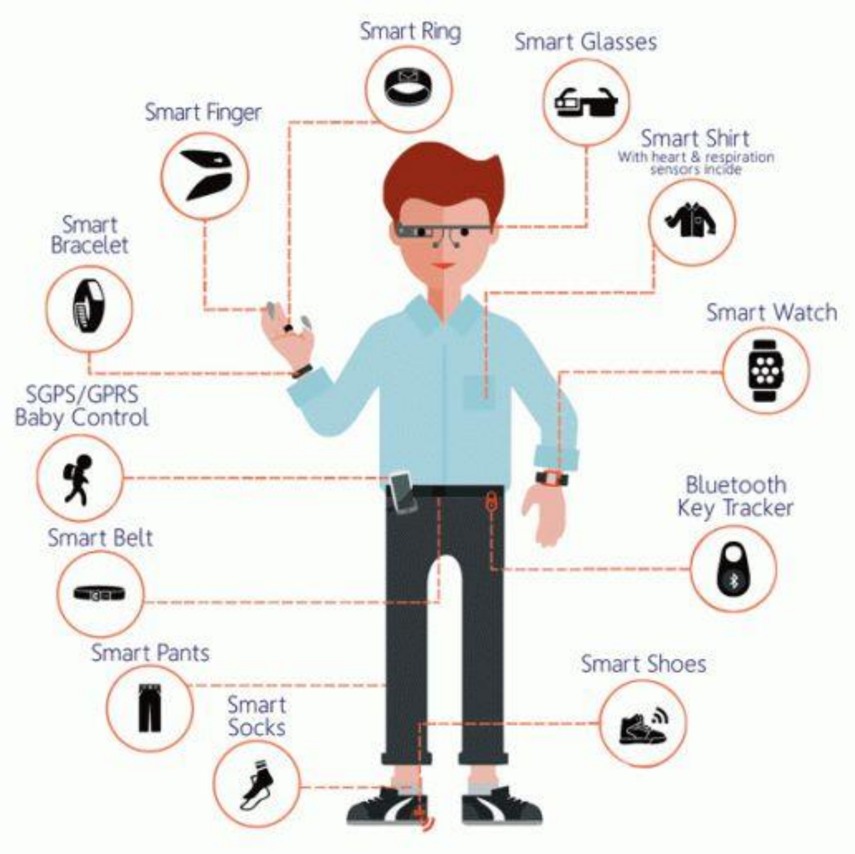
EVOLVING DEFINITION OF WEARABLES

- "**an item** that can be worn."

- "an **advanced electronic device** that is incorporated into an accessory worn on the body or an item of clothing"

- "**a category of electronic devices** that can be worn as accessories, embedded in clothing, **implanted** in the user's body, **or even tattooed** on the skin."



MEASURES OF INTEREST

- **Physical measures:**
  - Activity levels over time
    - Accelerometers
    - Inertial Measurement Units (IMUs)
  - Motion Capture:
    - Range of motion
    - Duty cycles
    - Posture
  - Contact forces
  - Metabolic rate (VO_2 and VCO_2)
  - Muscle oxygenation and SpO_2
  - Nutritional status:
    - Glucose
    - Lactate
    - Hydration level

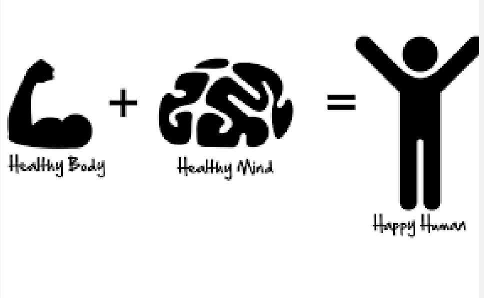
- **Psychophysiology measures:**
  - Heart Rate (HR)
  - Heart Rate Variability (HRV)
  - Respiration Rate (RR)
  - Respiratory Sinus Arrhythmia (RSA)
  - Galvanic Skin Response (GSR)
  - Skin Temperature

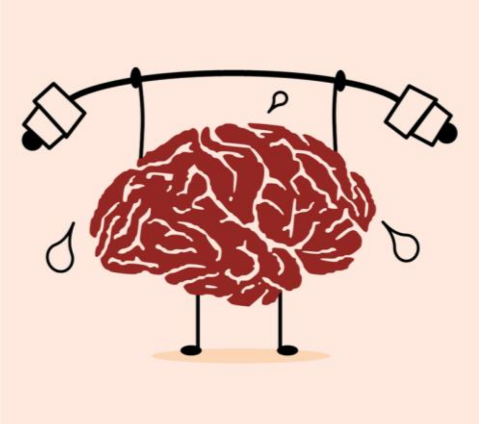
- **Cognitive measures:**
  - Eye Tracking
  - Electroencephalogram (EEG)
  - Functional near-infrared spectroscopy (fNIRS)

PHYSICAL AND COGNITIVE PERFORMANCE OF ASTRONAUTS

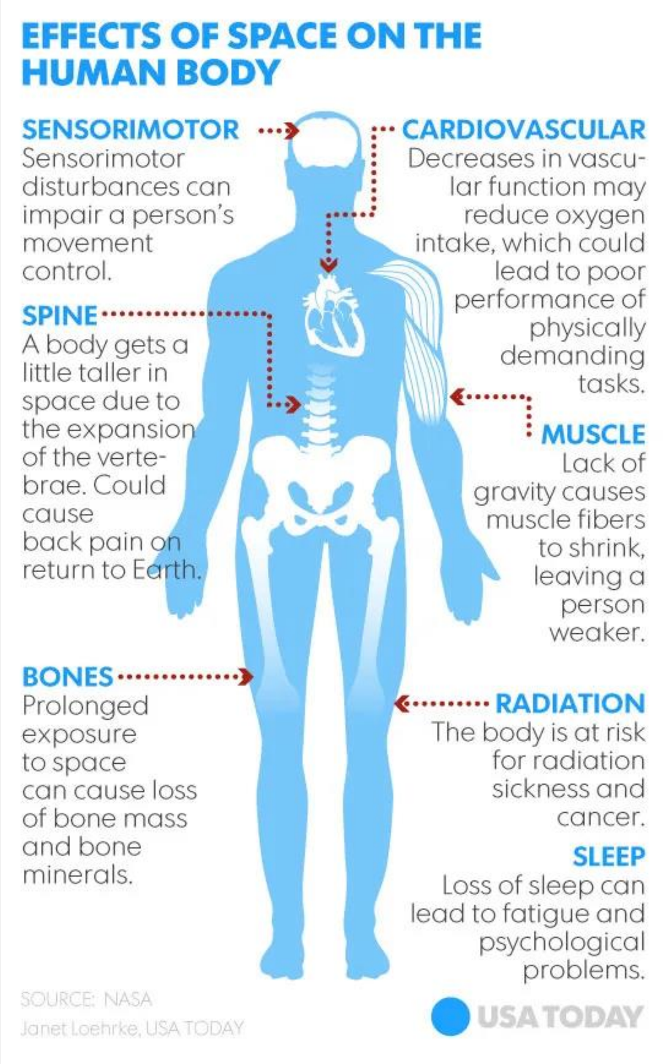
- Exercise Countermeasures
  - To Support and Maintain Physical and Cognitive Health

Muscle and Bone



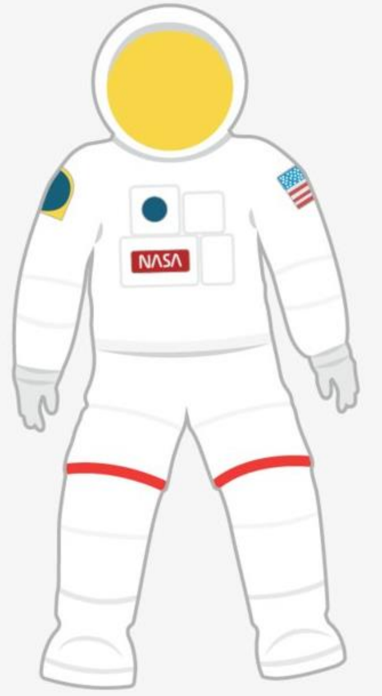


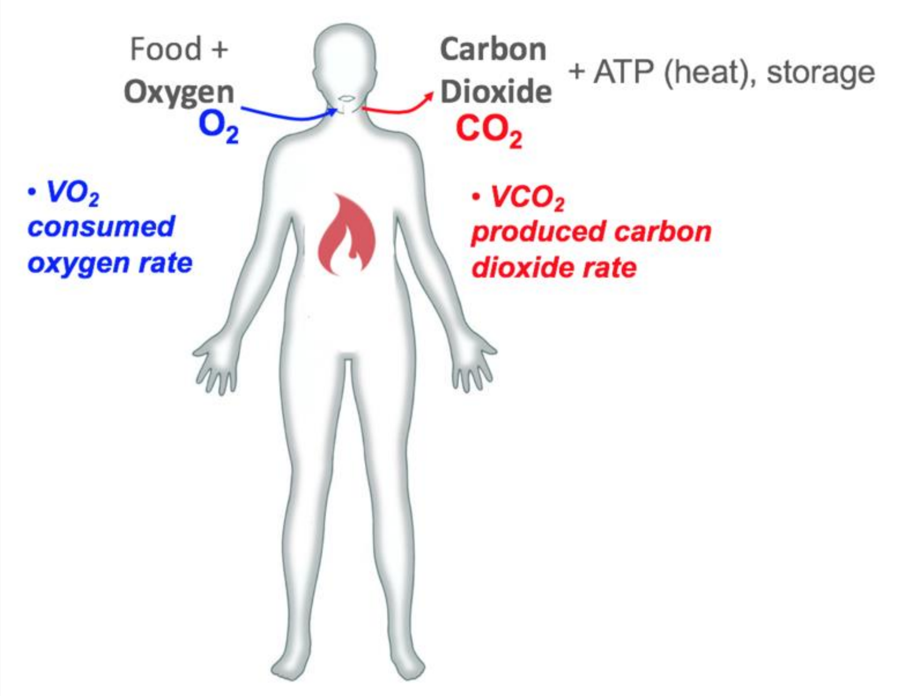
Neurobehavioral



PHYSICAL AND COGNITIVE PERFORMANCE OF ASTRONAUTS

- Extra-Vehicular Activities (EVAs)
  - Working in Spacesuits (limited mobility and limited visibility)
  - Performing Complex, Detailed Procedures for about 6 hours





Physical Work

EV1	EV2
BMRRM WORKSITE SETUP (01:00)	BMRRM WORKSITE SETUP (01:00)
WARNING 1. Verify gauntlets in place prior to translating outboard of SARJ. 2. Sharp edge hazard: Spring-loaded captive EVA fasteners (e.g. 6B boxes, BMRRM, RTAS, SARJ Covers); the end of the spring may protrude.	
1. Translate to green Hook HR ______ 2. Attach green hook 3. Translate to ______ BGA worksite 4. Stow BMRRM Cover on HR _______ with MUT/Ballstack/Scoop 5. Attach large hook of RET from BMRRM Cover tether point to handrail _______ 6. Translate to APFR _________ 7. Retrieve APFR, stow on BRT 8. Translate to WIF ______ 9. Install APFR in WIF ______ [__,__,__,__] ❑ √Locking collar black-on-black ❑ Pull / twist test 10. Perform: ❑ Glove inspection ❑ HAP check	1. Translate to APFR in WIF _______ 2. Stow Crewlock Bag bundle on APFR 3. Retrieve APFR; stow on BRT 4. Translate to green Hook HR ______ 5. Attach green hook **CAUTION** ITT Cannon connector: On demated connectors, do not rotate collar or manipulate cable/connector using collar or connector tool. (i.e. handle cable by cable) 6. Translate to **P5/S5**; retrieve 1 large (size 37) Cannon Connector Cap from **P5** (J153, J154, J159, or J160) or **S5** (J43, J44, J45, or J46) 7. Translate to ______ BGA worksite 8. Install APFR in WIF ______ [__,__,__,__] ❑ √Locking collar black-on-black ❑ Pull / twist test 9. Temp stow Crewlock bag #1 on HR __________ 10. Stow Cannon Connector cap in Crewlock Bag #1 (or to exterior for EV1 access) 11. Temp stow Crewlock Bag #2 on HR __________ 12. Perform: ❑ Glove inspection ❑ HAP check

Cognitive Work

H-3PO PROJECTS

- Human Physiology, Performance, Protection, and Operations (H-3PO)

- Technical Areas:
  - Spacesuits and Exploration Operations
  - Exercise Physiology and Performance
  - Occupant Protection

- 1-g Monitoring
  - Increasing Pre-flight baseline data collection

- Physical and Cognitive EVA Simulations (PACES)
  - APAC**HE** - Hybrid Reality Environment

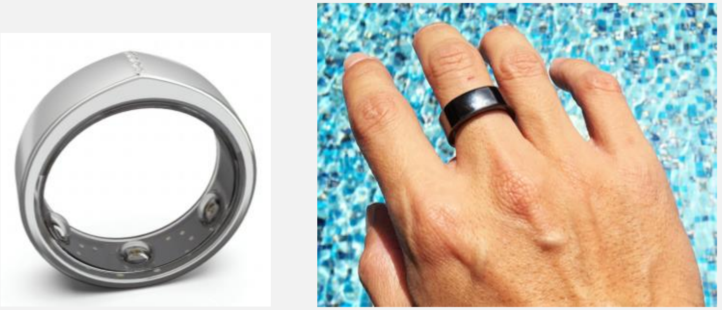
- EVA Operations Software (EOS)
  - Suite of tools for EVA decision support

- Exploration Atmosphere – chamber study
  - Higher Oxygen / Lower pressure environment
  - Flammability Concerns

USING COMMERICAL OFF-THE-SHELF (COTS) WEARABLES

- 1-g Monitoring
  - Increasing Pre-flight baseline data collection
- Sleep duration and quality
  - Heart rate while sleeping
- Activity levels
  - Heart Rate while exercising
- Nutrition (manually logged)

Polar H10 Heart Rate sensor chest strap



Oura smart ring

Polar M600 smart watch

Garmin Vivoactive3 smart watch

CHALLENGES WITH COTS WEARABLES

- Limited choice in the resolution / sampling rates of devices' sensors
- Individual preferences vary
- Limited "real estate" on the person
- Wire management and robustness
- Fit for a range of body shapes and sizes
- Spaceflight constraints:
  - Data syncing and transmission
  - Flammability and Radiation concerns
  - Lack of a gravitational vector (e.g. "steps" data is not meaningful in micro-G)

CHALLENGES WITH COTS WEARABLES

- Raw data is often not accessible, or requires multiple applications or custom code development
- Seldom provide access to full and complete data
  - Lack of standardization in sensor design
  - Lack of control over the format of data output
  - Proprietary algorithms
  - Software license fees
  - API programming overhead

DATA INTEGRATION

- Integrating / combining data from multiple sources
- Post-processing to time sync and bin appropriately
- Loss of resolution when combining at the "lowest common denominator" resolution
- Workarounds:
  - Time syncing devices before data collection
  - Event Markers for laboratory testing

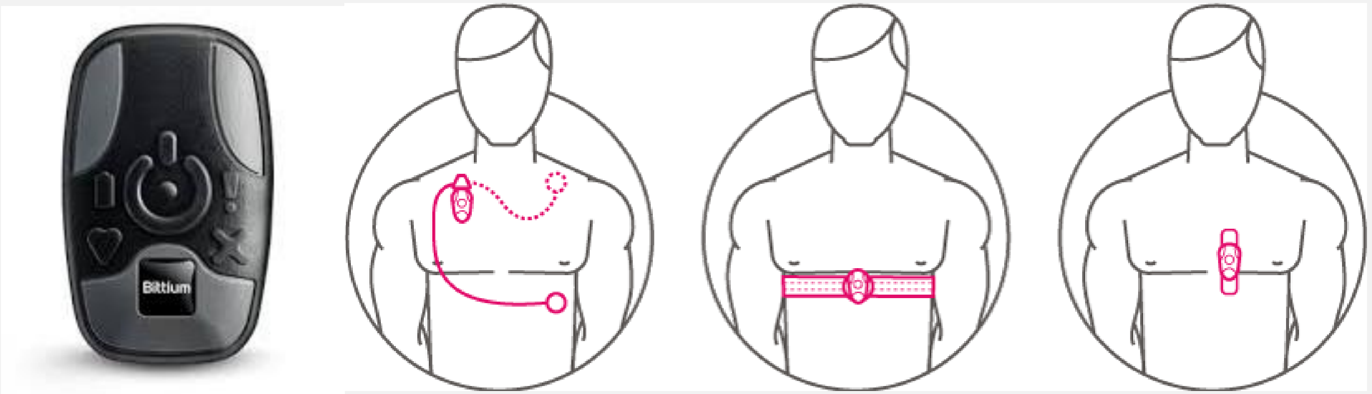
PHYSICAL AND COGNITIVE EVA SIMULATIONS (PACES)

- Wearables Data Collection:

OxyCon – breath-by-breath analysis

HTC Vive Movement Trackers

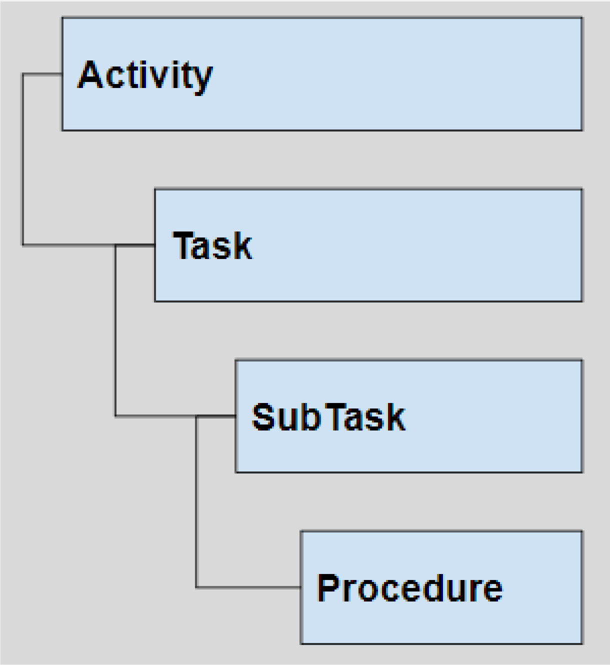
Equivital - Activity, HR, RR



Bittium Faros 360 – Electrocardiogram (ECG) with 3-lead and 1-lead configs

Polar H10 Heart Rate sensor chest strap

PHYSICAL AND COGNITIVE EVA SIMULATIONS (PACES)

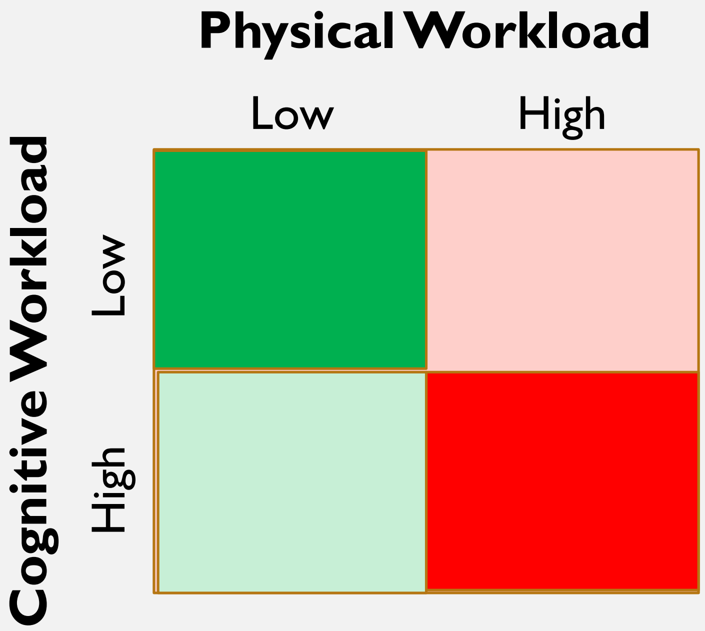


- Scenarios in development:

- **Overhead Activity:**
  - Airlock / Egress Operations
  - Loading and Unloading Equipment
  - Airlock / Ingress Operations
  - EVA Close / Clean up

- **Translation Activity:**
  - Ambulation on foot
  - Transporting Equipment
  - Transportation by driving

- **Station Activity:**
  - Documentation / Inspection
  - Experimental Package Deployment
  - Handheld Instrumentation
  - Maintenance / Repair / R&R
  - Construction / Deploy

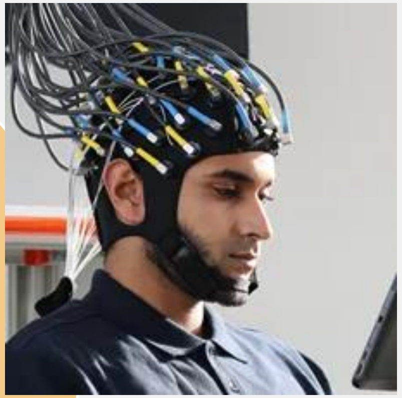


PHYSICAL AND COGNITIVE WORKLOAD

Physical Performance Measures

Psychophysiological Measures

Cognitive Performance Measures



- Heart Rate Variability (HRV)
- Respiration Rate (RR)
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ALGORITHM DEVELOPMENT

Physical workload ↔ **Cognitive workload**

- **Psychophysiology measures:**
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Example: Changes in heart rate and temperature occur when performing physical work and similar changes also occur when under psychological stress.

Algorithms for integrating and analyzing multiple data sources are required to differentiate between physical and cognitive changes.

CONCLUSIONS & FUTURE WORK

- Access to full and complete data is necessary
- Individual preferences vary, so we need standardization between various devices
- Operational environment of spaceflight puts constraints on:
  - Data syncing and transmission
  - Flammability and Radiation concerns
  - Lack of a gravitational vector ("steps" data is not meaningful in weightlessness)
- Algorithms are needed to infer physical workload and cognitive workload changes from various psychophysiological measures