Enhancing Sensorimotor Adaptability Training

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SPACE LIFE SCIENCES
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Introduction
Internship Experience

Article Review Experience:
- European Archives of Oto-Rhino-Laryngology and Head & Neck (EAOR)

Get Locomotion Study Going:
- Review IRB.
- Informed Consent / Layman’s Summary.
- Test Readiness Review (TRR).
- Look at individual subjects’ data from Peters et al., 2013.
- Learn hardware & software.
  » GVS device.
Background

Sensory discordance during gravitational transitions may affect planetary EVAs:
- \( \downarrow \) locomotor stability.
- \( \uparrow \) cognitive cost.
- \( \uparrow \) metabolic cost.

Sensorimotor adaptability training may be used to mitigate these effects by challenging multiple sensorimotor systems.
- Brain “learns to learn” (adaptive generalization) and solves motor challenges better.
  - More efficient at generating appropriate strategies.
    - \( \uparrow \) adaptation tools \( \Rightarrow \) \( \downarrow \) adaptation time.

(Mulavara et al., 2009; Peters et al., 2013)
Background

Sensory Weighting and Functional Performance
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We hypothesize that subjects who are more dependent on a single sensory modality and/or show reduced function within a given sensory modality will have reduced ability to adapt to a novel discordant sensory environment compared to subjects who use multiple sensory modalities equally.
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**Background**

- **Stochastic Resonance (SR)**
  - Detection of weak input signals may be enhanced by addition of low levels of noise.
    - Vestibular or proprioceptive.
    - ↑ external cues.
    - ↑ adaptability in sensorimotor adaptability training.

  ![Threshold Examples](image)

  (Mulavara et al., 2011)

  (Hijmans et al., 2008)
Background

Purpose:

- Determine if SR can be used to improve individualized sensorimotor adaptability training programs by enhancing vestibular signal detection.
Methods

Subjects:

- Healthy (passed modified Air Force Class III physical).
- ~10 in control group.
- ~10 in experimental group (+SR).
- Naïve to support surface perturbations.
Methods

Equipment & Procedures:

- Vestibular Stimulus Device
  - Maximum amplitude of 4 mA.
  - Threshold Testing:
    - Subject moves joystick with stimulus perception.
      - Sinusoidal signals (0-2,000 uA).
    - Threshold and optimal stimulus are determined.
  - Optimal amplitude of stimulus delivered is at 20-40% of individual’s perceptual threshold.
  - White Noise (100 Hz).

Enhancing Sensorimotor Adaptability Training

(Mulavara et al., 2011)
Methods

Equipment & Procedures:

- Sensory Discordant Environment:
  - Six Degree of Freedom Motion Base (Moog, East Aurora, NY):
    - 0.3 Hz continuous, sinusoidal, lateral motion.
      - Started after 8 minutes of baseline walking.
  - Treadmill (Quinton Model Q55, Philadelphia, PA):
    - 1.1 m/s for all subjects.
  - Virtual Hallway:
    - 3.6 m x 2.6 m screen.
    - 2 m in front of subjects.
    - Forward translating.
      - Perceptually matched to treadmill speed.
Methods

Equipment, Procedures, & Analysis:

- **Locomotor Instability ⇒ Stride Frequency:**
  - Collected continuously.
    - Foot switches (Motion Lab Systems, Baton Rouge, LA).

- **Metabolic Cost ⇒ VO₂:**
  - Collected continuously.
    - Cosmed K4b2 (Cosmed USA Inc., Chicago, IL).

- **Cognitive Cost ⇒ Reaction Time (RT):**
  - Collected at BL 1, BL 2, T 1, T 2, T 3, & T 4.
    - Custom LabView code (National Instruments, Austin, TX)
      - 7 auditory tones presented at varied timing to reduce anticipation.
      - Response via thumb switch.
Control Group?

Adaptation in Locomotor Stability, Cognition, and Metabolic Cost During Sensory Discordance

Brian T. Peters, Rachel A. Beaud, Crystal D. Buxon, Jamie R. Guerri, Robert J. Flouta-Snyder, Astrumna P. Mufuna, and Jacob J. Bloomberg

Locomotor adaptive responses and their associated costs interest us because astronauts encounter sensory discordance during gravitational transitions and must produce an adaptive locomotor response to walk, allow their return to Earth (19). Locomotor instability associated with gravitational transitions may affect planetary extravehicular activities during the initial adaptation period and might lead to decrements ability to multitask and increased metabolic costs. The goal of this study was to quantify the adaptive locomotor effects, as well as the cognitive and metabolic costs, of adaptation to walking in a discordant sensory environment.

After spaceflight, balance control and locomotor function are known to be compromised (5,16,19). Our laboratory is interested in sensorimotor adaptability training as a potential approach for mitigating these effects. An individual can enhance his or her ability to adapt by learning to solve a class of motor challenges rather than a specific challenge (4,20,25) because the brain "learns to learn" and becomes more efficient at generalizing appropriate strategies. Using this approach as the basis for a countermeasure, we believe that preflight treadmill training presented under novel and challenging sensorimotor conditions could expedite an astronaut’s ability to ambulate safely on return to Earth or landing on the Moon or Mars.

Because some effects associated with sensory discordance are destabilizing enough to interfere with astronauts’ mission objectives (during Earth-to-space transitions or space-to-partial-gravity transitions) and delay their return to activities of daily life (during space to Earth transitions), our laboratory develops training programs to expedite adaptation processes. Since gravitational transitions cannot be simulated in a laboratory, our approach has been to train individuals to solve a broad class of sensorimotor challenges—rather than any one in particular—so that they are better prepared to adapt to new ones, including those associated with gravitational change. By introducing new strategies and providing safe opportunities for subjects to experiment with and move between those strategies, we equip individuals with more adaptation “tools” and a broader range of experiences from which to draw. Reducing the adaptation time required after unexpected sensory cues are perceived requires efficient and safe gait patterns in discordant sensory conditions.

Training benefits stem from early stage (or fast) learning, typically seen within the same training session, and later stage (slower) learning that normally results in long-term performance gains after repeated practice (23). The early and late stage learning mechanisms are driven by two distinct neural systems (26). In this study, performance gains drew on an individual’s early stage, or surface “strategic,” learning response. We previously performed a pre- and postflight functional assessment.

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Methods

Additional Analysis of Peters et al., 2013 Data:

- My goals were to:
  1. Look at the individual subjects’ responses to the discordant environment.
    - What is the variability across subjects?
  2. Examine relationships between the locomotor stability, metabolic cost, and cognitive ability parameters based off individual subject responses.
Results

Normalized Stride Frequency

Stride Frequency Deviations (Hz) From Individual Baseline Means

Normalized Stride Frequency

Minutes

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## Results

### Normalized Reaction Time

The graph shows the normalized reaction time deviations (seconds) from individual baseline means over time. The x-axis represents minutes, ranging from -5 to 20, while the y-axis indicates the reaction time deviations. Each subject (labeled S2 to S16) shows a different pattern of reaction time changes, with some subjects demonstrating an immediate improvement and others showing a gradual decrease over time. The normalized mean is indicated by a thick black line, which generally follows the trend of the individual subjects, albeit with a slight variation. The data suggests that Enhancing Sensorimotor Adaptability Training may lead to improved reaction times over the measured period.
Results

Normalized VO₂

VO₂ Deviations (ml/min) From Individual Baseline Means

Minutes

Enhancing Sensorimotor Adaptability Training
Results

- Normalized Max Response Correlations:

  o General Trend:
    - ↑ Stride Frequency Resp. ⇔ ↑ VO2 Resp. ⇔ ↓ RT Resp.
      - No significant correlations though.

  *Take Home:* Decreased locomotor stability is associated with increased metabolic cost and increased cognitive cost while adapting to novel sensory discordance.
Discussion

What I learned:

- Subjects display considerable variability in their responses to the discordant environment.
- General trend in max response data between stride frequency, reaction time, and VO₂.
  - ↑ Stride Frequency Resp. ⇔ ↑ VO₂ Resp. ⇔ ↓ RT Resp.

Contributions to NASA’s knowledge base:

- Adaptation to sensory discordance can incur tradeoffs in locomotor, metabolic, and cognitive abilities.
  - Decreased locomotor stability is associated with increased metabolic cost and increased cognitive cost while adapting to novel sensory discordance.

Uses for future research/mission planning:

- Determine if vestibular SR helps improve adaptation to a novel sensory discordant environment.
- Design individual sensorimotor adaptability training programs to promote multisensory reliance in individuals to enhance ability to adapt.
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