Psychophysiology of Spaceflight and Aviation

Patricia Cowings, Ph.D.        NASA Ames
William Toscano, Ph.D.        NASA Ames
Psychophysiology

- Investigates the relationship between physiology and behavior.
- Examines the impact of environment on health and performance.
Primary Mission Goal of Space Human Factors

**Enable a permanent human presence in space**

Develop protocols to:

- Accurately assess spaceflight effects (zero-gravity, confinement) on crew health, safety, and performance.
- Evaluate and test countermeasures that will remedy these environmental effects.
Technical Background

- Extended spaceflight affects physiology with associated adverse effects on crew performance and health.

- Other factors like workload, isolation, fatigue, etc. are known to effect operational efficiency.

- There is a wide range in the ability of individuals to adapt to space and re-adapt to Earth.

- Future crew complements: men and women, multi-cultural, different professional backgrounds and physical condition.
Statement of Problem

Methods are needed:

• to examine individual differences in crew responses to extended spaceflight

• to evaluate the efficacy of countermeasures for individuals
Assessment Tool: Converging Indicators
- physiological measures
- performance metrics
- standardized self-report scales

Correction Tool: Autogenic Feedback Training Exercise
- AFTE is a 6-hour physiological conditioning program
Converging Indicators

**Physiology**
(ANS and CNS responses)

**Subjective States**
(mood, symptoms)

**Performance**
(cognitive, perceptual, neuromotor)
AFTE to Control Motion Sickness

- AFTE reduces physiological response levels to motion sickness stimuli

- Subjects tolerate rotating chair tests longer, at higher speeds, and with fewer symptoms
AFTE Reduces Physiological Responses to Motion Sickness Stimuli and Improves Tolerance

Before AFTE

After AFTE
Changes in Motion Sickness Tolerance

Baseline tests

1. AFTE
2. DRUG
3. No Treatment Control

Rotating chair tests
1. 100 rotations tolerated
2. 250 rotations tolerated
3. 300 rotations tolerated
4. 800 rotations tolerated

Dosages:
- Baseline tests
- Placebo
- 50 mg
- 25 mg

Time:
- 2 hrs - AFTE
- 4 hrs - AFTE
- 6 hrs - AFTE
Summary of Motion Sickness Research

- Total suppression of motion sickness in 65% of subjects.
- Significant improvement in tolerance in 85% of subjects.
- No difference between men and women in learning symptom control.
- Learned autonomic control is retained up to 3 years with rapid relearning.
- Initial susceptibility to motion sickness is unrelated to training effectiveness.
- Control of motion sickness symptoms transfer across multiple environments.
- Training is an effective treatment for airsickness in military pilots flying high performance aircraft.
Preflight Training in 0-G Aircraft
Preflight Training During Shuttle Simulations
Autogenic-Feedback Training Exercise: AFTE

A 6-hour training method used to teach voluntary control of physiological responses and normalize autonomic balance. Patented by NASA in 1997.

Spaceflight research
Originally tested as a countermeasure for space motion sickness

Ground-based research
• reduces or eliminates motion sickness
• improves pilot performance under emergency conditions
• relieves nausea and syncope in dysautonomia patients
• effective control for increasing blood pressure
Physiological Measures

- skin temperature
- skin conductance level
- heart rate
- respiration rate

Autogenic Feedback System-2
Special Equipment Used During Early AFTE Research
Autogenic Clinical Laboratory System
PC-Based Training
Autogenic Clinical Laboratory System  
Training Cosmonauts in Russia
AFTE Trainer Controls 20 Displays

1. Blood Volume Pulse left hand
2. Blood Volume Pulse right hand
3. Respiration Rate
4. Heart Rate
5. Skin Conductance Level
6. Hand temperature
7. Blood flow – head
8. Blood flow – toe
9. EMG – left arm
10. EMG – right arm
11. EMG – left leg
12. EMG right leg
13. Systolic Blood Pressure
14. Diastolic Blood Pressure
15. Mean Arterial Pressure
16. Thoracic Fluid Volume
17. Stroke Volume
18. Cardiac Output
19. Total Peripheral Resistance
20. Vagal Tone
Exercising Smooth Muscle to Normalize Autonomic Balance

Human Responses on Earth and in Space
Heart Rate Response During a Space Shuttle Launch

![Graph showing heart rate response during a space shuttle launch.](image)

*MECO* = Main Engine Cut-Off
Heart Rate Decreases Over Days of Early Exposure to Microgravity

Heart Rate - Subject 9

beats per minute

10 minute means
Heart Rate Decreases Over Days of Early Exposure to Microgravity

Heart Rate - Subject 8

10 minute means
AFS-2 in Space
Donning and Doffing
Control of Autonomic Responses During Long-Duration Space Flight

Patricia S. Cowings, Ph.D.       NASA Ames
William B. Toscano, Ph.D.       NASA Ames
Bruce Taylor, Ph.D.             U of Akron
Ludmilla Kornilova, M.D., Ph.D.  IMBP
Innessa Koslovskaya, M.D., Ph.D. IMBP
Charles DeRoshia, M.S.          NASA Ames
Neal E. Miller, Ph.D., Ds.C.    Yale
Objectives

✓ To facilitate adaptation to space and readaptation to Earth.
✓ To compare training effects on control of autonomic responses in space to those effects observed during ground-based AFTE.
✓ To determine AFTE effects on postflight orthostatic tolerance.
✓ To examine AFTE effects on cognitive and psychomotor performance, mood states, sleep quality, and motion sickness.
Methods

**Preflight**
- To provide 6 hours of preflight AFTE to cosmonauts
- To test training effects during tilt-table tests

**Inflight**
- 8-days of ambulatory monitoring (AFS-2) at 30-day intervals
- Each flight day included:
  - Three 15-minute AFTE sessions
  - Cognitive and psychomotor tasks
  - Vestibular perception tests
  - PC-based self-reports of mood states, sleep and symptoms

**Postflight**
- Tilt-table tests of orthostatic tolerance
- Crew debriefings
Subject 1 Final Preflight AFTE Session

Heart Rate

Stroke Volume

Cardiac Output

Mean Arterial Pressure

Skin Conductance Level

Total Peripheral Resistance

bpm

ohms/cm

liters/min

mmHg

micromhos

units
Preflight Learning Curve of Crewmember
(16 months between sessions 8 and 9)

Subject 1 Heart Rate

Cardiac Output
Subject 1: Autonomic Control in Space (difference scores between arousal and relax trials)

Heart Rate

Skin Conductance Level
Conclusions

- Converging Indicators method can accurately describe individual differences in environmental effects and countermeasure effectiveness.

- Crewmembers can reliably maintain autonomic control during and after sustained exposure to space environment.

- Preliminary results of AFTE indicate that it is effective for controlling space motion sickness and postflight orthostatic intolerance.

- AFTE technology will be beneficial to future space crews.
Autogenic Feedback Training Exercise Improves Pilot Performance During Search-and-Rescue Operations

Patricia S. Cowings
*NASA Ames Research Center Moffett Field, CA*

Michael A. Kellar and Raymond A. Folen
*Tripler Army Medical Center Honolulu, HI*

William B. Toscano
*NASA Ames Research Center Moffett Field, CA*

Johannes D. Burge
*Department of Psychology Stanford University*
Ambulatory Monitoring and Controlling Autonomic Responses on Earth

- **Sustained Operations:** Fatigue, vigilance, sleep loss, contribute to human error accidents

- **Autonomous Mode Behavior:** A condition when a high state of physiological arousal is accompanied by a narrowing of the focus of attention
Participants

- 17 pilots, CG Air Station, Barbers Point, HI
  - 8 were given AFTE (4 HC-130 and 4 HH-65 pilots)
  - 9 served as Controls (3 HC-130 and 6 HH-65 pilots)

1. Pre-training flight 1 in HC-130 and HH-65 aircraft
2. AFTE – twelve 30-minute daily sessions
   control group received no treatment
3. Post-training flight 2

Two instructor pilots rated participant pilot performance:
- IP not told group assignment of individual pilots
- IP rated performance of same individual on both flights
- IP provided instructions (simulated emergencies) to pilot
Simulated Emergency Flight Scenario: (HC-130)
- Engine 1 fire during touch and go
- Search and Rescue case (downed A-4 pilot, 20 miles offshore)
- Engine 2 failure at 200 feet AGL
- Airframe damage, minor fuel leak
- AC bus failure, engine 1 fire
- Landing gear malfunction

Simulated Emergency Flight Scenario: (HH-65)
- Simulated engine stall at take off
- Search and Rescue case (distressed boat with injured crew)
- AC bus failure with loss of gyro, and pitch and roll
- Servo-jam warning
- Hydraulic failure at 50 feet AGL
- Engine 1 stall on short-final approach
## Performance x Phases of Flight

flight 2 (post-training) group comparisons: AFTE vs Control

<table>
<thead>
<tr>
<th>Performance Dimensions</th>
<th>Crew Coordination and Communication</th>
<th>Planning and Situational Awareness</th>
<th>Stress Management</th>
<th>Aircraft Handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checklist execution</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi/takeoff</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial cruise</td>
<td></td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Touch &amp; go</td>
<td></td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Cruise search &amp; rescue</td>
<td></td>
<td>*</td>
<td>*</td>
<td>+</td>
</tr>
<tr>
<td>Emergency initiation</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Emergency return to base</td>
<td></td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Emergency approach &amp; landing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* p <0.05

flight 1 (pre-training) group comparisons were not significant, except a higher score for Controls (+) on cruise search and rescue
# Performance x Phases of Flight

flight 1 (pre-training) vs flight 2 (post-training): **AFTE**

<table>
<thead>
<tr>
<th>Performance Dimensions</th>
<th>Crew Coordination and Communication</th>
<th>Planning and Situational Awareness</th>
<th>Stress Management</th>
<th>Aircraft Handling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Checklist execution</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Taxi/takeoff</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial cruise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Touch &amp; go</td>
<td>+</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cruise search &amp; rescue</td>
<td>*</td>
<td></td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Emergency initiation</td>
<td>*</td>
<td></td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Emergency return to base</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
<tr>
<td>Emergency approach &amp; landing</td>
<td></td>
<td>*</td>
<td></td>
<td>*</td>
</tr>
</tbody>
</table>

flight 1 vs flight 2 for Controls were not significant, except a lower score for touch and go (+) on flight 2  

* p <0.05
Summary

AFTE effects:

• improves overall performance and execution of duties
• Improves crew coordination and communication:
  - crew briefings
  - workload delegation
  - planning
  - overall technical proficiency
• may reduce physiological reactivity to stress
• may aid in successful use and expansion of CRM training
Future Applications of AFTE

Transfer NASA Technology and Validation Studies

• Training of Polish Military Pilots
• Training of U.S. Naval Pilots for Airsickness Mitigation
• Training of U.S. Veterans as a Treatment for Post-Traumatic Stress Syndrome
• Training of Astronauts and Cosmonauts

Develop/ Test New Monitoring and Training Capabilities

• Stream-line software
• Neuro-feedback and autonomic coherence
• Unobtrusive physiological Monitoring
BioHarness and Software

**Measures**

- Electrocardiography
- Respiration
- Chest Skin Temperature
- Posture
- Activity
- Acceleration (XYZ), minimum and peak

**BioHarness**

- Requires non-skin contact sensors
- Can interface with a PC or cell phone
- No sensors for skin conductance, hand temperature, and blood flow, EMG