SENSORY AND MOTOR SYSTEMS

SENSORY-MOTOR CONTROL

- We have considerable experience in weightless environments but virtually none in partial-g environments.
- We are basically totally ignorant.

HUMAN EXPOSURE TIME ON THE LUNAR SURFACE

Lunar Gravity Exposure Time over the Apollo Missions

Mission	EVA Time	Total Time on Lunar Surface
Apollo 11	2h, 31m (1 EVA)	21h, 38m, 21s
Apollo 12	7h, 45m (1 EVA)	31h, 31m
Apollo 14	9h, 23m (1 EVA)	33h, 31m
Apollo 15	18h, 35m (3 separate EVA's)	66h, 54m, 53s
Apollo 16	20h, 14m (3 separate EVA's)	71h, 2m
Apollo 17	22h, 4m (3 separate EVA's)	74h, 59m, 40s

Information gathered from:
http://www.nasm.si.edu/collections/imagery/apollo/apollo.htm

EFFECTS OF WEIGHTLESS EXPOSURE

- Muscle atrophy
- Bone demineralization
- Altered motor unit properties of muscle
- Sensory and motor re-entry disturbances
- Altered sensory and motor cortical maps
- Motion sickness

SENSORY AND MOTOR RE-ENTRY DISTURBANCES

- Locomotory and balance disturbances
- Impaired eye-head coordination
- Impaired eye-hand coordination
- Illusory motion of base of support and visual world during whole-body movements
- All disturbances more severe with longer exposure durations

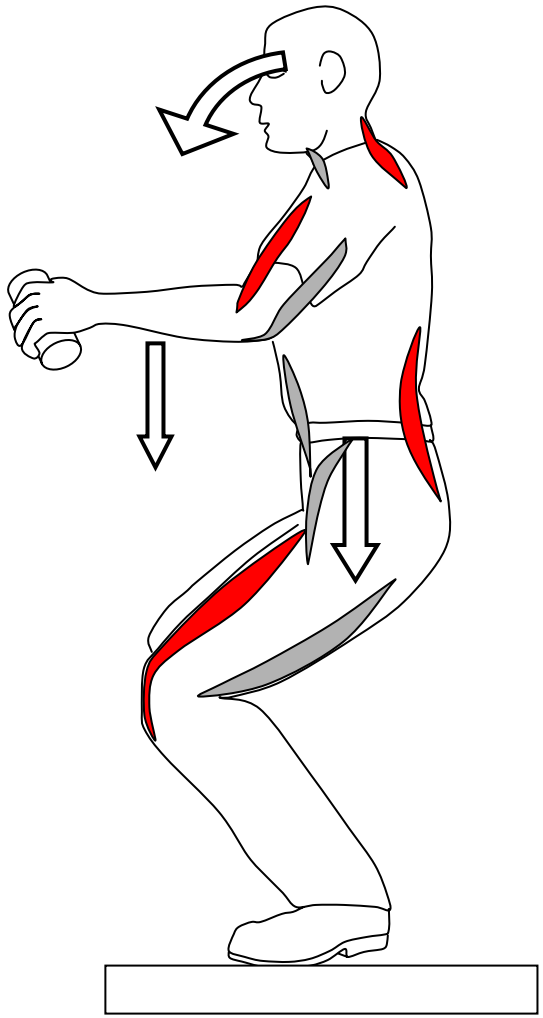
SENSORY AND MOTOR CORTICAL MAPS

- Cortical representation of somatosensation and motor control is rapidly modifiable by exposure.
- Parts of the body with finest sensory and motor control have the greatest cortical space devoted to them.
- Being in a 0g or partial g environment for a long time drastically changes the somatosensory inputs and motor control.
- Can expect major changes for representation of feet and legs.

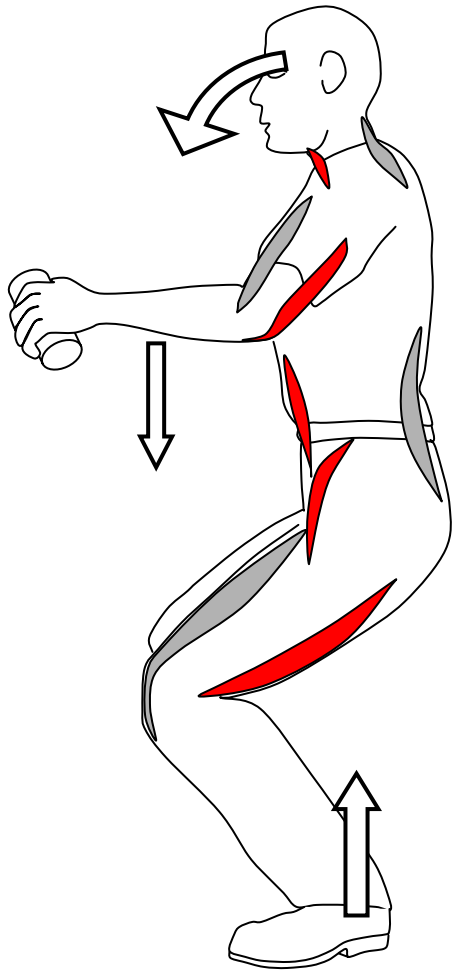
- Hands will be affected too because of changes in object weight.
- We have no idea of what the consequences of these changes will be for performance.

TRANSITIONS BETWEEN FORCE ENVIRONMENTS

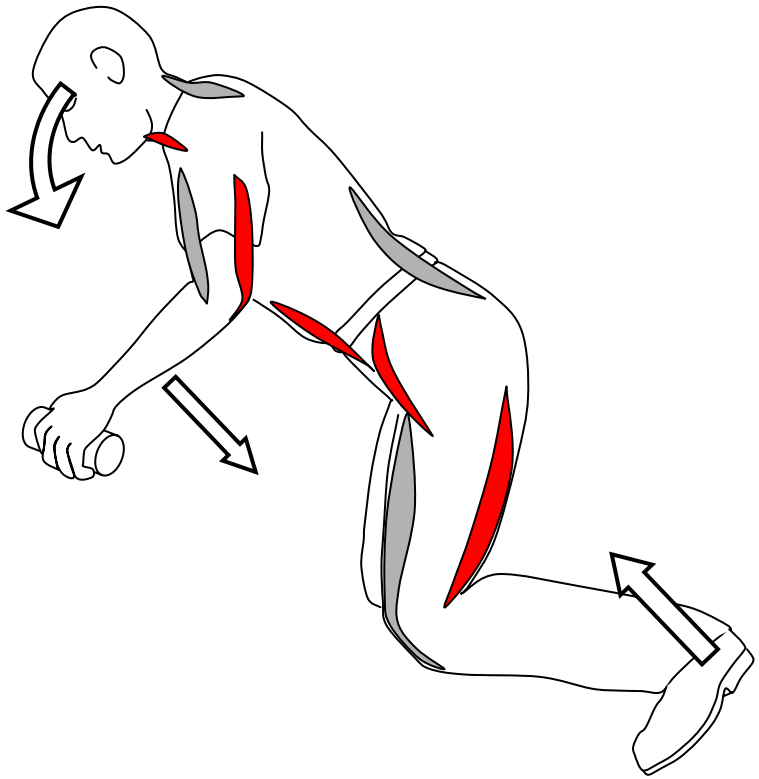
- On earth, all movements carried out in relation to gravity.
- Human body dynamically calibrated to 1 g environment.
- Normally our movements feel virtually effortless unless we are fatigued.
- Don’t fully sense or perceive the forces we actually generate in a 1g background.



1 g



0 g



0 g

LUNAR ENVIRONMENT

- Fractional-g environment nearly midway in level between 0g and .38g of Mars.
- Expect greater disturbances of motor control in lunar than Mars environment.
- Lunar gravity constitutes a great challenge to sensory-motor control.
- If you can adapt to lunar environment, you can adapt to Mars.

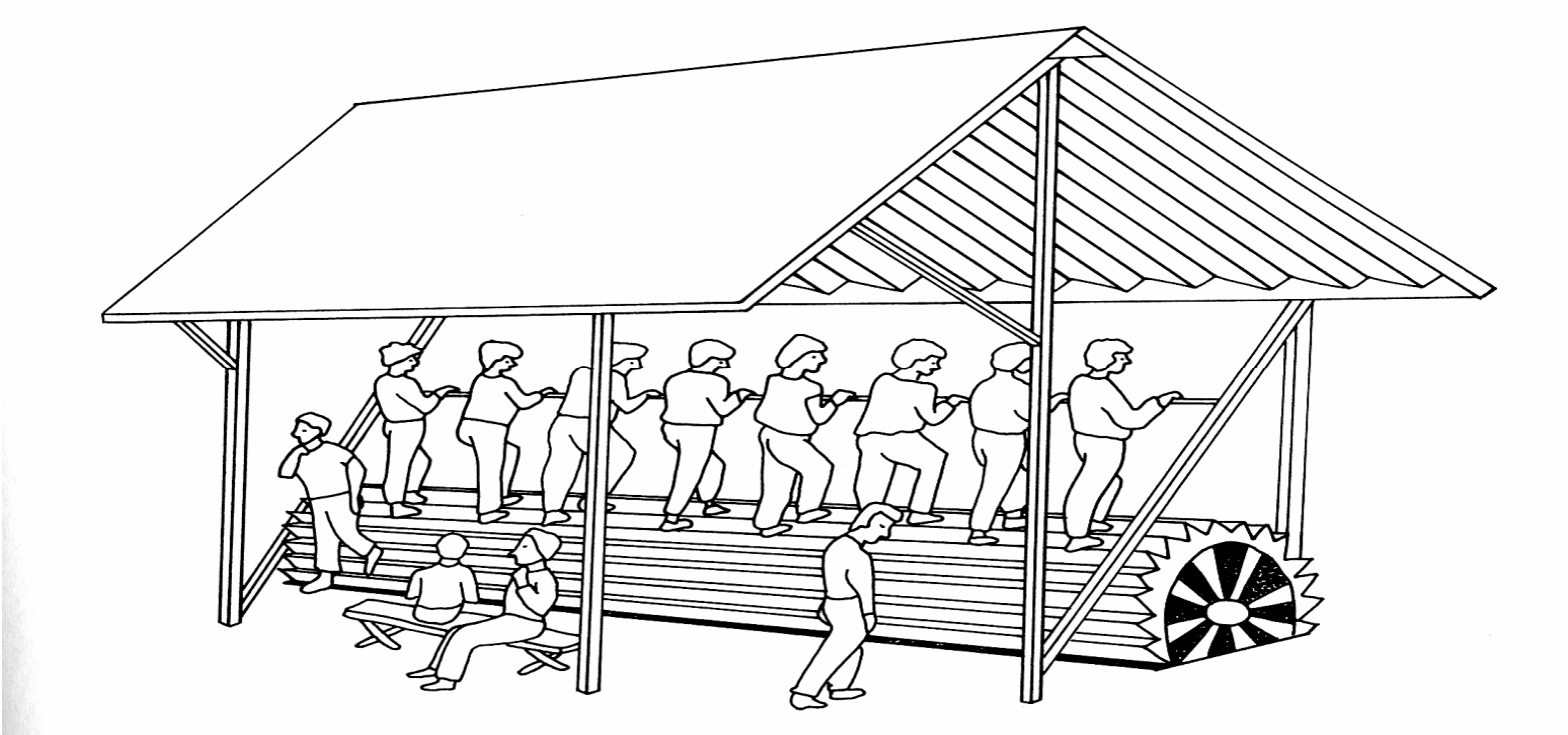
DISUSE VERSUS RECALIBRATION SYNDROMES

- In 0g, there is a total reorganization of skeletal-motor movement control.
- Can expect partial recalibration with “1 g treadmill” but basically a disuse syndrome.
- Lunar-g, there will be a recalibration of motor control for balance, locomotion, tool use, and whole-body coordination. Can expect greater adverse consequences for return to earth.

ARTIFICIAL GRAVITY

- Lunar base ideal site to determine level of artificial gravity necessary to prevent bone and muscle loss.
- Can expect full transfer of results to Mars mission.
- Short radius devices aversive with prolonged use.

PENAL TREADMILL
(New York City Prison, 1824)



- "….some claimed to prefer hanging to working on the treadmill." (Vogel, "Prime Mover", pg 232)
- Inessa Kozlovskaya – Russian cosmonauts falsify their treadmill exercise logs.

ESSENTIAL EXPERIMENTS

- What level of artificial gravity is necessary to maintain bone, muscle, and sensory-motor integrity?
- Is simultaneous adaptation to multiple force levels, rotating and non-rotating possible?
- What artificial gravity configurations will minimize side effects?
  - Configuration parameters include: radius, rate of rotation, exercise duty cycle, nature of “off cycle”.

- What schedules of exposure are best for achieving adaptation to lunar-g and space suit use vis a vis manual control, tool use, and locomotion tasks?
- Motion sickness: Key is to identify ways to detect non-adapters
  - Non-adapters could threaten mission success of Mars endeavor

PREDICTING SEVERITY OF DISRUPTION ON TRANSITIONS IN FORCE LEVEL

- Balance control
- Whole-body coordination
- Assessments need to be done with and without space suits, holding and not holding objects
- Earth-to-lunar and lunar-to-earth

- Assessments of sensory function re cortical maps EEG
- Assessments of functional hand capacity, simple tests of hand fine-motor control
- Precision grip tasks and dynamics
- Motor learning with robotic manipulanda

TEST DEVICES FOR MONITORING SENSORY AND MOTOR FUNCTION

- Simple rotator for artificial gravity
- Motion tracking – limbs, whole-body, head, eyes
- Dual force plate
- Force sensors
- Accelerometers
- Treadmill
- Instrumented objects for hand manipulation – e.g. catching, grasping
- High density EEG
- Robotic manipulandum
- Only need to return data (and astronauts) to earth

LUNAR EXPLORATION RISKS

- Entry disturbances of balance, locomotion, whole-body coordination, tool use
- Orientation disturbances
- Motion sickness
- No “show stoppers” with relative brief exposures (weeks)