Neurovestibular Illusions and Countermeasures

Space Illusions

• In weightlessness, “down” cues from the inner ear otolith organs are absent. Astronauts are thought to rely more heavily on vision.

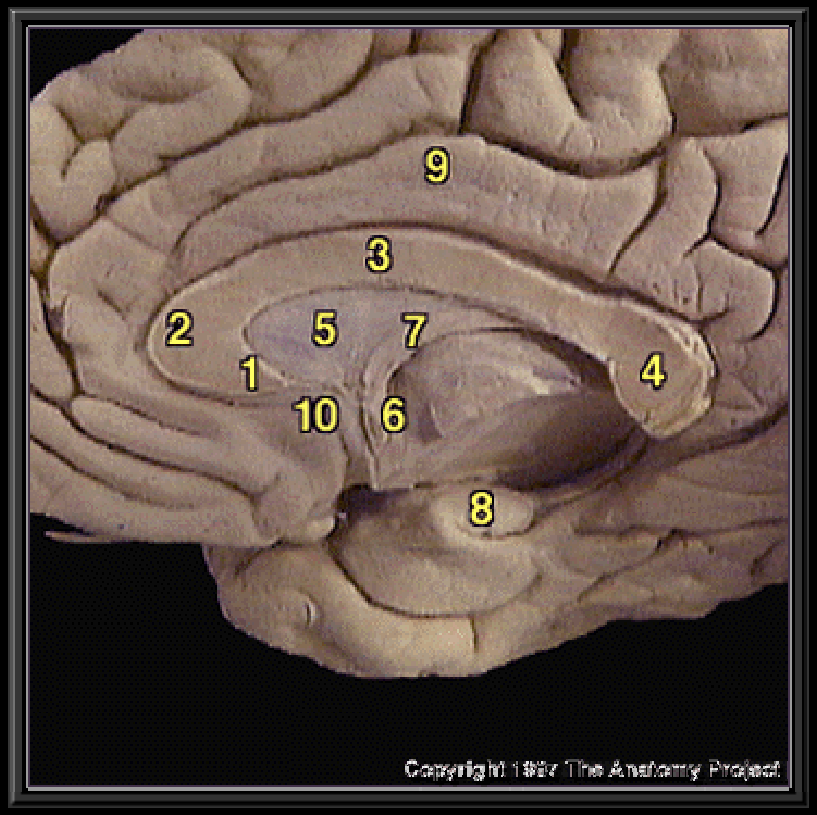
• Many astronauts perceive a “subjective vertical”. When it changes direction, it can cause disorientation and motion sickness.

Inversion Illusions - Common immediately after reaching orbit

Visual Reorientation Illusions (VRIs) - surface below feet seems like floor

EVA acrophobia - sudden fear of falling towards the Earth

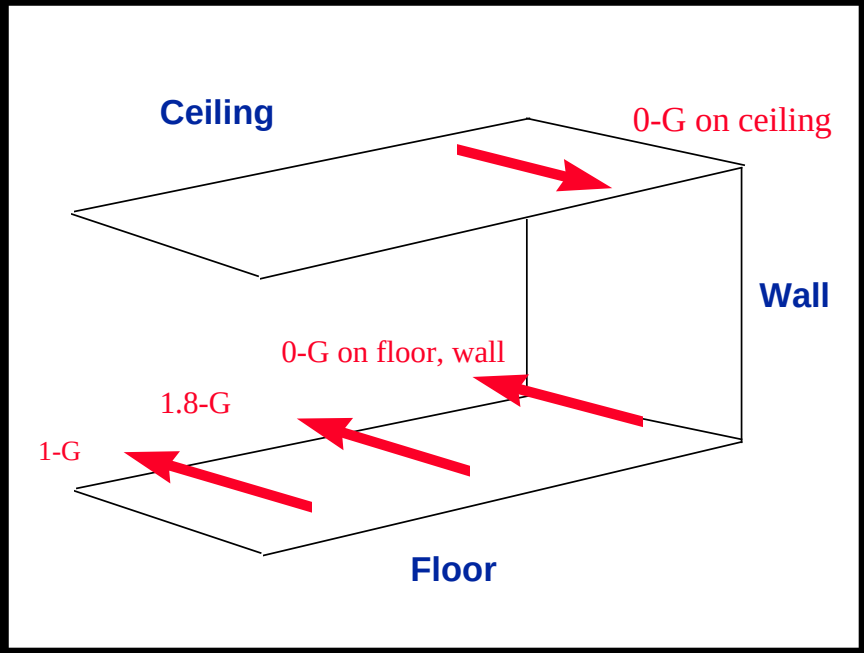
Neural Encoding of Orientation



- Studies have shown that animals construct internal neural representations of their spatial environment.
  - "Place cells" have a response component related to the animal's location in an environment.
  - "Head Direction" cells discharge as a function of the animal's head direction in a horizontal plane, independent of the animal's place, behavior, or head pitch or roll (up to 90 deg).

HD cell responses in 0-G

Prof. Jeff Taube, Dartmouth College



Similar VRIs occur with Place cell responses (McNaughton et al., 1999)

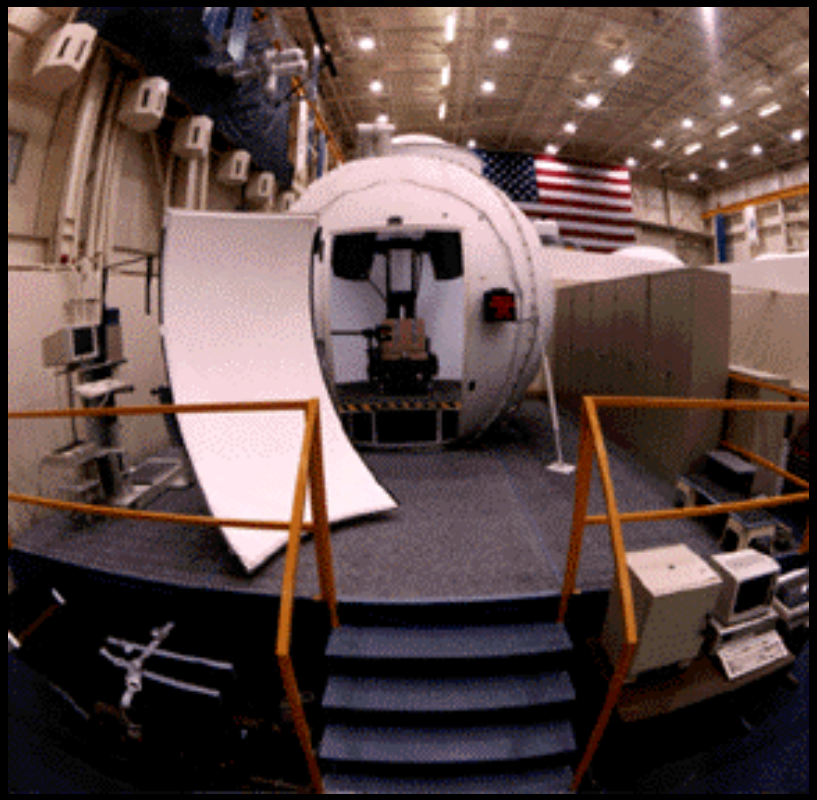
Neurovestibular Risks of Spaceflight

- Impaired cognitive and/or physical performance
- Disorientation and inability to egress safely or perform other physical tasks
- Impaired neuromuscular coordination and/or strength
- Autonomic dysfunction
- Permanent impairment of orientation or balance function

Countermeasures using VR

•Experience in mockups, parabolic flight, and neutral buoyancy and VR simulators is anecdotally helpful.

Preflight Adaptation Training



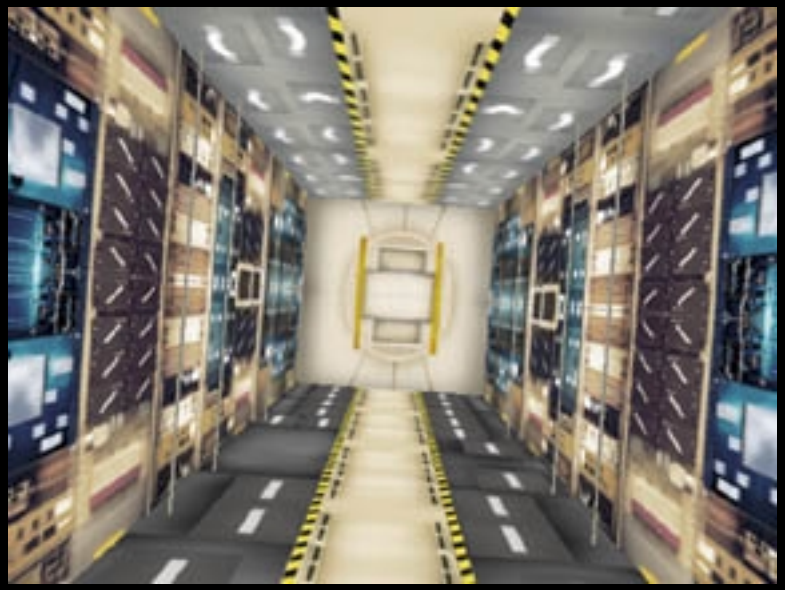
- JSC, early 1990's
- Device for Orientation and Motion Environments (DOME) apparatus
- Tilt Translation Device (TTD) device

Visual Clues to Orientation

- Three types of visual information contribute to our sense of gravitational orientation:
  - Motion of the visual surroundings
    - Roll rotation of a large field textured display induces an illusion of self-rotation (vection) and self-tilt.
  - Tilt of the visual frame
    - Tilt can cause displacement of the visual or postural vertical.
  - Visual polarity
    - Intrinsic polarity - Objects have a principle axis and perceptual “top” and “bottom”.
    - Extrinsic polarity - Spatial relationships between objects define principle axis and “top” or “bottom”.

Visual Orientation in 0-G

ISS Experiments (C. Oman, A Berthoz, et al.)



Subjects indicate the subjective floor of the room.

Visual Orientation in 0-G

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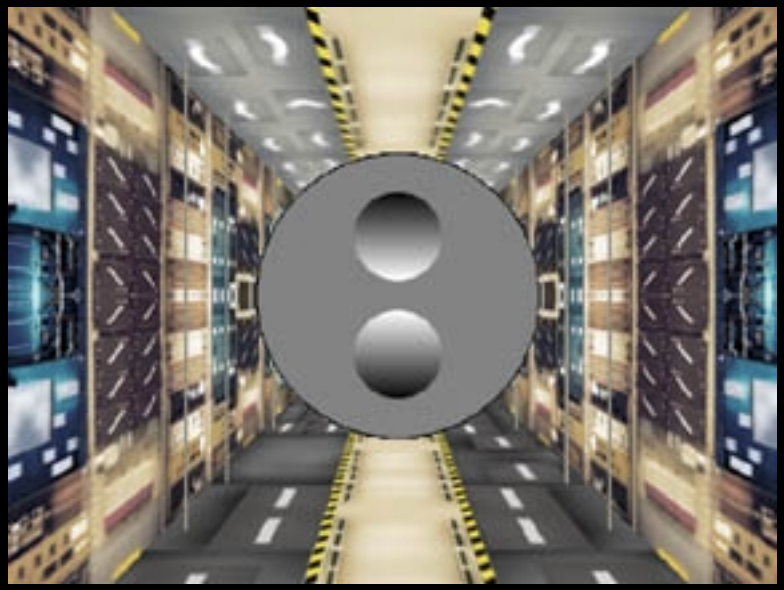
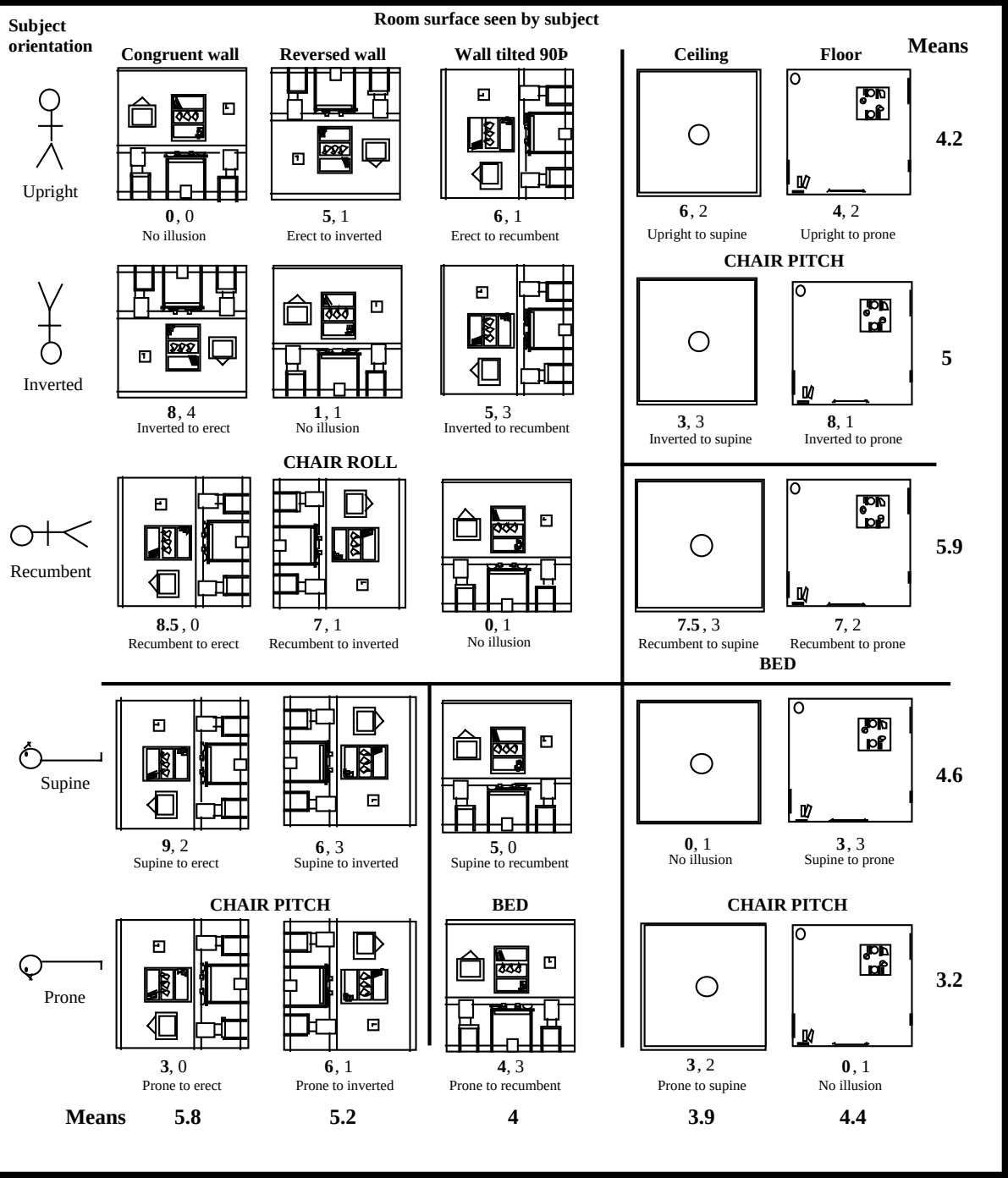


Perceived orientation will affect the perception of the shaded figure and ambiguous figure.

Visual Orientation in Static Real Environments

Prof. Ian Howard, York University

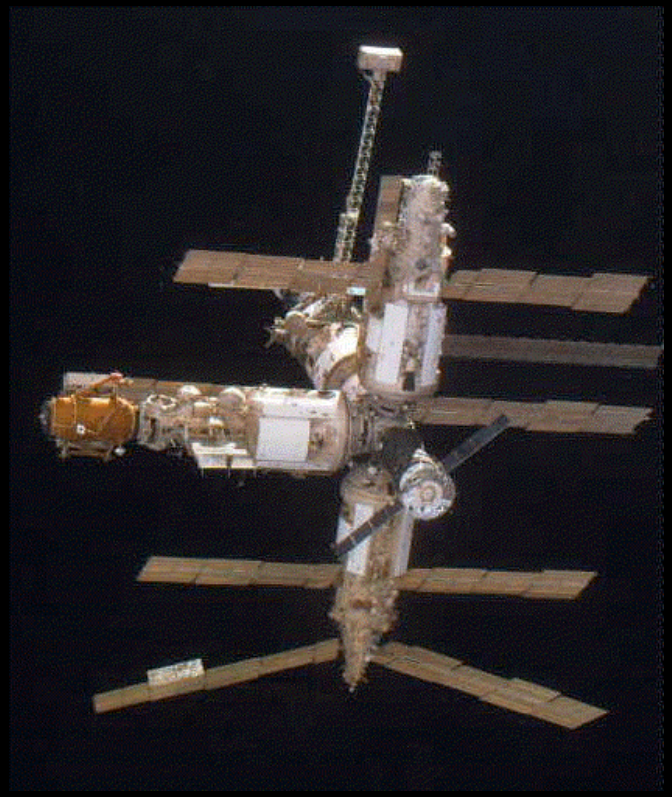
Tumbling Room
Human Performance Lab
York University, Toronto

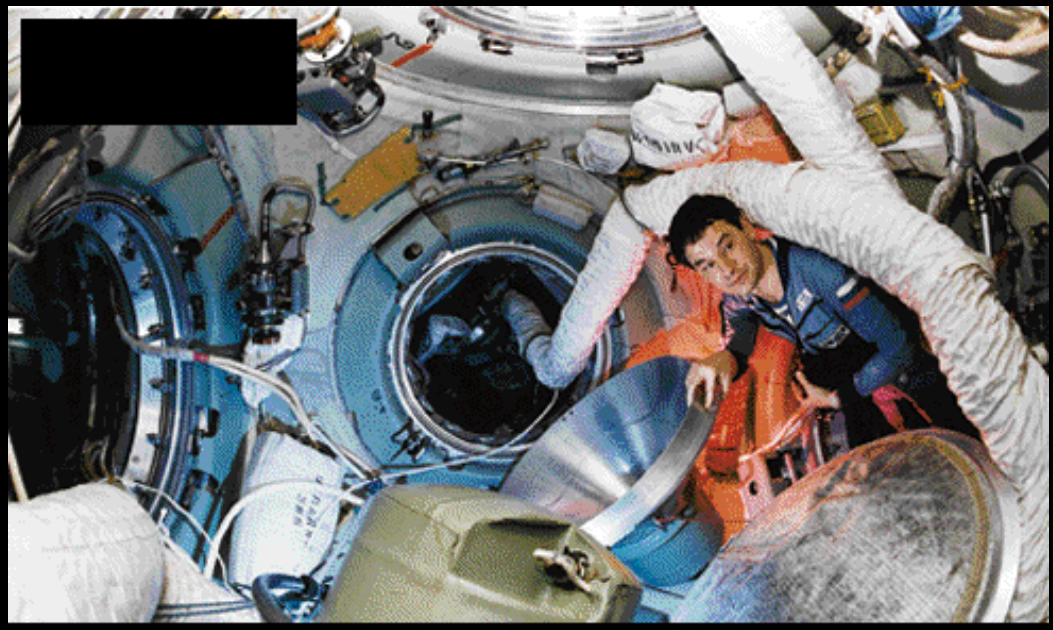

Subject orientation
Room surface seen by subject
Congruent wall
Reversed wall
Wall tilted 90Þ
Ceiling
Floor
Means
Upright
4.2
0, 0
No illusion
5, 1
Erect to inverted
6, 1
Erect to recumbent
6, 2
Upright to supine
4, 2
Upright to prone
CHAIR PITCH
Inverted
5
8, 4
Inverted to erect
1, 1
No illusion
5, 3
Inverted to recumbent
3, 3
Inverted to supine
8, 1
Inverted to prone
CHAIR ROLL
Recumbent
5.9
8.5, 0
Recumbent to erect
7, 1
Recumbent to inverted
0, 1
No illusion
7.5, 3
Recumbent to supine
7, 2
Recumbent to prone
BED
Supine
4.6
9, 2
Supine to erect
6, 3
Supine to inverted
5, 0
Supine to recumbent
0, 1
No illusion
3, 3
Supine to prone
CHAIR PITCH
BED
CHAIR PITCH
Prone
3.2
3, 0
Prone to erect
6, 1
Prone to inverted
4, 3
Prone to recumbent
3, 2
Prone to supine
0, 1
No illusion
Means
5.8
5.2
4
3.9
4.4

Visual Orientation and 3D Spatial Memory

- What makes orientation and navigation in 6 dof difficult?
  - Body movements are unconstrained by gravity.
  - Inconsistencies in visual verticals of the various modules.
  - 3D configuration of modules and nodes is difficult to mentally image and rotate.

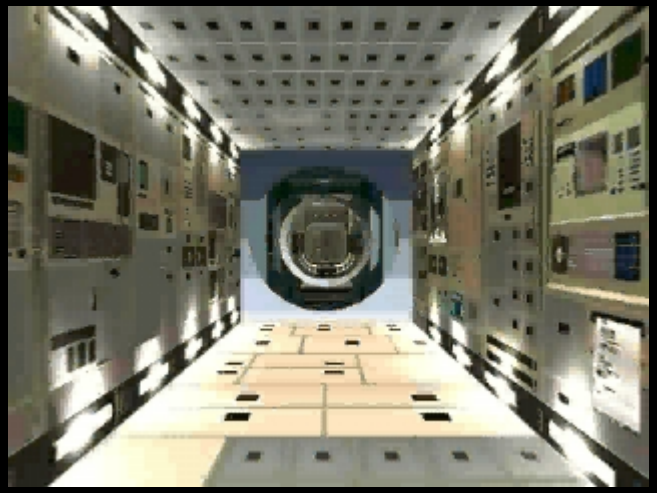
Visual Orientation and 3D Spatial Memory



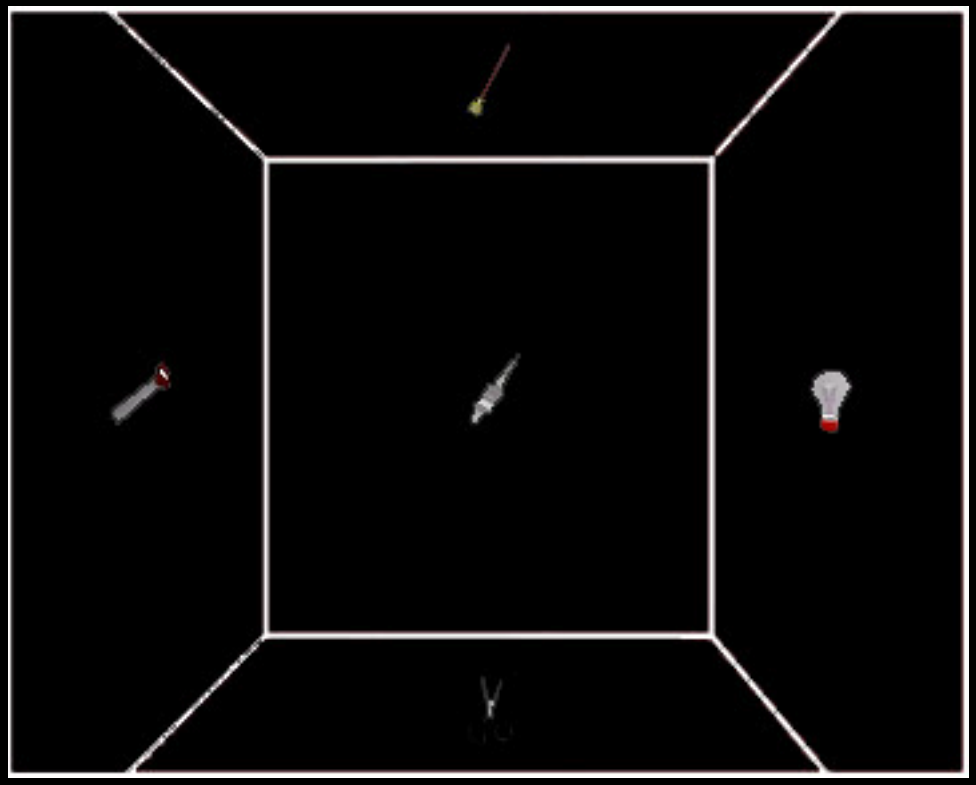


Mir-22 Mission Commander Valeri G. Korzun Enters Node That Connects Station Modules

Keep track of your starting location



Simulated Node



3D Spatial Memory Strategies

- Memorization of opposite pairs.
- Mnemonic devices to recall object locations is a canonical view.
- Memorization of the relationship of object triads.
- Mental image of the node in a canonical orientation.

VR Navigation Training Tools