The Vestibular System
The Vestibular System Senses:

- Angular Acceleration (in 3D)
- Linear Acceleration (in 3D)

Which way is up? Where am I going?
Inertial Guidance System
Signal

Vestibular Organs

Function

Head Motion: Angular acceleration

Head Motion: Linear acceleration

Head Position: Gravity

Semicircular Canals

Saccule and Utricle

Visual, Proprioceptive, Tactile Inputs

Forebrain: Perceived Orientation

Spinal cord, cerebellum: Postural Control

Oculomotor System: Gaze stabilization

Spinal cord, cerebellum, and Spinal cord, cerebellum: Postural Control

Oculomotor System: Gaze stabilization
Sense organs within the saccule & utricle are *maculae*.

Millions of particles of calcium carbonate (otoconia) add mass to otolithic membrane.
Linear Movement
Stereocilia
Kinocilium
VIIIth nerve
Resting
Excited
Inhibited

Diagram showing the movement of stereocilia and kinocilium under different conditions.
Utricular Hair Cell Directionality

Left utricle  Anterior  Right utricle

A  B

Midline of head
Utricular Hair Cell Directionality

Left utricle  Anterior  Right utricle

Head and body tilted to right
Utricular Hair Cell Directionality

Head and body tilted to left
Hearing with your otolith organs, if you are a little fish
Each “canal” is a closed tube ~8mm in diameter
Around 7000 hair cells per crista
All the hair cells are polarized in the same direction.
Linear Acceleration
  Start
Rotation
Continue
Rotation
  Stop
Rotation
Fluid tube rotation relative fluid flow
Utriculo-petal flow

Utriculo-fugal flow

Ampulla

Vestibular nerve

Scarpa’s ganglion

Auditory nerve

Cochlea

Semicircular canals

Utricle

Saccule

Otolith organs
Vestibular nerve activity (impulses per second)

Utriculopetal Flow
Utricle
Ampulla
Right lateral canal

Utriculofugal Flow
Left lateral canal

Head rotation to right

Time (sec)
Semicircular canals are paired / complementary
Geometry of Semicircular Canals

Front

Back

A

L

F.M.

P
Central Connections

Posture and locomotion

Position sense

Gaze stabilization
Vestibulo-ocular reflex

- Gaze direction

View straight ahead

- Canals

Turn head to right
Vestibular nystagmus

Sawtooth pattern movement of the eyes made up of a slow (VOR) phase and fast (saccadic reset) phase

![Diagram showing Vestibular Nystagmus](image-url)
Caloric Test

Test of intact vestibular function using thermal irrigation of the ear
Utriculopetal flow
As if rotation to right
Slow phase left
Quick phase right

[COWS: Cold Opposite Warm Same]
Disorders of the Vestibular System

A. Posture & Locomotion
   - Disequilibrium/
     Falling, Circling behavior

B. Gaze Stabilization
   - Impaired VOR

C. Position Sense
   - Vertigo/
     Dizziness/ Disorientation
Motion sickness
NASA MIND TRAINING TACKLES MOTION SICKNESS

Do you feel woozy during long car rides? NASA researchers believe it’s all in the mind and they have a training program to thwart it.

By Irene Klots
Wed Aug 4, 2010 11:37 AM ET
1 Comments | Leave a Comment

THE GIST

- NASA program uses biofeedback to train people mitigate motion sickness.
- Commercial applications include enhancing athletic performance and overcoming fear of public speaking.
- The Navy is testing the system to try to salvage the careers of airsick-prone pilots and flight crews.

Is quelling motion sickness a question of mind over matter? Possibly so, given the proper training, say researchers who are testing a NASA biofeedback system developed to try to help astronauts adjust to microgravity.

The disorientating effects of spaceflight will sound familiar to anyone who has ever grown dizzy, nauseous or faint riding in a car, flying in an airplane or sailing on a ship.

"It really is a problem. The incidence (of motion sickness) is extremely common. It occurs on every form of transportation -- even riding camels," Millard Reschke, chief of neuroscience at NASA's Johnson Space Center in Houston, told Discovery News.

About 70 to 80 percent of the astronauts experience symptoms of space sickness. Medications can help, but the side effects, which include sleepiness and a lack of mental acuity, present another set of potential problems for working in space.
About 70 to 80 percent of the astronauts experience symptoms of space sickness. Click to enlarge this image. NASA

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NASA psychologists wondered if space sickness could be controlled or mitigated by the astronauts themselves if they learned to regulate their heart rates, respiration and other responses of the body's autonomic nervous system. They developed a six-hour anti-motion sickness training program, known as the Autogenic Feedback Training Exercise, to find out.

The experiments didn't get too far, in part because the training required making astronauts sick enough on rotating chair tests so they could learn to master their body's responses. Not many wanted to participate, said Mae Jemison, a former shuttle astronaut now running a company developing commercial applications for the technology, such as enhancing athletic performance or mitigating fear of public speaking.