Physiological Effects of Postural Disorientation by Tilting During Weightlessness

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In the course of a recent study undertaken for the Naval Training Device Center, an effort has been directed toward developing concepts of probable mechanisms for maintenance of body posture under conditions of zero gravity. Body posture is maintained by the action of the eyes and by sensory receptors which are stimulated by mechanical forces, i.e., those of the vestibular labyrinth, the neuromuscular and neurotendinous nerve endings, pacinian and Meissner's corpuscles and free nerve endings in the skin, joints and muscles. It is to be expected that the pattern of sensory stimulation of all of the receptors except the eyes would be changed in the weightless state. This report is concerned with observations on labyrinthine function, and specifically the function of the utricular otolith during weightlessness.

In man and other higher vertebrates, the semicircular canals and the utricular otolith organs have separable functions in the maintenance of posture. The end organs of the semicircular canals respond to movement, but are not stimulated by the position of the head, i.e., by static conditions of disorientation. The utricular otoliths, on the other hand, respond to both movement and position. It is possible then to study the combined action of the semicircular canals and the otoliths in intact animals by observation of stato-kinetic postural reflexes, and the utricular function alone by observation of static postular responses.

Rotation of an animal would tend to produce a displacement of the otolith (a) by the weight of the otolith, a gravitational effect, and (b) by its inertia. The inertial stimulation, as the mass of the otolith is accelerated positively or negatively by movement of the head, would continue during the weightless state. Similarly, the end organs in the ampullae of the semicircular canals would be stimulated by angular acceleration.

It was reasoned, *a priori*, that since only gravity could cause displacement of the otolith in the absence of rotation or movement, no postural response would result by static disorientation of the head in the condition of zero gravity. Experiments were designed and conducted to test this hypothesis.

Man is for the most part more affected by impairment of postural receptors than lower animals. However, as long as sensory data are available from two of the three sensory receptor systems, human static and dynamic postural reactions can be performed adequately. Deaf mutes whose labyrinths have been destroyed by meningitis or other causes maintain posture by means of sensory data from the eyes and the muscle-tendon and touch receptors; the blind maintain posture with labyrinthine receptors and the muscle-tendon and touch end organs. Frequently the loss of one of the three senses results in an initial disturbance in postural reactions. Usually, however, there is a physiological compensation for the loss, so that an appreciable degree of degradation of performance is transient rather than chronic, and is not evident except under stressful conditions. It is expected then that the basic pattern of static postural responses may be disturbed in weightlessness, and in the absence of tactile-neuromuscular-neurotendinous stimulation, or of visual stimuli, such disturbances may become significant for human behavior.

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Both static and dynamic responses may be modified or suppressed as the result of influence of the higher centers. Suppression and modification of motor responses is developed to a high degree in man, so that reflexes which can be demonstrated in lower animals may not be evident in man. On the other hand, effective functioning of man's postural reflexes is well demonstrated by appropriate recovery reactions when the body is disoriented as when falling.

The tonic labyrinthine reflex effects on the musculature originate from the utricle macula.[1] As a result of these reflexes the head tends to retain its normal orientation in space; if the head is held, and the body disoriented by tilting or rotation, a compensatory pose of the eyes is assumed with the eyes retaining, insofar as possible, their normal orientation in space. In dogs and cats it is necessary to eliminate visual stimuli by blindfolding in order to ensure a purely labyrinthine response; in rabbits and guinea pigs reactions are not significantly augmented by visual stimuli.

The compensatory positions or poses can best be demonstrated in animals under conditions which minimize distraction or suppression of the basic reflexes, e.g., in animals in which the cerebral hemispheres have been removed. The pigeon serves as an excellent experimental animal for observation of compensatory positions of the head, and of the eyes if the head is held. For example, if a pigeon is rotated around its longitudinal body axis to the right, the head will rotate to the left and retain its original position in space, although no longer normally aligned with the body axis. If the head is held, the right eye moves up and the left eye moves down. If the pigeon is tilted 90° around its lateral axis, head up, tail down, the head is flexed and assumes and retains a compensatory position such that it is normally oriented in space. The static compensatory responses are the same in the normal and the decerebrate pigeon. The decerebrate, however, is quite predictable in its reaction since it is not subject to distraction. It is for this reason that they have been used in these observations.

METHODS

Observations on compensatory poses were made on pigeons in a C-131 airplane during normal and weightless flights through the cooperation of the Aero Medical Laboratory, U. S. Air Force, at Wright Air Development Center. Normal and decerebrate birds were used for the tests.

Normal adult pigeons were decerebrated approximately three weeks prior to the experimental trials. They were maintained by hand-feeding with soaked, dried green peas and canned corn kernels, and water containing an antibiotic.

Both normal and decerebrate birds were wrapped in lengths of cheese cloth and hand held for observations under normal gravity; they were wrapped but allowed to free float for brief periods in the weightless state.

Experimental Trials.—Two normal and four decerebrate birds were tested during flight. Both motion and still picture records were made of responses to tilting.

An attempt was made to photograph compensatory eye movement and eye pose. The eye was anesthetized and a wire speculum placed in position to keep the eye open to observe nystagmus and compensatory positions. The head was held to accentuate eye movement. While the movement and position could be observed directly, satisfactory photographic records were not obtained in normal flight. Further, since direct observation of the eye during weightless flight proved to be difficult, head movement and compensatory poses of the head were used to indicate the labyrinthine response. The heads and beaks were striped with nail polish to assist in accentuating the head position in the photographic records.

RESULTS

Observations were made on response to tilting, following rotation around the various body axes. While all of the birds showed characteristic head nystagmus and post-rotatory nystagmus (following repeated turning) when rotated around the dorsoventral axis, this is a semicircular canal rather than a utricular response. The responses to tilting 90 degrees to the right and to the left around the longitudinal axis were disturbed by the weightless condition. In some trials the normal birds failed to display compensatory positions and maintained their heads in alignment with their bodies. For the most

Figs. 1 and 2. Postural disorientation of pigeons by tilting under conditions of zero gravity; no absence of compensatory pose of heads.

clearly evident. When the birds were rotated around the lateral axis the heads maintained their normal orientation in space. Further, when the head was held by the beak, with the head in normal alignment with the body, and the bird was then tilted 90 degrees head up around its lateral axis and the beak released, the heads then showed compensatory downward movement until the beaks were horizontal; this compensatory pose was held.

Under conditions of weightlessness, the decerebrates failed to show compensatory poses following rotation. Particularly striking are the responses in which the beaks were held, the bird rotated head up and the beak released; the beaks were maintained in a vertical position in alignment with the body (Fig. 1). Further, tilting around the longitudinal body axis failed to elicit compensatory pose of the head (Fig. 2). Both still photographs and motion pictures showed periods in which the birds were free floating, i.e., completely free of possible transmission of accelerating force by the hands of the observer. Here the birds are in a truly weightless state.

The normal birds were apparently somewhat part, however, they appeared distracted and showed completely random movements while free floating.

DISCUSSION

Six series of observations in a normal gravitational field and the lively response to rotation in a horizontal plane demonstrated the responsiveness of both the normal and the decerebrate birds. Further, failure of compensatory responses of the decerebrates and normals during the weightless state provides evidence that the utricular otolith, which is the sensory receptor for eliciting static reflex compensatory poses, does not function under conditions of zero gravity. Failure of response occurred even though the birds were not hooded (blindfolded).

While considerable caution is required in extrapolating the results of animals to man, it may be concluded on these and on theoretical grounds, that the utricular otolith will not contribute to the sensory input for maintaining static posture of the body during conditions of weightlessness.

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REFERENCE

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"Moon Suit" Doesn't Have Two Pair of Pants, But Will Double as House

An aerospace manufacturer has gone into the couturier field with the fall showing of his "moon suit."

The model, conceived and tailored by company space scientists, will protect the astronaut on the moon during his stay outside of the mother vehicle. The lunar suit will incorporate a full range of internal apparatus to provide a completely liveable environment.

One fascinating feature of the outfit is that it can double as a house. When the lunar explorer gets tired, he can lower a tripod stand, withdraw his legs and sit inside the suit on a small shelf.

The model suit consists of a two-piece cylindrical aluminum tunic and torso with legs and arms attached. Final materials will be chosen for physical and chemical characteristics which make them resistant to repeated exposure to radio-activity, ultraviolet and infra-red radiation, high vacuum, extreme temperature variations and meteorite impact.

The dome-shaped top section is encircled by a 14-inch high window. Inside the capsule is the radio communication unit, the airconditioning and oxygen supply controls, lifting handles, resting seat, food storage bins, waste storage bins, searchlight control and electrical power supply.

To increase safety of the astronaut, there will be a system of remote monitoring of the physiological status of the man and the operation of his environmental control system.

The pilot model will undergo exhaustive tests in the company's space simulation chamber capable of re-creating conditions found 300 miles up, as well as in the nuclear radiation laboratory. Initially, the tests of the suit will not include a wearer; later on a subject will actually wear the suit during simulated space conditions.—*Aerospace*, December, 1960.