Send information for publication on this page to: **Philip J. Scarpa, M.D., M.S.**
Biomedical Dept., JJ-C
NASA-Kennedy Space Center, FL 32899
(407) 867-3152
philip.scarpa-1@ksc.nasa.gov

SPACE MEDICINE BRANCH REPORT

Artificial Gravity Research at Brandeis

by David Warmflash, M.D.

Research of human neuromotor adaptation to Coriolis forces produced during movement in rotating environments is being conducted at the Ashton Graybiel Spatial Orientation Laboratory at Brandeis University in Waltham, MA. The latest findings have implications for the possibility of using artificial gravity during future human space missions. These results, summarized below, will be presented at this year's AsMA scientific meeting in Seattle.

Weightlessness produces a variety of undesirable effects on many areas of human functioning including musculoskeletal, neurological, gastrointestinal, hematological, cardiovascular, immunological, psychological and reproductive. For this reason, artificial gravity may ultimately be required during long duration (months to years) human space missions.

For now and in the foreseeable future, the most feasible way of producing artificial gravity is by rotation of the spacecraft (or part of the spacecraft). Since rotation of a spacecraft to create artificial gravity may also create side effects for the crew aboard, it is first necessary to characterize these effects and quantify the limits of rotation tolerance vs. benefit.

The size and configuration chosen for a rotating spacecraft will be dictated by the level of gravity required as well as the maximum speed of rotation to which astronauts can adapt. Since a ship, or part of it, with a shorter radius of rotation must spin faster than a ship with a longer radius in order to produce the same level of gravitational force, it must be decided what is the largest ship that practically can be built vs. what is the smallest (fastest rotating) ship in which we can live and work.

Previous research done in Pensacola, FL, suggested that humans could not function properly at rotation rates much greater than 3 rpm. At 3 rpm, subjects became extremely nauseous and disoriented and their motor coordination was severely impaired. Since side effects were brought on by head movements during the rotation, it was assumed that these motor coordination problems had resulted only from Coriolis forces acting on the semicircular canals. Because of this assumption, attempts to correct the problem of motor coordination focused on trying to adapt the vestibular system to the Coriolis force. While this approach helped to reduce (although not completely eliminate) the problem of nausea, it was not helpful in the area of motor coordination and for this reason, it was concluded that 3 rpm would be the limit for a rotating spaceship.

If 3 rpm were the limit for an artificial gravity spaceship then, in order to produce a force of 1 G ($9.8\ m \bullet s^{-1} \bullet s^{-1}$) for those aboard, the ship would require a rotational radius of 100 m. Such a ship would be very difficult and costly to build. However, if the 3 rpm limit could be increased, the size of the ship could be greatly reduced. Since attempts to correct the motor control problems by adapting subjects to vestibular input had failed, researchers at the Graybiel Lab began to wonder whether the motor control problem was primarily the result of a vestibular effect or, rather, a separate Coriolis effect acting directly on the moving body parts. If the problem were due more to the latter, then it would be easy to understand why adaptation techniques directed at the vestibular system were not successful in reducing the motor control problems. It would also open up the possibility that humans might be able to adapt the motor control system to higher revolutions per minute under the right conditions.

To study this possibility, Graybiel researchers began by looking at reaching arm movements made inside a rotating room. In this experiment, the subjects were seated in the center of the room during rotation and were asked to make 40 reaching movements for each preset condition during prerotation, rotation, and postrotation. The room was spinning counterclockwise at 10 rpm creating a Coriolis force on the moving arm. They found that subjects were able to adapt to the non-vestibular Coriolis force produced when the arm was moved linearly with respect to the room. Since the reaching movements were made in the forward direction, the direction of the Coriolis force was predicted to be to the right. The equation for the Coriolis force is $F_{Cor} = -2\ m\ (w \bullet v)$ where w is the velocity of rotation of the room in rad $\bullet$ s^{-1} and v is the velocity of the arm. The results were: the subjects' reaching arm movements were deflected in the direction predicted by the equation during the early trials of the rotation condition compared to baseline and a gradual return to baseline by the end of the rotation condition. During the early trials of the postrotation condition, the arm was deflected in the opposite direction with a return to baseline by the end of the condition so that the postrotation curve of trial number vs. amount of deviation was a mirror image of that of the rotation condition. The results helped show the existence of a non-vestibular/motor control Coriolis effect for the arm and that adaptation was rapid.

More recently, the same experiment was performed to study this effect during leg movements. As in the arm experiment, the subjects were seated in the center of the room during prerotation, rotation at 10 rpm counter-clockwise and postrotation. Since the leg movements were also in the forward direction, it was predicted that the Coriolis deflection would be to the right. The results obtained were very similar to those obtained in the arm reaching experiments: subjects' leg movements were initially deflected to the right and returned to baseline as the rotation trials progressed. These results helped to suggest a motor control Coriolis effect for the leg and that, as in the case of the arm, adaptation was rapid.

Since it was important to know if a similar effect would occur during eye movements, experiments were conducted to study eye saccades (very fast eye movements) during the conditions of prerotation, rotation, and postrotation, as in the case of the arm and leg. Because saccades are small compared to the other types of movements studied, the room was rotated at 28 rpm instead of 10 rpm as was in the case of the arm and leg experiments. The results obtained were again similar to those found in the arm and leg experiments in that the eye was initially deflected in the direction of the Coriolis force (toward the subjects' feet) with a return to baseline in the late rotation trials.

Thus, a non-vestibular/motor control Coriolis effect was shown to occur during arm, leg, and eye movements in an artificial gravity environment and that adaptations occurred rapidly and at high levels of rpm (10 and 28).

By establishing and increasing our understanding that there are separate motor control and vestibular effects of rotation on the human body, we may be better able to learn how to adapt astronauts to rotation levels substantially greater than 3 rpm. Since rapid adaptation of the motor control system to 10 rpm (arm and leg) and 28 rpm (eye) is much higher than the 3 rpm limit, experimental artificial gravity environments that only produce rotational effects on motor control should be expected to raise this human rpm limit. This means that 1 G of artificial gravity could be generated with a spaceship much smaller than 100 m in radius and still be tolerated by its crew so long as they limited their head motions during adaptation. Adding to this the possibility that a full 1 G may not be needed by the body to prevent the undesirable effects of weightlessness, an artificial gravity equipped space ship may not need to be overly large at all.

Attention Society of USAF Flight Surgeon Members!

Join us during the Seattle AsMA meeting on Wednesday, May 20, 1998, 6-9 p.m. at the Pyramid Alehouse for our annual Society Social.

- Pay as-you-go bar.
- Complimentary appetizers.
- Located near many restaurants--a great starting point for your "reunion" dinners.
- Free to members and a guest--get your ticket at the Society Membership table as you update your membership dues (or join the Society for the first time).