Microgravity Measures of Acuity

Leslie Sabbagh, Editor in Chief

Special Report is a new department that will cover, from time to time, cutting edge research and developments in ophthalmology.

Spectacular, glorious, awe-inspiring. The terms astronauts have used over the past 25 years to describe earth from their vantage point in orbit are widely reported. Less well known, however, is that for some of them that stunning view may begin to blur within hours of their launch.

In fact, about 34% of astronauts say they lose acuity during their missions, said Keith Manuel, a Houston-based optometrist who provides vision care for the astronaut core and the pilots and crews of NASA's Ellington Field aircraft operations division.

To date, all astronauts have been able to complete their jobs so "my guess is that they've lost no more than a line of acuity," Manuel said. Usually near acuity blurs a bit, with the majority of changes seen in pre-presbyopic hyperopes.

Qualified data

Weightlessness is a challenging environment in which to make an ophthalmic diagnosis; to date, there are no hard data to quantify vision loss in orbit. Manuel bases his estimate of vision loss on pre- and post-flight exams. He performs an annual comprehensive eye exam on every astronaut and another comprehensive exam six months pre-launch when he programs vision needs (contact lenses, spectacles) for a particular mission. He does comprehensive exams again at launch minus 10 days (L-10); three days after their return to earth (R+3); and, if necessary, in another five days (R+8). He compares pre-flight to post-flight data and evaluates questionnaires that ask a barrage of questions including whether astronauts have experienced any trauma or change in vision.

Usually astronauts adjust to the vision loss within days, he said. If they maintain the vision loss throughout the flight, they usually regain it within hours of their return to earth and gravity. Only 3% who notice a vision change sustain that change at their R+3 exam. All have returned to their pre-flight acuity by R+8.

"Astronauts aboard the International Space Station have a similar experience; they adapt to the change and move on," Manuel said.

While these changes seem benign in the short term, NASA wants a better idea of how astronauts' acuity might be affected in longer missions, say the two- to three-year Mars journey.


Figure 1. The KC-135 microgravity airplane at NASA's Glenn Research Center in Cleveland. (left to right): Kwang Suh, (senior research associate), James King (design engineer), Rafat Ansari, (principal investigator), Ace Beall (pilot), Frank Marlow (co-pilot), John Yaniec (lead flight test director), John Lamb (flight engineer), James Withrow (flight test director).

Etiology

Weightlessness induces a 1.5 liter fluid shift above the navel. That's why, at least early in missions before they've adapted, astronauts' faces look puffy. It can take hours to a few days before endothelial baroreceptors detect and regulate the body's fluid distribution in zero gravity.*

But the choroid has no

**Zero gravity does not mean that gravity has disappeared. Rather, the environment is weightless because the vessel (space ship or aircraft) is in a free-fall configuration—the centripetal and centrifugal forces on the vessel are balanced because they are equal and acting in opposite directions.*

baroreceptors. The hypothesis is that as it engorges with fluid, it shifts and pushes the retina forward thereby creating a shorter focal length, Manual said. This would likely affect hyperopes, particularly pre-presbyopic hyperopes.

Figure 2. Blood pressure and LDF measurements in zero-g. left to right, (Upside down) Keith Manuel, (Back) Bobby Clark, King, (Front) Raul Blanco (blood pressure test subject), Ansari, and Geoffrey Iszard (LDF test subject).

Testing the hypothesis

Two years ago Manuel and Rafat Ansari, PhD, a fluid physics and aerospace scientist at Cleveland's NASA Glenn Research Center, began to investigate non-invasively choroidal hemodynamics in weightlessness. Ansari and his team in collaboration with Martial Geiser of the Haute Ecole Valaisanne in Sion, Switzerland, developed a head-mounted laser Doppler blood flowmeter (LDF) to measure choroidal blood flow. The helmet weighs about two pounds and supports a 100-microW laser which is directed through the pupil for about five seconds where it interacts with choroidal red blood cells. It was tested first in the lab then in the only place that can simulate the conditions astronauts experience in orbit—NASA's Weightless Wonder V, a refitted Boeing KC-135, an aircraft designed to house microgravity experiments and their researchers. Each two-hour flight session consists of 40 to 45 parabolic trajectories that reach zero, lunar, and Martian gravity. It varies, depending on weather and weight conditions, but usually the pilots can coax up to 23 seconds of zero-g, 15 seconds of lunar-g, and 20 seconds of Martian-g for each parabola. To reach the 50° nose high angle necessary to launch into weightlessness, the pilots accelerate close to the speed of sound. At this point the pilot pulls back on the control wheel to establish a 2-g pullup and the co-pilot throttles back the engines.

In October 2002, Ansari and the team's design engineer, Jim King, tested the LDF on KC-135 flights. They used the device to measure choroidal blood velocity, volume, and flow and simultaneously used a blood pressure cuff to measure pulse-to-pulse, systemic blood pressure.

Since that time Ansari has performed measurements on 25 volunteer subjects including a few astronauts. The subjects were strapped into a seat in front of a specially designed rig which was bolted to the airplane's floor. At the beginning of the flight the head-mounted LDF unit and the blood pressure (BP) cuff were put on the test subject and all the instruments were turned on. Focus adjustments were made on the LDF unit by the test subject to align the instrument to obtain the maximum light output (DC signal) and Ansari and King took the LDF and BP measurements.

The data are still being analyzed. In general, the researchers found that both systolic and diastolic blood pressure changes significantly during flight, decreasing in weightlessness and increasing in 2 g's. The choroidal blood velocity and flow increased in weightlessness and decreased in 2 g's. The volume data in 2 g's, however, had higher than acceptable noise levels due to excessive aircraft vibrations during 2 g maneuvers, so these data could not be compared reliably with the weightlessness volume data.

Future

Although these experiments showed that the choroidal hemodynamics can be monitored non-invasively in weightlessness and 2 g's, "they did not provide us with a detailed picture, for example, whether the choroid is self-regulating," Ansari said. His plan is to fly the experiment on the space station where longer and more stable periods of weightlessness

Figure 3a. Simultaneous choroidal hemodynamics and blood pressure measurements in weightlessness (left to right) Ansari, King, Manuel, Clark.

Figure 3b. Blood pressure and LDF measurements in zero-g. Note facial edema in BP subject King. (left to right, seated) King, Rafat Ansari, Laura Moore. Rahila Ansari manages BP data.

can be achieved. Kwang Suh, PhD, of the Ohio Aerospace Institute in Cleveland is working with Ansari to refine the LDF device for astronaut use in space.

Another point to consider is whether vision loss is different in eyes with thinner corneas due to PRK or LASIK. Due to their inherent instability, “RK eyes are not allowed and never will be allowed to fly these missions,” Manuel said. **RRS**

Images courtesy Rafat Ansari.

An excellent adventure

NASA’s Zero-g Bird is a specially modified KC-135 turbojet transport that flies parabolic arcs. The cargo bay test area is about 60 feet long, 10 feet wide and 7 feet high. A typical mission consists of 40 to 50 manuevers and lasts two to three hours. While lunar (1/6 g) and Martian (1/4 g) gravity can be achieved, scientists usually want the pilots to give them as much time as possible in zero-g, about 25 seconds per parabola.

This aircraft is special to the eight pilots who fly her. “Pilots like flying the Viet Nam era vintage aircraft because they're less automated than current aircraft,” said Ace Beall, chief of flight operations, Johnson Space Center, Houston. Weightless Wonder V will be retired this year to make way for NASA's new microgravity aircraft, a former U.S. Navy C-9, the military equivalent of a DC-9 (30 series).

It isn’t easy winning a seat on the world’s biggest, highest, fastest roller coaster. Academic, industry, and government scientists battle like club fighters just for the chance to fly their experiments on NASA’s KC-135 microgravity aircraft. Non-scientists almost never fly.

So when I learned that NASA Glenn Research Center scientist Rafat Ansari, whose work I’d covered for years,* got the nod to fly his choroidal hemodynamic experiment on the KC, I petitioned NASA to ride along and write about it. In January 2003 the agency granted approval to start the process that would eventually allow me to undergo physiological training for microgravity flights. After a battery of physical exams and a trip to Johnson Space Center’s Neutral Buoyancy Lab for high altitude flight simulation chamber testing, NASA cleared me to fly.

On July 22, 2003, I get my reward on the Weightless Wonder V when I fly as a test subject in Rafat and Keith Manuel’s study. I sit in the jumpseat behind aircraft commander Arthur C. (Ace) Beall and co-pilot Bruce Arnold for takeoff. We fly northwest from NASA’s GRC in Cleveland through rough air to the Steelhead MOA (Military Operations Area) over Lake Michigan, just east of Bad Axe, Mich. This is protected airspace—that means we have free roam in this MOA from altitudes spanning 18,000 to 39,000 feet.

Jim King, the experiment’s design engineer, hurries me from the cockpit to the back of the plane through the floor-to-walls-to-ceiling padded cabin crammed with crew, scientists and experiments. Rafat and Jim belt me in, strap my feet to the floor and my forearms to the armrests, attach the blood pressure cuff, and clamp their laser Doppler flowmeter to my head. My job seems simple enough—stay as still and quiet as possible so that Rafat and Jim can get reliable blood pressure and choroidal hemodynamic data. All I need to do is fixate with my right eye on the laser’s red pinpoint through a series of weightless and 2-g maneuvers. But I can’t. Even though I fixated easily in the pre-flight and level flight tests, I find it hard to fixate now, first in the rough 2-g ride, then in zero-g. We discover later that my exophoria probably got in the way.

Aboard the KC-135 in microgravity.

They release me after the first set of parabolas and begin work on a new experiment designed to test acuity in microgravity. We fly level for a few minutes in the turnaround phase. Back at our starting point, the aircraft trembles at first, then shakes with power as Bruce throttles up the four massive turbojets and Ace angles the KC in a 50° nose high ascent at 600 mph. It’s a rocketing roar up the sky and in a few seconds we go weightless. The pilots throttle back to idle, level the KC and we catapult into silence, floating for about 30 seconds.

On the descent, the other side of the parabola, the pilots hold steady then ease the aircraft 50° nose low, back into earth’s gravity. At 25,000 feet we level out, then launch into another 2-g climb.

Before we left Cleveland, flight engineer John Lamb promised me that if I didn’t get sick during the parabolic manuevers, I could return to the cockpit for landing. At the 36th parabola I unzip the right breast pocket of my flight suit and partially pull out one of the two flimsy airsickness bags NASA provides to microgravity fliers. After the 39th parabola I replace it, unused, as I rush to the cockpit to reclaim my jumpseat.

—Leslie Sabbagh

****see RRS May 2002; “Dynamic Light Scattering Focuses on the Cornea” pp.28, 30-31***