- Tuesday, June 17, 1997
  Vestibular Adaptation During Microgravity

3.1 Andy Clarke. "Measuring the vestibulo-ocular reflex in micro-gravity"

3.2 Some of the history of measuring eye movements in space was described. This put Andy Clarke's use of three-dimensional video-oculography in the orbiting MIR space station in context.

3.3 The vestibulo-ocular reflex is when the eyes move to compensate for head rotation under vestibular control. To remove the visual drive to the same system, measurements are usually made in the dark. Ideally the eyes would move equally and oppositely to the head, that is they would rotate at the same speed and by the same amount and around the same axis as the head, but in the opposite direction. This would ensure a nice stable visual image during head rotation.

3.4 Although ocular stability is roughly achieved by vestibular influence alone for rotation about the yaw and pitch axes (yaw is about an axis through the top of the head, the pitch axis goes through the ears), the response to roll rotation (the roll axis sticks out your nose) is not so good. It has a much smaller gain (efficiency, defined as output divided by input, 1.0 would be perfect) and is often around the wrong axis, that is instead of being around a roll axis, there are actually yaw and pitch components in the response.

3.5 This can be quantified by what is called a GAIN MATRIX. The velocities of the three components (yaw, pitch and roll) of the response to rotation about each of the yaw, pitch and roll axes are measured. If they were perfect, then yaw head movement would only evoke yaw eye movement, pitch head movement would only evoke pitch eye movement and roll head movement would only evoke roll eye movement. This is what it would look like if it was perfect:

These head movements ---> ROLL PITCH YAW

Evoke this much roll eye movement> -1.0 0 0

.....this much pitch eye movement> 0 -1.0 0

..and this much yaw eye movement> 0 0 -1.0

But it is not perfect:

These head movements ---> ROLL PITCH YAW

Evoke this much roll eye movement> -0.39 0.05 0.06

.......this much pitch eye movement-> -0.16 -0.80 0.04

...and this much yaw eye movement-> 0.23 0.01 -0.84

The minus signs indicate that the primary eye movements are moving opposite to the head (as they should). The response to roll rotation was the primary focus of this talk (left hand column). Notice that roll head rotation evokes roll eye movements with a gain of only 0.39. In other words, 61% of the roll head motion is not compensated by roll eye movements. Also, there is bleed through into the pitch and yaw eye movement systems. These eye movements are not helpful for the task in hand (compensating for roll head movement) but indicate some central linkage in the eye movement generation system.

3.6 In space, where no one can hear you scream, the gain matrix changes:

These head movements ---> ROLL PITCH YAW

Now evoke this much roll eye movement> -0.27 0.03 -0.02

..........this much pitch eye movement --> -0.10 -0.81 0.06

....and this much yaw eye movement --> 0.16 0.07 -0.93

The main things are that the roll gain is reduced and that bleed through from the roll head movement into the generation of pitch and yaw eye movements has reduced.

3.7 And afterwards, it comes back:

These head movements ---> ROLL PITCH YAW

Now evoke this much roll eye movement> -0.35 0.08 0.12

...........this much pitch eye movement --> 0.06 -0.84 0.09

....and this much yaw eye movement --> 0.27 0.06 -0.84

Especially the roll gain and the yaw bleed through to roll head movements.

3.8 Longitudinal studies indicate that the roll gain becomes unstable for several days after arrival at the station but then settles to a lower value for the duration of the stay in space. After return to earth some 175 days later, it again becomes unstable but then recovers its pre-flight value. The time constants of these "adaptations" is considerably longer than previously assumed, largely on the basis of subjective measures of neurovestibular function during the much shorter Shuttle flights.

3.9 These findings are probably related to the fact that roll rotation on earth is accompanied by a change in orientation with respect to gravity but, of course, not in microgravity. The changes support the idea of neural adaptation in the interaction between the afferences from the semicircular canals and the otoliths. The data represent a challenge that any three-dimensional description of the eye movement control system must meet.

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