- Friday, October 4, 1996
  Ocular Torison During Roll

1.0 Today's talk was by Eric Groen. He talked about otolith and canal contributions to the generation of ocular torsion (eye movements around the line of sight) during head tilt. This was work he had done in Holland at the TNO with Willem Bles, Jelte Bos, Bernd de Graaf and Lex Wertheim.

1.1The OTOLITH system detects linear acceleration (including, of course, gravity) and discharges action potentials in proportion. When you tilt your head, the OTOLITHS of the saccule and utricle have their orientation with respect to gravity changed and their firing rates change accordingly. Since there are two sets at approximately 90 degs to each other, this enable the details of the tilt to be reconstructed at least theoretically even without access to the value of 'g'. The two systems are called the utricle and the saccule and there is some doubt about how active the saccule is in humans.

1.2 A static tilt of the head around the ROLL axis (going through the nose) causes a counter- rotation of the eyes. However this response has a low gain (output/input) reaching a maximum of only about 4 degs of eye tilt for tilts up to 90 degs. The curve LOOKS like it saturates at around 4 degs for tilts beyond 30 degs. Experiments using a centrifuge, however, show that static torsional eye movements can be evoked up to at least 12 degs.

1.3 During the actual act of tilting, the semicircular canals are also active and might be expected to contribute at least to the dynamic part of the response.

COMMENT: (added by me during the write up - not at the time)

WHY SHOULD ANYONE BE INTERESTED IN OCULAR TORSION?

There are a number of reasons why this is an interesting topic, not just a laboratory curiosity. Perceptual judgements rely on a knowledge of where the eye is and when the head is tilted, the perceptual consequences might be in part explicable in terms of the orientation of the eye. Clinically, the response to head tilt is one of the few ways available for assessing otolithic function. And physiologically, almost all head movements contain elements of tilt, so these responses are part of the solution the brain adopts in dealing with real, ie. three-dimensional, head motion.

2.0 In order to look at the relative contributions of the canals and otoliths to the oculomotor torsion response during head tilt, Eric designed a very simple experiment. People were rotated about their ROLL axis either while they were upright (axis of rotation earth-horizontal) or lying on their backs (axis of rotation earth-vertical). When they were upright, rotations stimulated both the otoliths and the canals; when they were lying down, only the canals were stimulated by the rotation. Eye movements were recorded, using a video system. This eye movement recording technique is becoming quite popular although it is still very expensive and goes by the name of VIDEO-OCULOGRAPHY (VOG). Although both eyes were measured, no interesting differences between the eyes' responses have yet emerged.

2.1 When you rotate a person in either of these postures, you get a torsional eye movement which has slow phases which tend to be in the opposite (compensatory) direction to the head tilt and a fast phase which is in the same direction as the head tilt and tends to bring the eyes back to where they started from.

2.2 The gain (peak velocity of the slow phase as a fraction of the peak stimulus velocity) and phase tend to be quite constant over a range of amplitudes (12-50 degs @ 0.25 Hz), with the otolith + canal condition yielding a slightly higher gain.

2.2.1 COMMENT: These data are similar to those published by Misslisch, H.//Tweed, D.//Fetter, M.//Sievering, D.//Koenig, E. "Rotational Kinematics of the Human Vestibuloocular Reflex" 1,2,3. JOURNAL OF NEUROPHYSIOLOGY (1994) 72: 2467--2502 and the phase lead might be due to a leaky velocity to position integrator in the torsional system. (Peak velocity to the left, say, must happen before peak position in that direction is achieved, so a tendency to not integrate before sending the signal to the eye muscles can produce a phase lead).

2.3 Gain increases a bit with freq (0.05-0.4 Hz) but the difference between the two conditions is fairly constant over this range. The phase lead however is consistently above about 60 degs for the canal-only condition but is nearly 0 (the correct value for really compensatory eye movements) for low frequencies (0.05Hz) when both otolith and canal stimulation are present. The phase lead reappears, even for when both otoliths and canals are stimulated, for frequencies above about 0.2 Hz.

2.4 At low frequencies, at any rate, the systems seem to add complementarily and produce genuinely compensatory eye movements.

3.0 Looking at the raw records indicated a much larger overall range of positions (which you might call the beating field) for the canals and otolith condition than for the canal alone condition.

3.1 This seems to be because of faster and more frequent saccades or fast phases in the canal- only condition. This is despite the larger SLOW phases of the combined condition which you might have thought would have taken the eyes into the "let's trigger a fast phase to get back" mode more. So it seems that the concurrent otolith stimulation is inhibiting the fast phase generation mechanism.

3.2 The functional consequence of suppressing fast phases is to fit the otolith generated response more to compensating for a POSITIONAL change of the head. Fast phases CHANGE the position of the eyes in space, so they are rather counterproductive to the aim of stabilizing the position or orientation of the eyes in space.

4.0 COMMENT: of course some of these effects might be at least partially due to the different body postures between the two stimulations. Perhaps looking at the canal-only response to tilt in space might be useful...

Eric Groen