- Friday, February 7, 1997
  Neural Basis of the Translational Vestibulo-Occular Reflex

  1.0 These are the minutes for YORKVIS 2/97

  1.1 Next meeting March 1st by Laurie Wilcox. Something to do with stereovision, I am sure.

  2.0 Dave Tomlinson of the dept of Otolaryngology of the University of Toronto gave us a talk last Friday on the translational vestibulo-ocular reflex.

  2.1 The vestibulo-ocular reflex (VOR) operates to move the eyes so as to try and minimize image movement during head movement. Head movements (like movements of anything) have angular and translational components. The eye movements required to compensate for the ANGULAR component of head movement are always the same: they just need to rotate by an equal amount in the opposite direction. The TRANSLATIONAL component is more tricky because what the eyes need to do depends on context. (And notice that pretty nearly any rotation of the head involves translation of the eyes as well as rotation).

  2.2 The execution of the angular VOR involves two distinct classes of VESTIBULAR NUCLEUS neurones. In the monkey these are called Position-Vestibular-Pause cells (PVPs) and floccular-target-neurones (FTNs). (LRH: although others would disagree that this is the relevant division, also this is probably not a comprehensive list of all the vestibular cell types involved)

  2.2.1 PVPs have behaviour that is altered in response to several factors including angular head acceleration, eye velocity and eye position. Their eye and head velocity sensitivities are in opposite directions so that a PVP cell that is, for example, excited by head movements to the left will be excited by eye movements to the right. Head rotation elicits compensatory eye movements in the opposite direction (the angular VOR) so that during head rotation the two signals augment one another. During saccadic eye movements, these cells pause.

  2.2.2 Floccular target neurones (FTNs) are identified anatomically as receiving input from the flocculus which is part of the cerebellum. Their behaviour is distinct from PVPs since, although like PVPs they respond in a way related to eye velocity and eye position, their behaviour is more noticeably non-linear. That is, while the PVP's firing rate is proportional to, say, eye velocity, FTNs will have a slope or sensitivity that varies depending on the velocity. Another difference is that most, although not all, FTNs have eye velocity and head velocity sensitivities in the SAME direction. Thus during the angular VOR these two signals tend to cancel since the eye and head velocities are in opposite directions.

  2.2.3 So how do these cells respond during TRANSLATIONAL head movements?

  2.3 Dave has cleverly used 'off centre rotation' to look at the behaviour of these cells during translational movements. The centrifugal forces are kept below threshold and a tangential translation is thus applied simultaneous with the rotation. The geometrical determination of eye movement required to maintain fixation on a target during this compound movement depends on the direction the subject is looking and the position of the target relative to the axis of rotation.
  The ANGULAR component is always the same (to the left in response to rightward rotation) but the translational component varies with the context: in particular it varies with the distance. When looking in towards the axis with the target CLOSER to the animal than the axis of rotation it requires a rightward eye movement (for the rightward off-centre rotation). When looking AT the centre of rotation, it requires no eye movement at all. When looking at a target BEYOND the fixation point it requires a leftward eye movement. Eventually, when the target is far enough away, the required eye movement becomes the pure angularly-driven response.

  2.3.1 Looking at the EYE MOVEMENTS shows that these geometric demands are met and that monkeys show appropriate responses to fixate these targets, at least at the relatively high frequencies used in these studies.

  2.3.2 Latency studies suggest the response to the translational component cuts in with a latency of shorter than 40 ms which is far too fast to be under visual control.

  2.4 By looking at PVP and FTN cells during these various stimulus combinations one can compare their responses. If they ONLY responded to the angular component, for example, then the vestibular component of the response would be unchanged: although the eye position and velocity components would be affected by the different motor response elicited under each condition. If eye-related effects are controlled for, the VESTIBULAR component can be isolated. Assuming linear summation of vestibular components, the translational vestibular component can be deduced by subtracting the response to angular rotation alone (on-centre rotation) from the response to translation + rotation (off-centre rotation).

  2.4.1 PVP cells. Their response to compound stimuli seem have a phase inappropriate for generating the eye responses found. Furthermore, the magnitude of their response (revealed by the subtraction technique 2.4) is inadequate to do the job. When the eyes are kept still (by providing them with a monkey-stationary target: so-called 'cancellation') the response of PVP cells is essentially unaffected by the simultaneous translation.

2.4.2 FTN cells. Their response shows a huge modulation in response to the translational component. So much so that the cells often 'clip': that is their firing rate hits zero and they essential rectify the signal (only let half the cycle through). Cancellation experiments showed them to be strongly affected by the translational component and by the distance of the target.

2.5 FTNs are thus significant candidates for the role of controlling a flexible reflex (if that is not an oxymoron) that needs to alter its properties from moment-to-moment as target distance and direction of gaze vary. PVPs are not.

2.5.1 But in fact the behaviour of neither class of cell is so correlated with the eye movements to be able to deduce that any of these angularly-and-linearly-driven vestibular nucleus cells are the drivers.

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