Electrical Stimulation of the Paramedian Reticular Formation: II. Testing a Gaze Control Hypothesis.
Edward G. Freedman and Stephen Quesy - Dept. of Neurobiology and Anatomy, University of Rochester Medical Center, Rochester, NY.

Introduction:
The Neocerebellar Reticular Superficialis (NRG) receives direct input from the Superior Colliculus, and projects innervatonally to receive sensory control of voluntary eye movements. The NRG is well placed to play a critical role in controlling head movements that are a component of head or eye head orienting movements. This assumption is confirmed by electrical stimulation of the NRG which in the absence of ongoing movements causes a percentage of head movements (rotatory eye movements). Here we use electrical stimulation of the NRG during a visually-guided gaze shift in order to limit the critical probe of normal gaze control models.

Hypotheses:

**A.**

- **Critical Predictions:**
  - The model outlined in panel A makes two critical predictions based on artificial activation of the head command pathway during ongoing gaze shifts.
    1. Saccadic kinematics will be altered - as a result of the hypothesized gaze-eye interaction in signal proportionality to head velocity following the gaze velocity elicited by the hypothesized prediction that stimulation along the ipsilateral head command pathway will inversely increase saccadic velocity and latency.
    2. Gaze shifts will be HYPERMETRIC.

- **This hypothesis does not assume that gaze amplitude is under dynamic feedback control.** As a result there will be no ocular compensation for the increased head contribution resulting from stimulation of the ipsilateral head pathway. The resulting gaze shifts will be hypermetric.

**B.**

- **Alternative Hypotheses:**
  - Panel B illustrates a class of gaze control models which utilize an estimate of gaze displacement as feedback to control gaze amplitude. In this particular schematic's description the gaze signal is decomposed into separate eye and head commands. These separate signals serve as inputs to separate eye and head burst generators. If the head command pathway were electrically stimulated the neural network of a visually-guided movement (the model predicts):
    1. no difference in gaze shift amplitude - feedback control produces normometric gaze shifts despite the artificially increased contribution of the head.
    2. no difference in saccadic kinematics - there is no real head-eye interaction within the neural network of a visually-guided movement (the model predicts):
       - Saccadic velocity is plotted as a function of time for central movements (black) and for movements made during NRG stimulation (gray). The difference is minimal. 
       - Superimposed saccade velocity increased. 

- **Gaze shifts will be HYPERMETRIC.**

**C.**

- **NRG Stimulation effects on Saccade Kinematics**
  - The upper panel shows the critical features of the model. Panel B, mean saccade velocities are plotted as function of time for four sets of the movement control model - central control (black), and NRG stimulation (gray) including 24 stimulation sites, 4 target locations, up to 3 stimulation frequencies and 3 stimulation durations.
  - The bottom panel shows the comparative effects of the NRG stimulation on the kinematics of saccades. 
  - NRG stimulation produces HYPERMETRIC gaze shifts.

**Results:**

- **NRG Stimulation Affects the Kinematics of Ongoing Saccades.**
  - Saccade latency was reduced during NRG stimulation, and a hypermetric ratio of the latency to saccade amplitude was observed. The change in saccadic kinematics is qualitatively similar - the time required to complete each 20 deg of the saccade. This specific analysis of saccades following NRG stimulation shows the dramatic changes in saccadic kinematics observed with NRG stimulation. Statistically significant hypermetric saccades were observed at all 24 sites at which data were collected (this included over 75 unique stimulation conditions. The NRG stimulation increased saccade latency, decreased the velocity, and altered the duration and frequency of saccadic kinematics).

- **In all examples, gaze shift amplitudes are < 150 deg.**

- **Note that eye movement amplitudes are slightly smaller during NRG stimulation than during control testing.** This could be a result of the vestibulo-ocular reflex working to lower eye movements during the epoch when NRG gaze was calculated based on NRG stimulation without an ongoing movement. This hypothesis and findings here, however, suggest that large gaze movements are corrected for this effect (Uk) as they are not statistically significantly different when compared to control movements.

- **Similar results were observed all 75 conditions tested.** This indicates an increase in stimulation time, up to 4 stimulation frequencies and 6 stimulation durations.

**Summary:**

- In order to test the differential predictions of several alternative gaze control models, we stimulated in the NRG near the onset of visually-guided, head-unrestrained gaze shifts. Data were collected from two subjects at more than 24 sites using several sets of stimulation parameters and locations for visual targets. 
- All sites and under all conditions the results consistently showed the following:
  1. **Electrical stimulation of the NRG altered the kinematics of ongoing visually-guided gaze shifts in a manner consistent with transient reductions in saccade burst generator gain.**
  2. **Gaze shifts were HYPERMETRIC when the ipsilateral NRG was stimulated near the onset of a gaze shift.**

- The degree of hypermetria depended upon the amplitude of the stimulation-induced head movement and the location of the target. Gaze shifts having amplitude 150% larger than control amplitudes were observed.

- These data are consistent with the predictions of the Freedman (2001) hypothesis which proposed that a copy of the head velocity command reduces the gain of the saccade burst generator.

- In addition, the observation that gaze shifts are hypermetric may be inconsistent with models which assume that gaze amplitude is under feedback control.