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Attentional modulation of eye torsion responses

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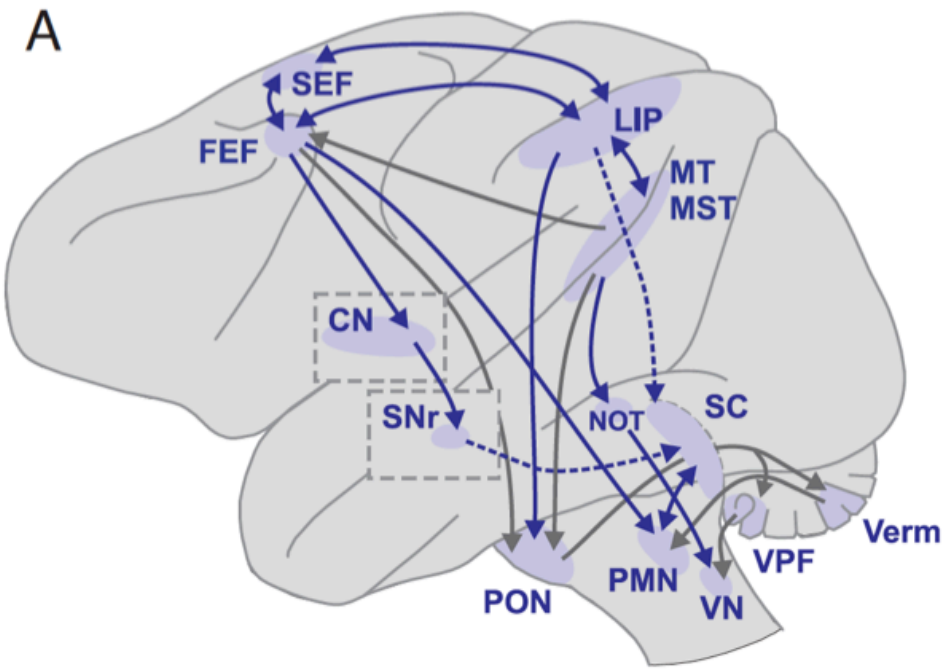
Levels of Oculomotor Control

Eye movements are produced by an interplay of many brain areas. We consider some aspects of eye movement control to be voluntary, involving target selection and visual spatial attention to guide them. We consider others to be reflexive, involving a relatively automatic response to visual input.

Saccades and pursuit movements usually involve target selection and attention. OKN, vertical eye alignment, and eye torsion are usually considered to be reflexive.

Attention also has effects at multiple levels in the brain. In the case of endogenous attention, controlled through verbal instruction, we assume the effect originates in cortex.



Krausliz, (2004) J Neurophysiol 91: 591–603

Does the eye torsion response to a rotating stimulus change with attention?

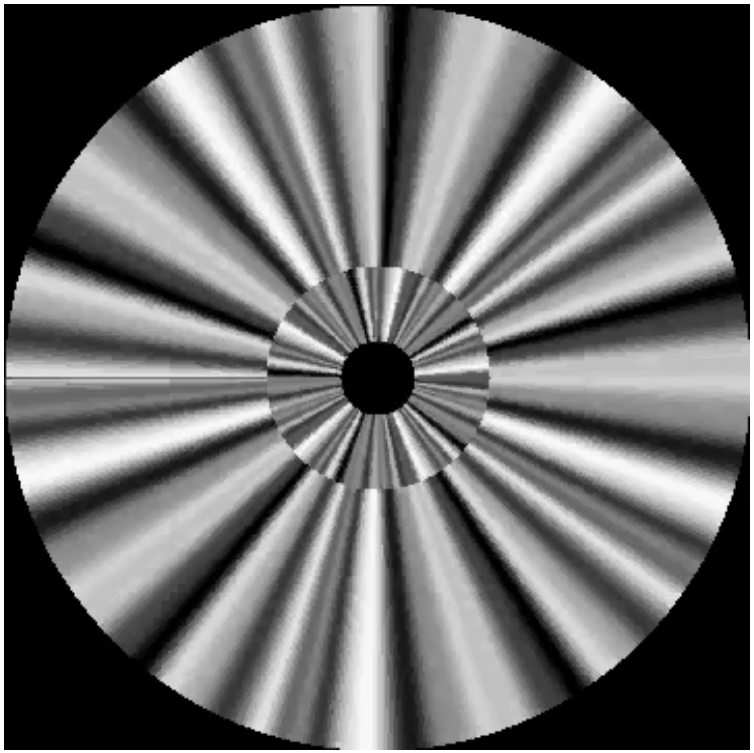
Torsion is a rotation of the eye around the line of sight.

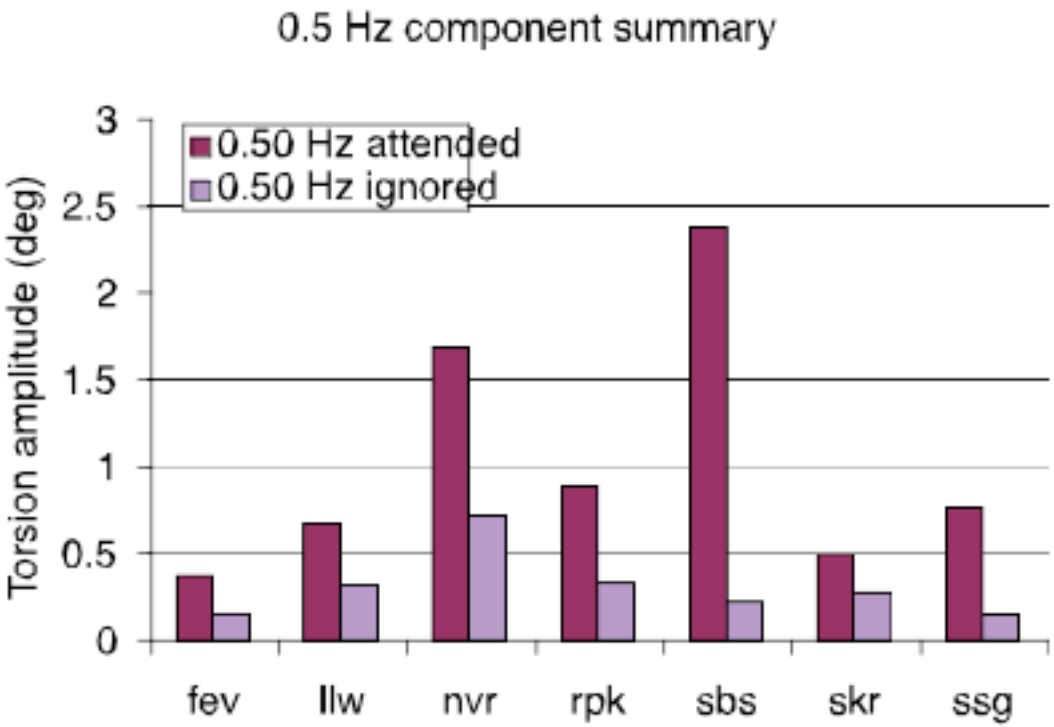
Torsion occurs in response to head roll (VOR) and to rotations of the retinal image around the visual axis (torsional OKR).

Torsion has conjunctive (cycloversion) and disjunctive (cyclovergence) components. Here we look at cycloversion, the common motion of the two eyes.

High level control of torsion?

- Balliet and Nakayama (1978) showed that subjects were able to learn to produce torsion on command, after training.
- In a previous VSS presentation, we showed that subjects respond with higher gain to a torsion stimulus they are attending, compared to one they are ignoring. Attention was manipulated endogenously, by verbal instruction to fixate the center but attend to the motion of either the outer or inner ring.
- The size of the attention effect was around a factor of two overall, but varied among subjects. One subject showed a factor of 10 effect, and this subject was also able to produce torsion at will.





Stevenson, Gopinath, Visco, 2004 VSS

The Eye Movement Correlogram.

In order to study the effect of attention on torsion in more detail, we applied a technique called the Eye Movement Correlogram.

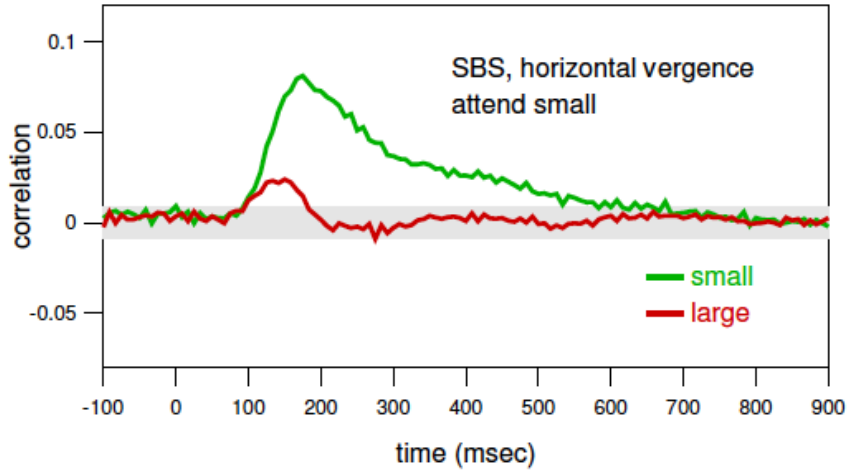
The Eye movement correlogram (Mulligan et al. 2013) is a representation of the latency distribution of eye movement responses to unpredictable target motion, found by correlating pursuit velocity (saccades are removed) with target velocity over a range of latencies.

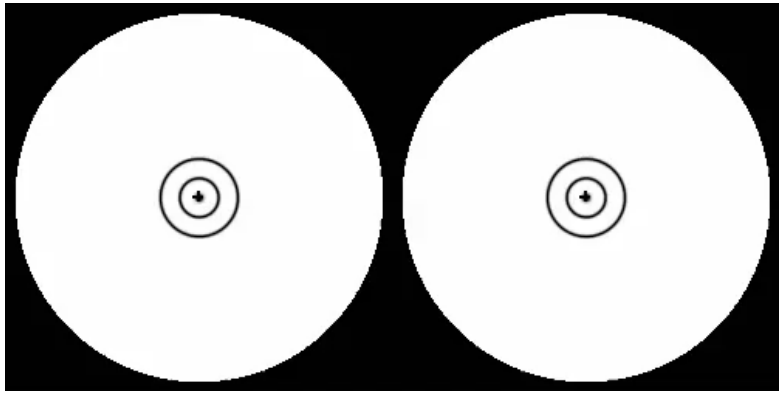
Subjects were presented with two targets, viewed with both eyes. The targets jittered randomly in each eye, stimulating both version and vergence, in both horizontal and vertical directions.

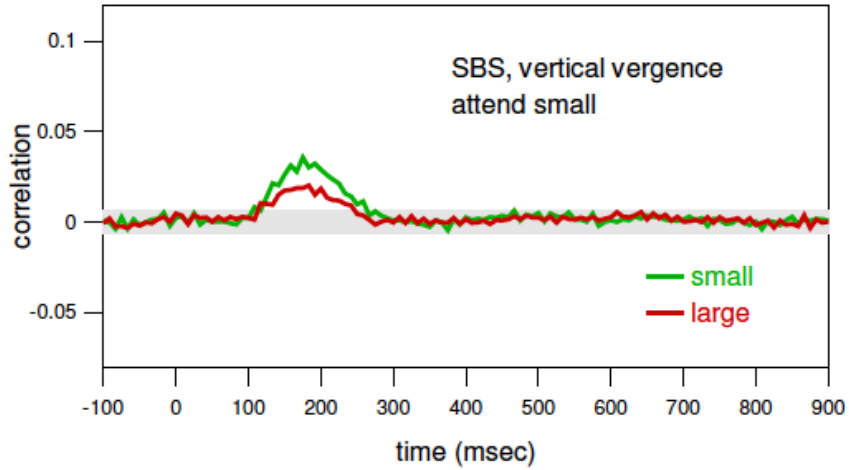
When subjects are asked to track one jittering target and ignore the other, the ignored target is followed with short latency.

The tracked target is followed with both short and long latency components.

The exception is for vertical vergence, where both are followed with short latency.





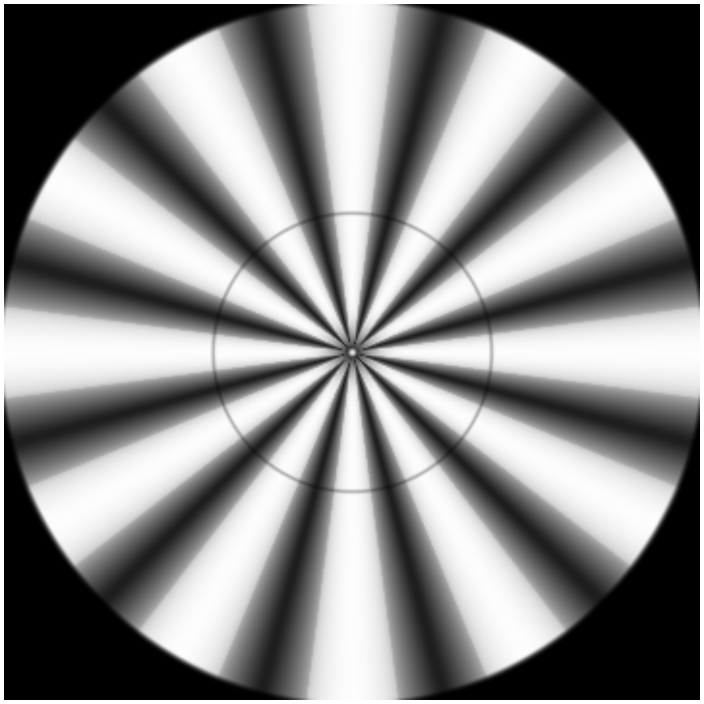


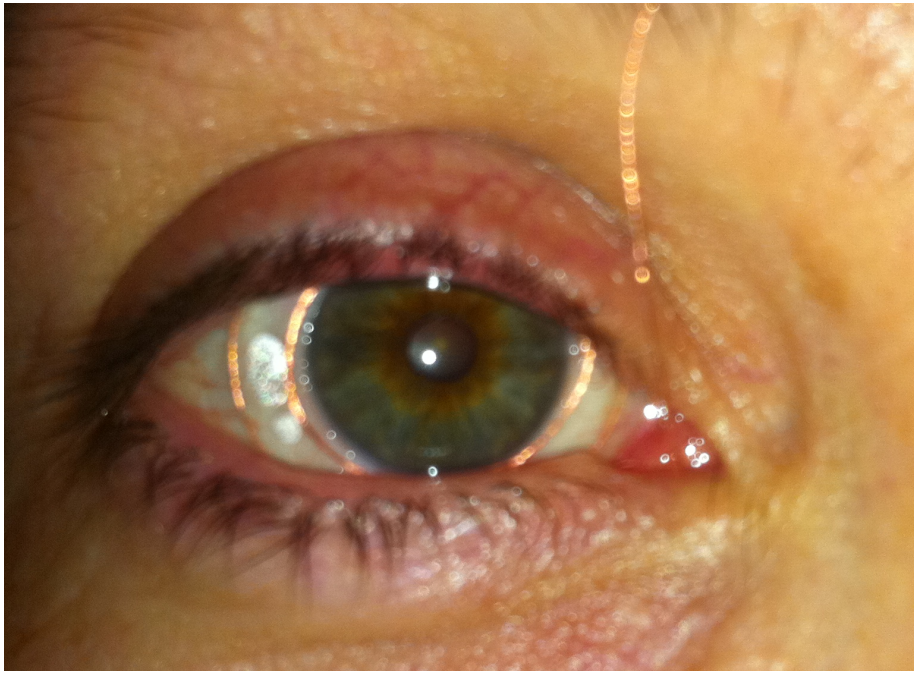
Mulligan, Stevenson, & Cormack 2013 SPIE

Eye movement correlograms for torsion

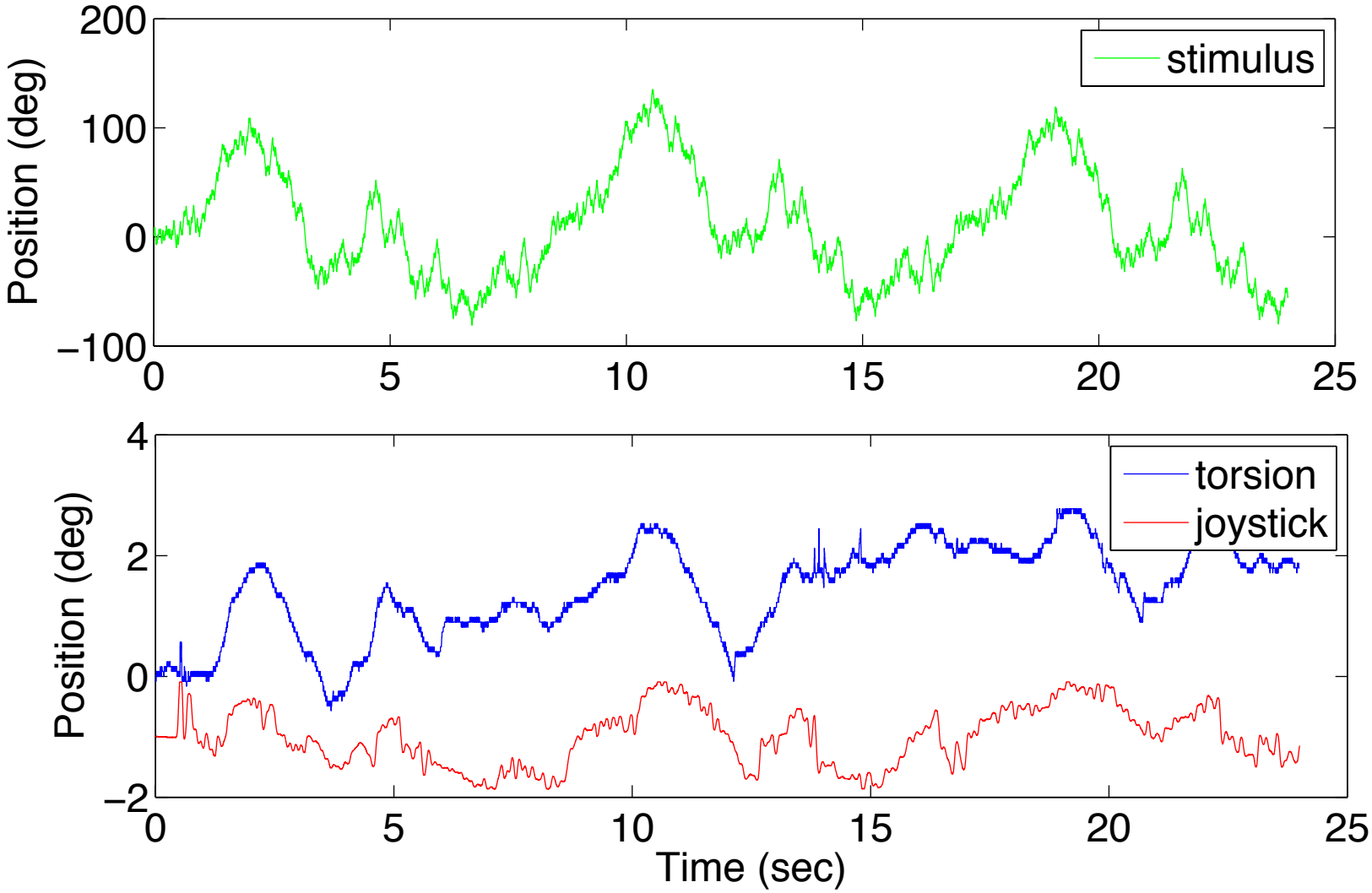
The stimulus rotated CW or CCW in an unpredictable sequence, and subjects were asked to fixate the center, but pay attention to just one annulus or the other ("inside" vs. "outside"). The subjects were also given a joystick that we asked them to wiggle back and forth to track the motion of the stimulus they were attending. The joystick task is primarily designed to help focus attention, but we also correlated joystick responses against the two components' velocities.

Eyes were tracked at 500 Hz with the scleral search coil technique. The stimulus was rear projected at 60 Hz and subtended about 70 degrees of visual angle.



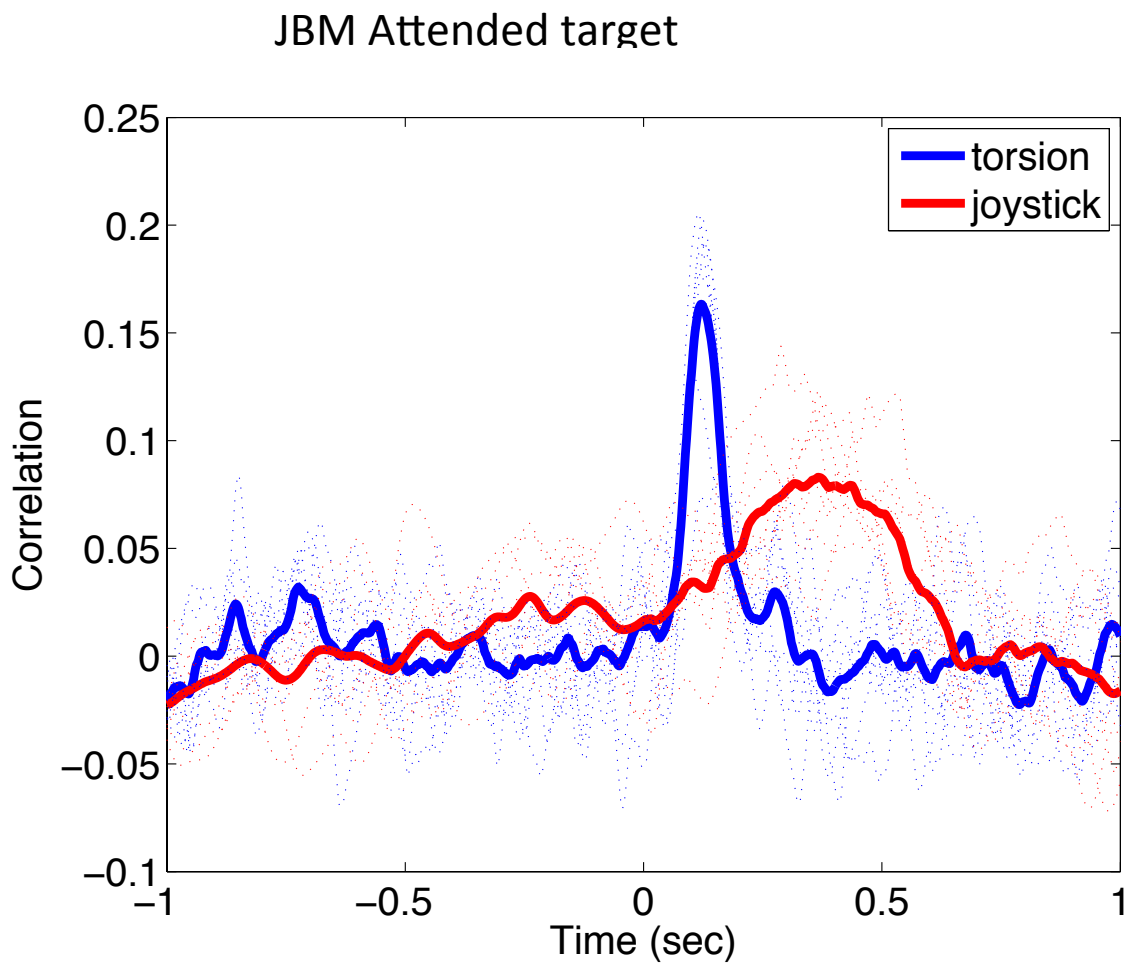


Raw traces


200
100
0
−100
Position (deg)
stimulus
0
5
10
15
20
25
4
2
0
−2
Position (deg)
torsion
joystick
Time (sec)

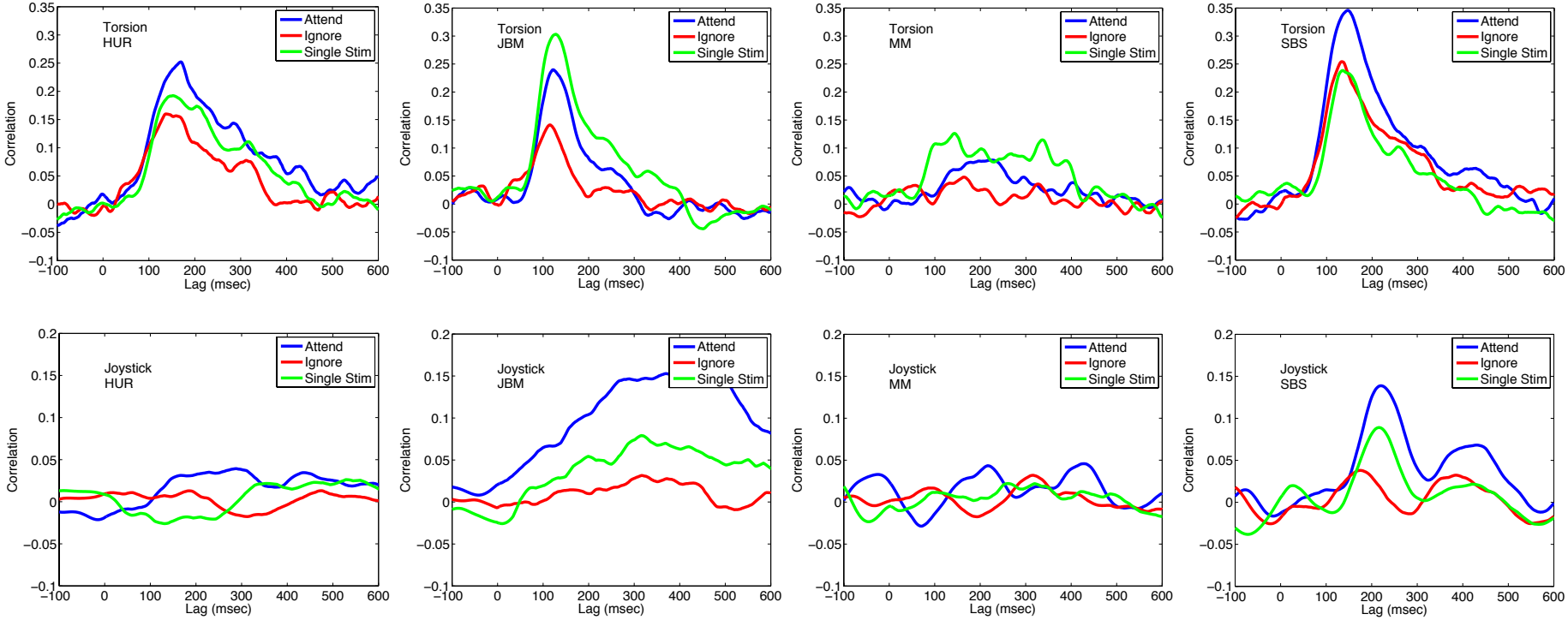
Correlogram

Position traces are converted to velocity and then cross-correlated over +/- 1 second to produce the correlogram



Eye and Hand Movement Correlograms

Correlograms

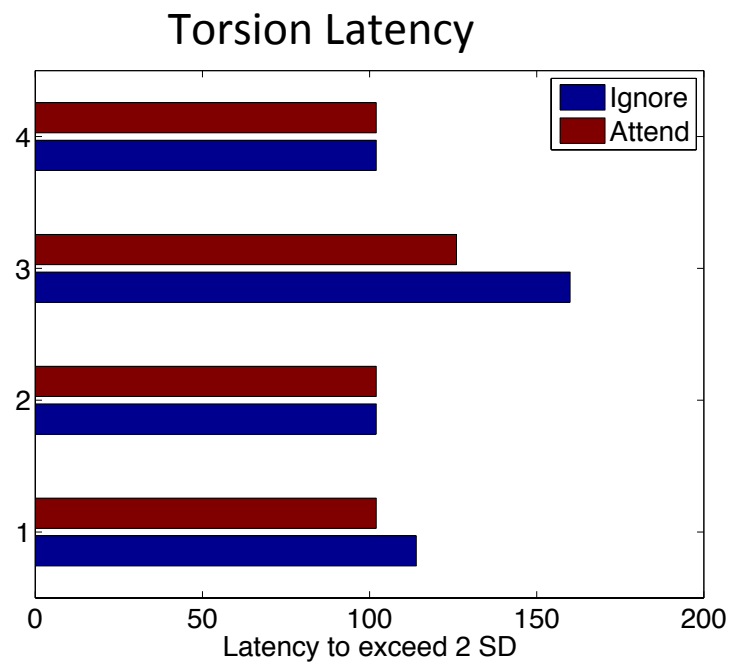


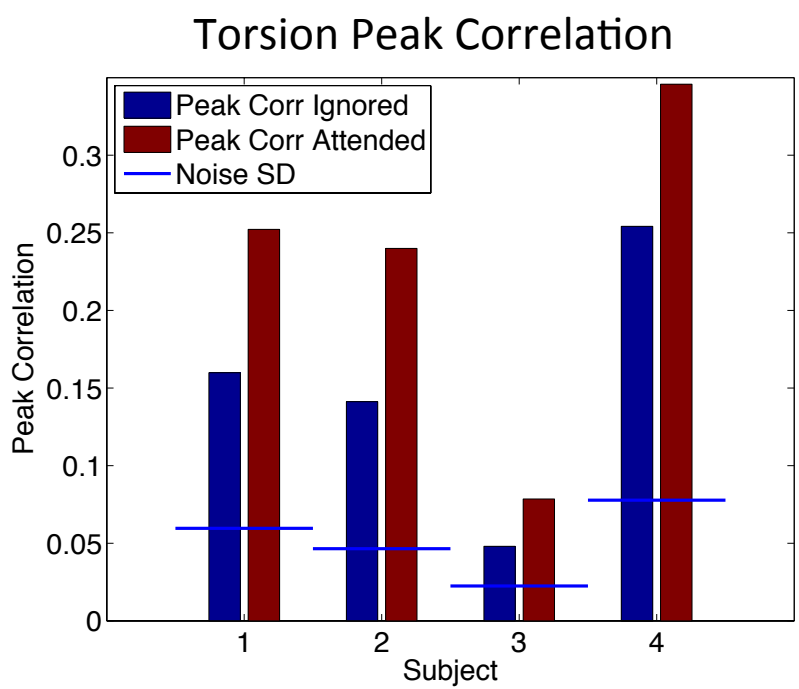
Results

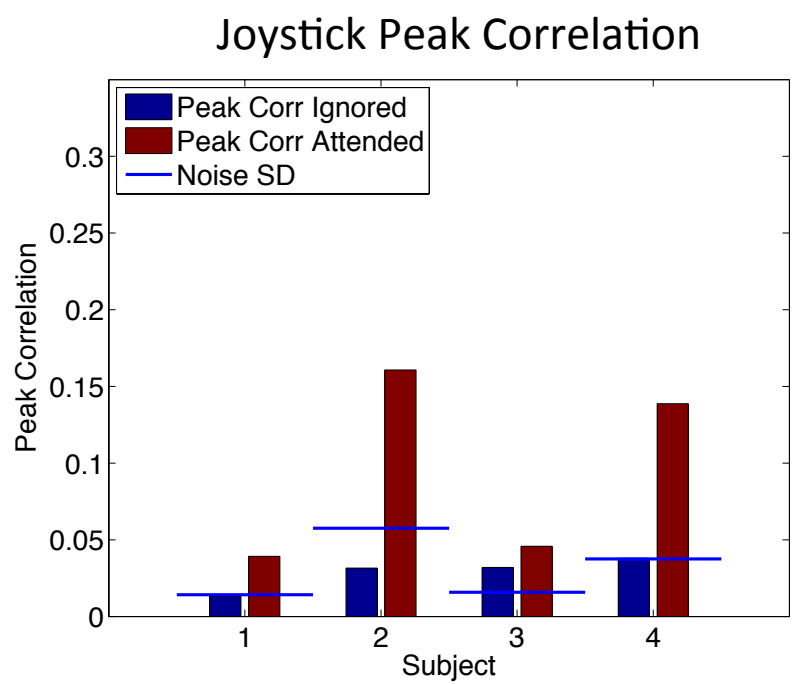
Joystick responses indicated that subjects were attending as requested.

Subjects showed robust torsional responses to the spinning vanes with the earliest response beginning at about 100 msec.

Attention increased the relative amplitude of torsion, but did not change the latency of responses.







Conclusions

- Covert Spatial Attention enhances eye movement responses, even those that are not considered voluntary. This applies to both torsional version and vertical vergence.
- We do not see evidence for a distinct, long latency component to tracking, as occurs for horizontal and vertical pursuit and for horizontal vergence.

Thanks for your attention!