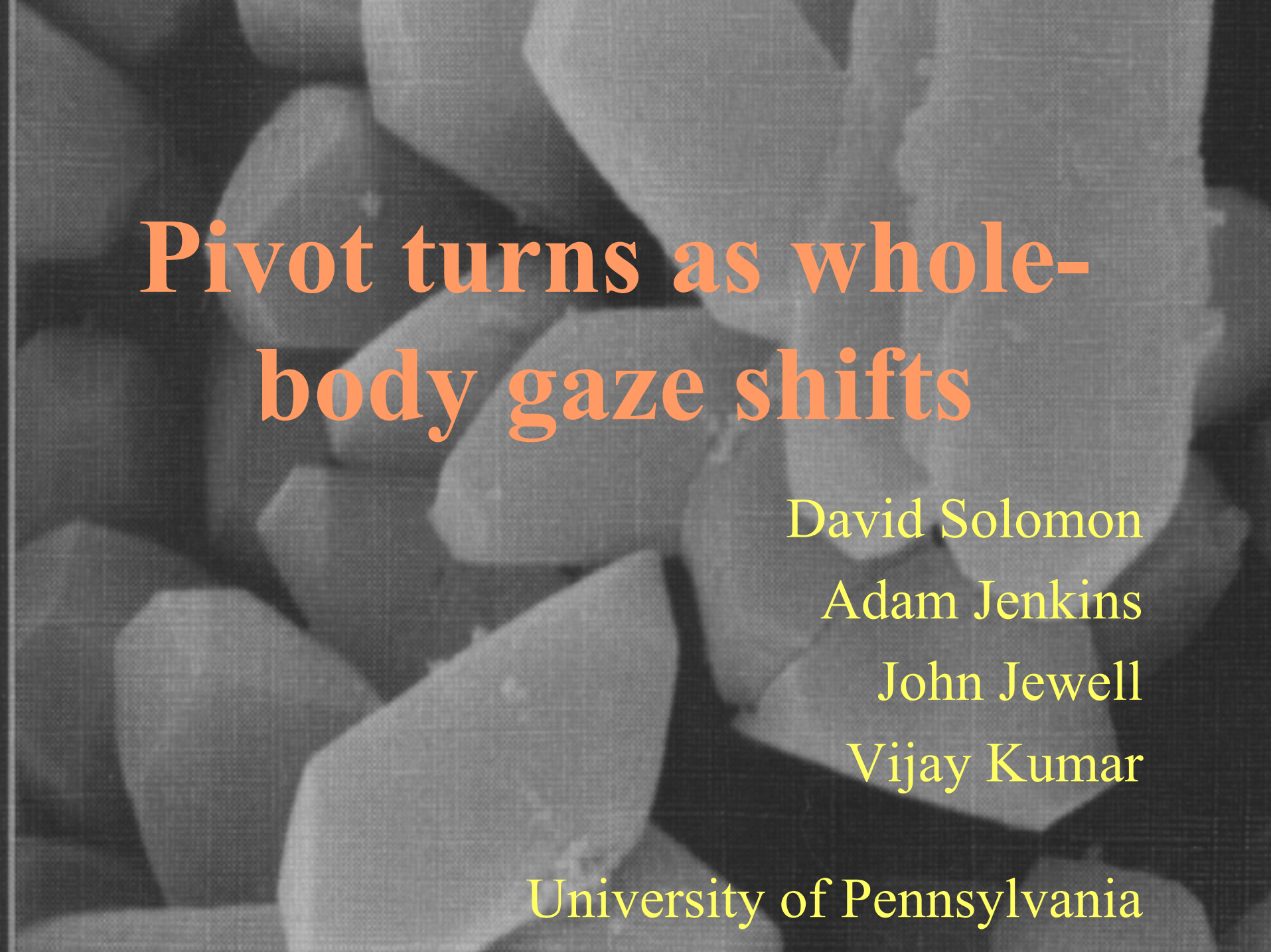


Pivot turns as whole-body gaze shifts

David Solomon
Adam Jenkins
John Jewell
Vijay Kumar

University of Pennsylvania

Questions

- Does the head move on the body during pivot turns?
- Is the concept of a “whole body gaze shift” appropriate to describe this behavior?
- Are there similarities between eye-head gaze shifts and foot-driven gaze shifts?

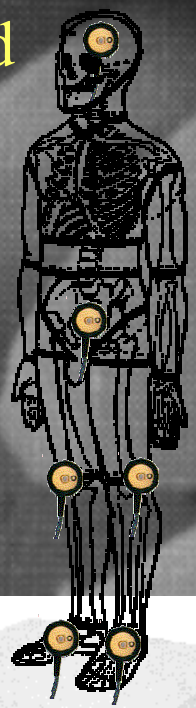
Neck = Head - Pelvis
Hip = Pelvis - Leg
Ankle = Leg - Foot

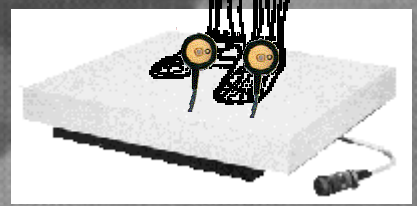
Head

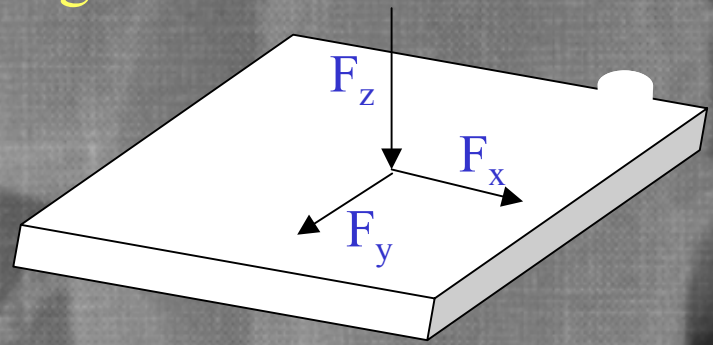
Pelvis

Leg

Foot

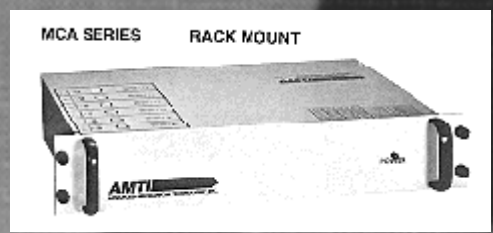


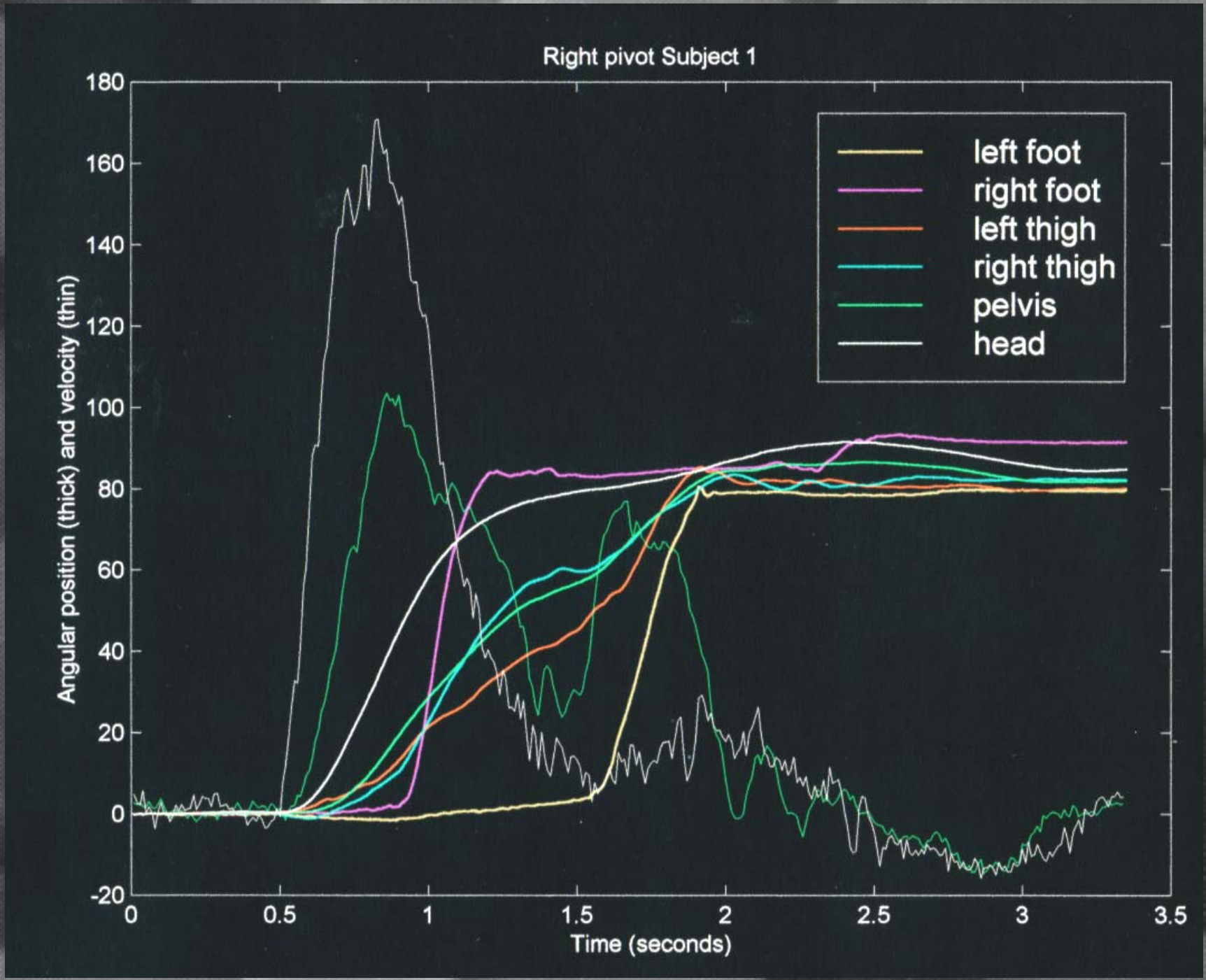


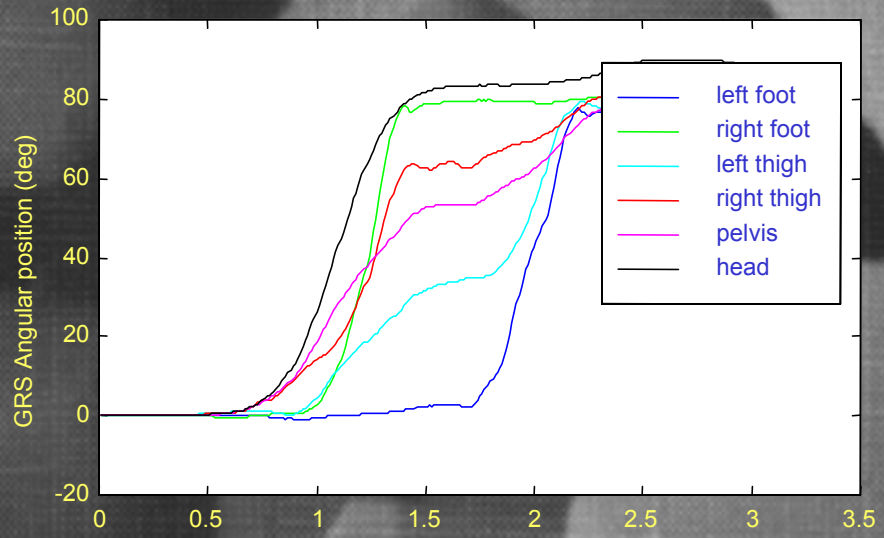


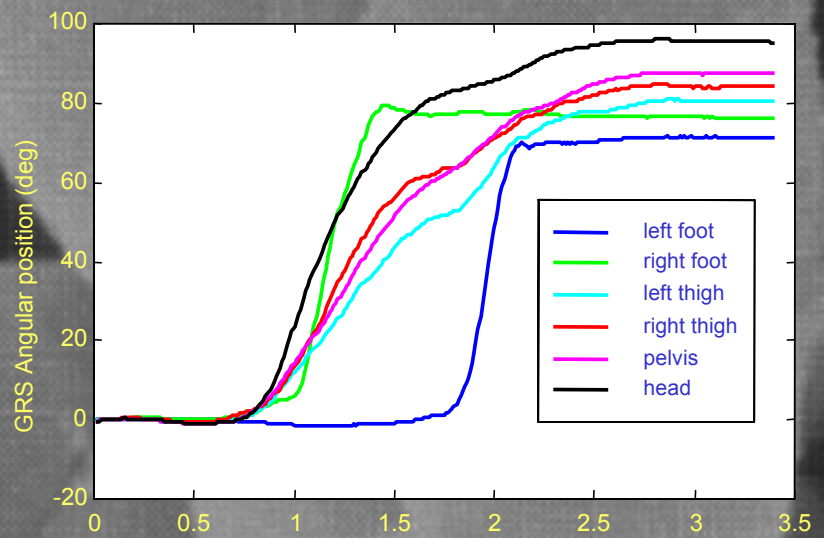
Shear forces
F_x, F_y, F_z

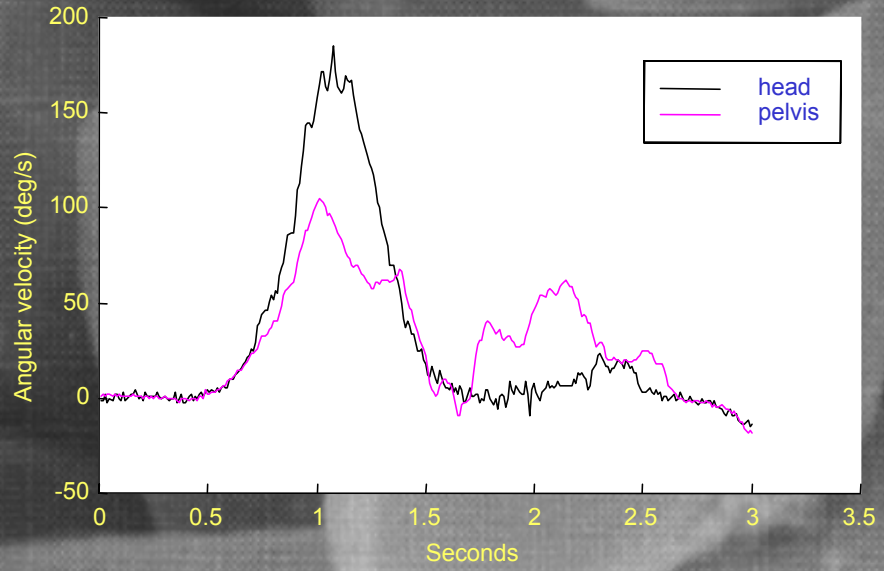
Moments:
M_x, M_y, M_z

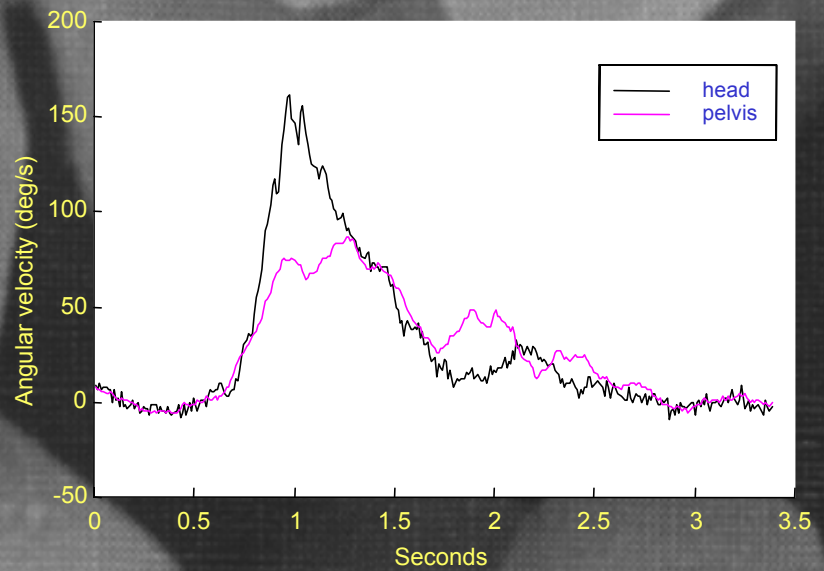



Right pivot Subject 1
Angular position (thick) and velocity (thin)
Time (seconds)
left foot
right foot
left thigh
right thigh
pelvis
head
180
160
140
120
100
80
60
40
20
0
-20
0
0.5
1
1.5
2
2.5
3
3.5

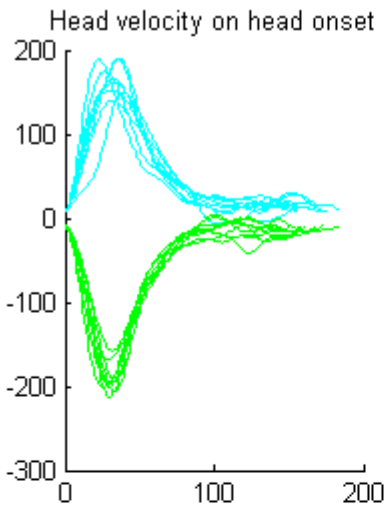

GRS Angular position (deg)
100
80
60
40
20
0
-20
0
0.5
1
1.5
2
2.5
3
3.5
left foot
right foot
left thigh
right thigh
pelvis
head

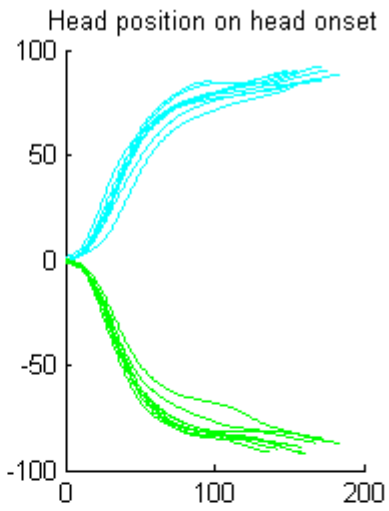

GRS Angular position (deg)
100
80
60
40
20
0
-20
0
0.5
1
1.5
2
2.5
3
3.5
left foot
right foot
left thigh
right thigh
pelvis
head

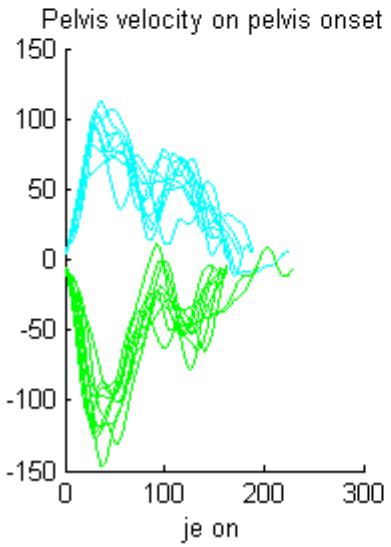

Angular velocity (deg/s)
200
150
100
50
0
-50
0
0.5
1
1.5
2
2.5
3
3.5
Seconds
head
pelvis

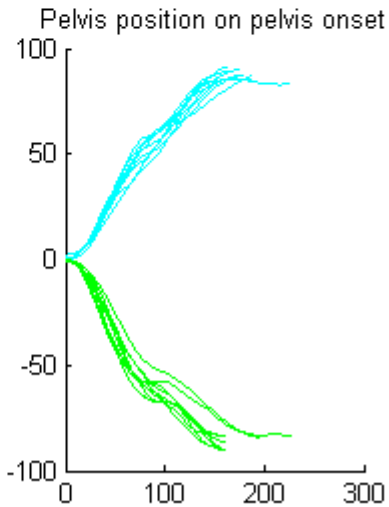

Angular velocity (deg/s)
200
150
100
50
0
-50
0
0.5
1
1.5
2
2.5
3
3.5
Seconds
head
pelvis

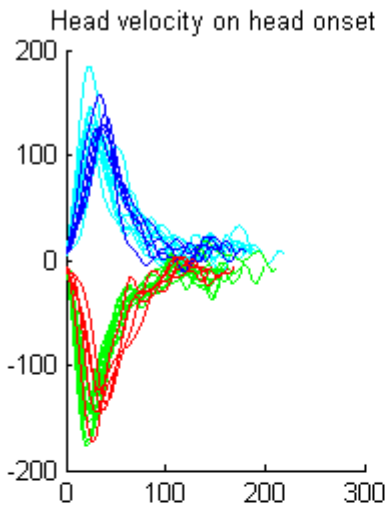
Consistency of the pattern of body-head rotation during turns

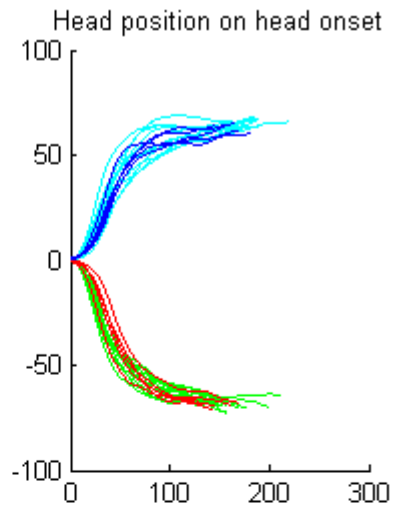


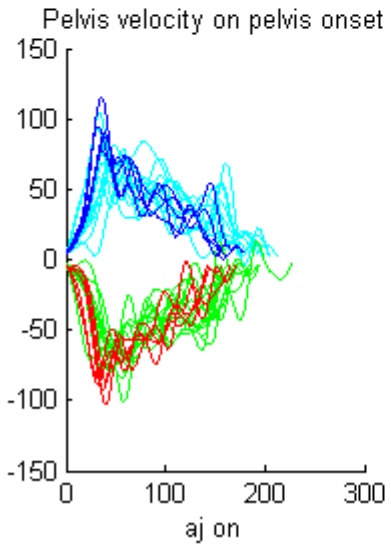


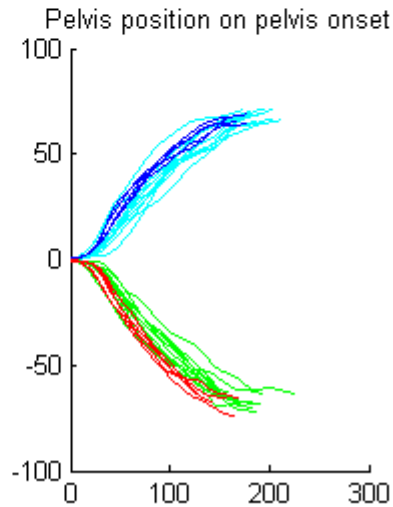


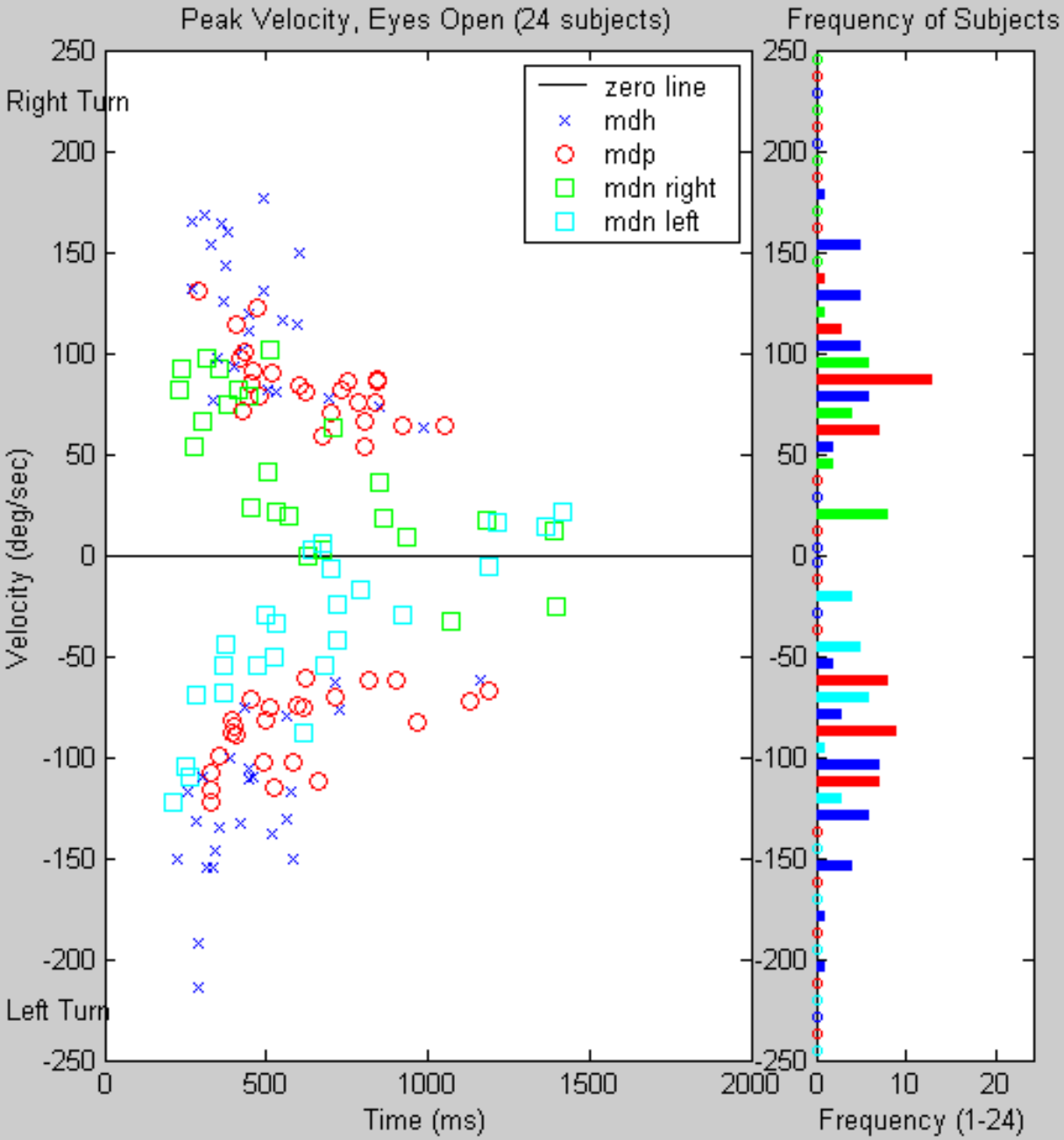












Average peak velocity of head, pelvis and neck

Target visible

Eyes opened n = 20 subjects

	Max dH deg/s	dP at max dH deg/s	Max dP deg/s	Max |dN| deg/s	max |N| deg
Right turns n = 246	123 ± 39 (57-233)	69 ± 27 (10-144)	85 ± 21 (44-154)	63 ±30 (18-153)	17 ± 9 (3-45)
Left turns n = 258	124 ± 42 (45-271)	68 ± 27 (3-146)	87 ± 21 (45-147)	65 ± 32 (17-175)	17 ± 10 (3-41)

- On average, right and left turns were remarkable similar
- Though some subjects did have significant differences

Eyes opened n = 20 subjects

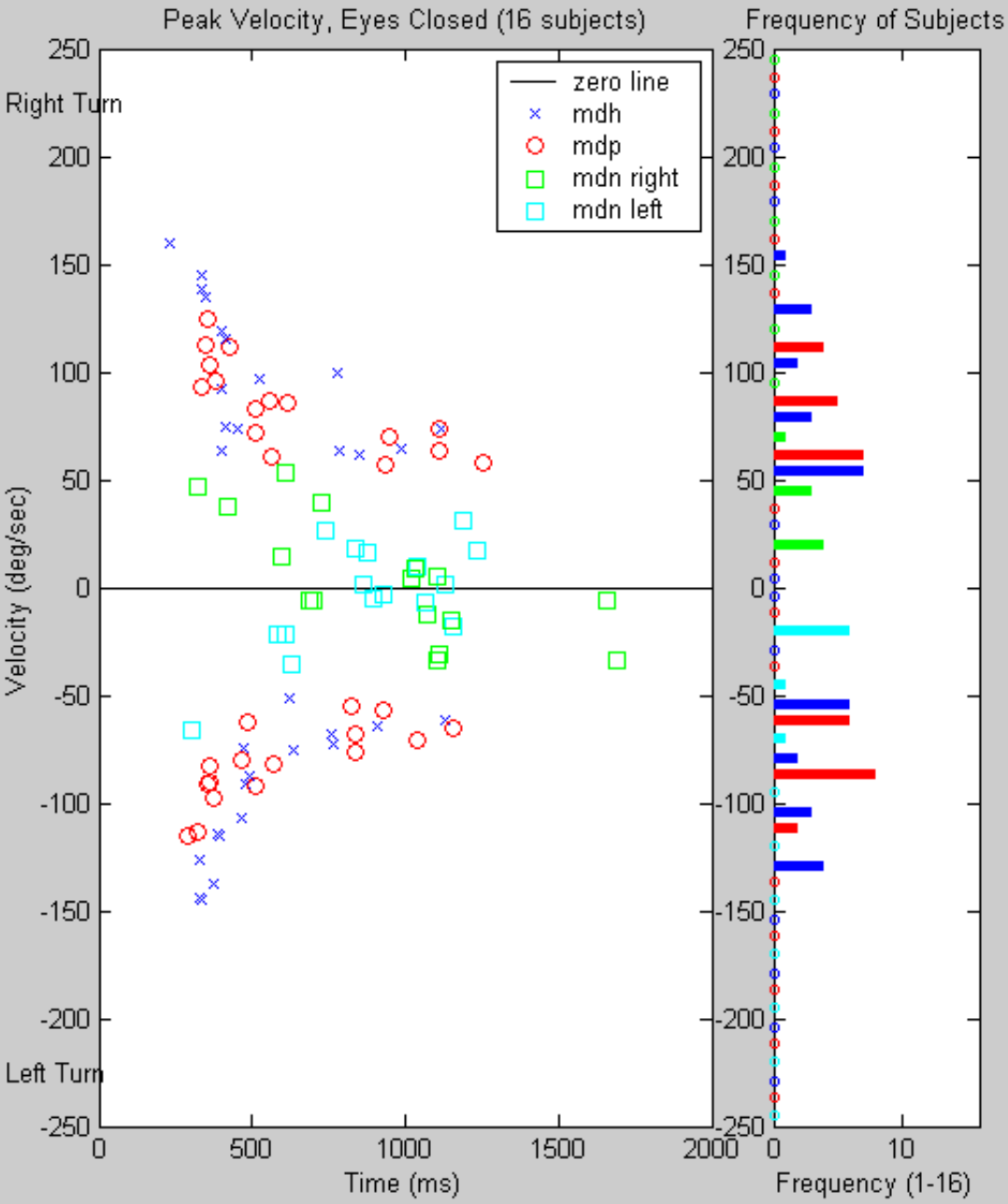
	Max dH deg/s	dP at max dH deg/s	Max dP deg/s	Max |dN| deg/s	max |N| deg
Right turns n = 246	123 ± 39 (57-233)	69 ± 27 (10-144)	85 ± 21 (44-154)	63 ±30 (18-153)	17 ± 9 (3-45)
Left turns n = 258	124 ± 42 (45-271)	68 ± 27 (3-146)	87 ± 21 (45-147)	65 ± 32 (17-175)	17 ± 10 (3-41)

- Peak head in space velocity was always significantly greater than pelvis velocity…
  - At the time of peak head velocity (max dH)
  - At peak pelvis velocity (max dP)

Eyes opened n = 20 subjects

	Max dH deg/s	dP at max dH deg/s	Max dP deg/s	Max |dN| deg/s	max |N| deg
Right turns n = 246	123 ± 39 (57-233)	69 ± 27 (10-144)	85 ± 21 (44-154)	63 ±30 (18-153)	17 ± 9 (3-45)
Left turns n = 258	124 ± 42 (45-271)	68 ± 27 (3-146)	87 ± 21 (45-147)	65 ± 32 (17-175)	17 ± 10 (3-41)

- Though there was great variability between subjects, peak neck (head on body) velocity was roughly half of peak head velocity in space
- Maximum neck excursion was generally only ~25% of the total gaze shift



Average peak velocity of head, pelvis and neck

Vision occluded

Vision occluded n = 15 subjects

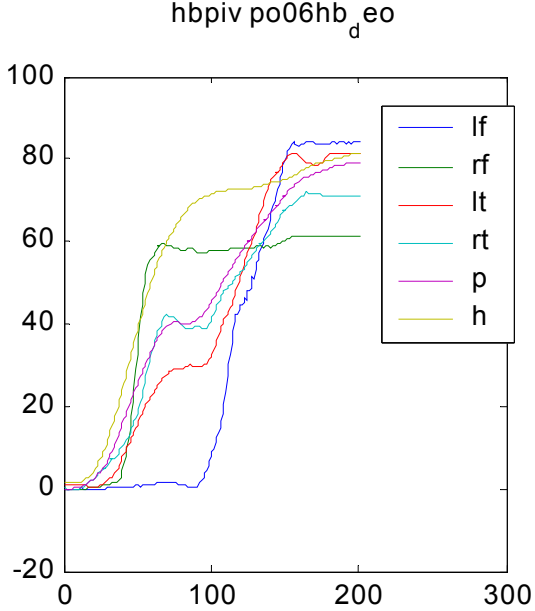
	Max dH deg/s	dP at max dH deg/s	Max dP deg/s	Max |dN| deg/s	max |N| deg
Right turns n = 94	105 ± 33 (43-177)	80 ± 26 (34-143)	89 ± 22 (49-143)	42 ±18 (16-104)	11 ± 5 (3-25)
Left turns n = 95	99 ± 31 (44-173)	75 ± 24 (15-128)	85 ± 20 (48-128)	39 ± 16 (15-112)	10 ± 6 (3-28)

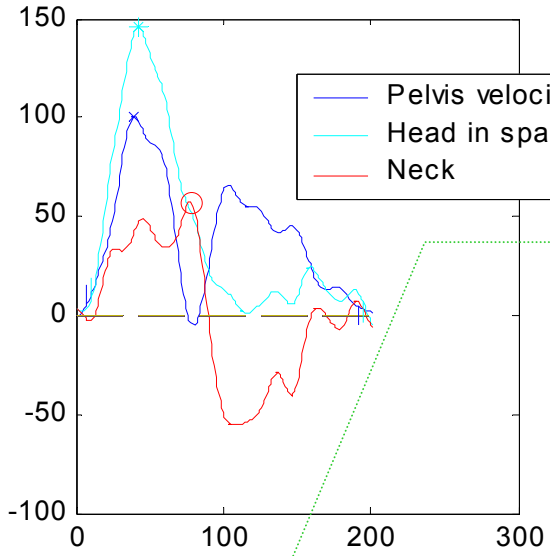
- Right and left turns were similar
- Peak head velocity was smaller than when the target was visible, however…
  - Peak head in space was still greater than pelvis velocity
- Peak pelvis velocity was unaffected by vision

Vision occluded n = 15 subjects

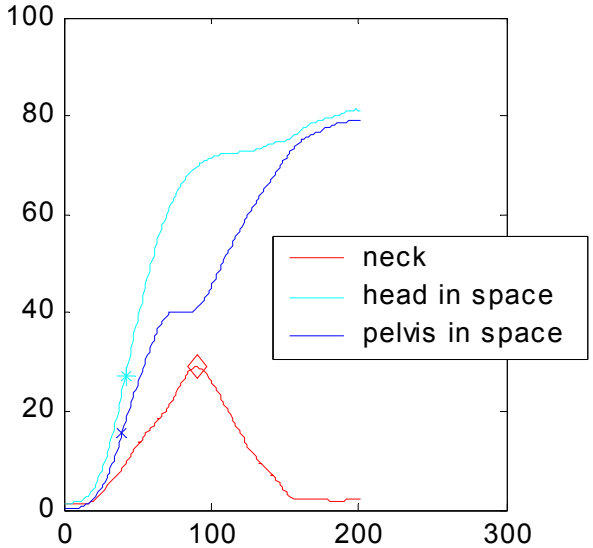
	Max dH deg/s	dP at max dH deg/s	Max dP deg/s	Max |dN| deg/s	max |N| deg
Right turns n = 94	105 ± 33 (43-177)	80 ± 26 (34-143)	89 ± 22 (49-143)	42 ±18 (16-104)	11 ± 5 (3-25)
Left turns n = 95	99 ± 31 (44-173)	75 ± 24 (15-128)	85 ± 20 (48-128)	39 ± 16 (15-112)	10 ± 6 (3-28)

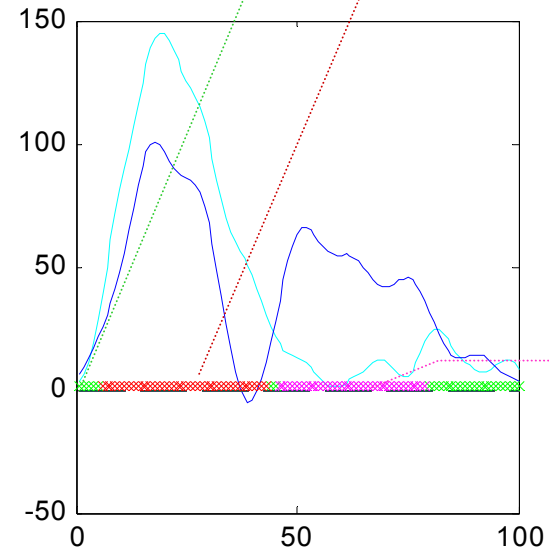
- Neck position change and peak velocity were smaller, consistent with the relatively slower head movements when the target was not visible





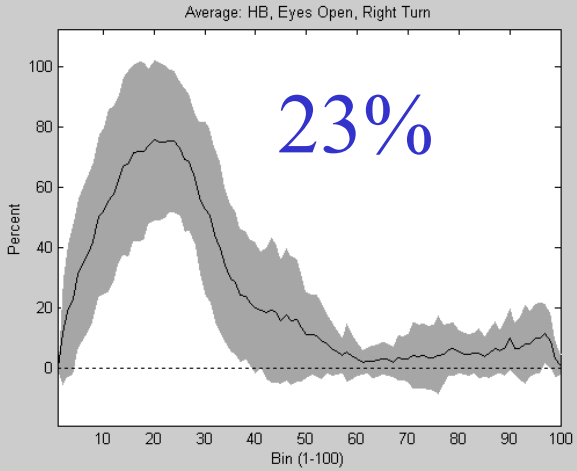
‘*en bloc*’ if head and body velocity were within 10 deg/s

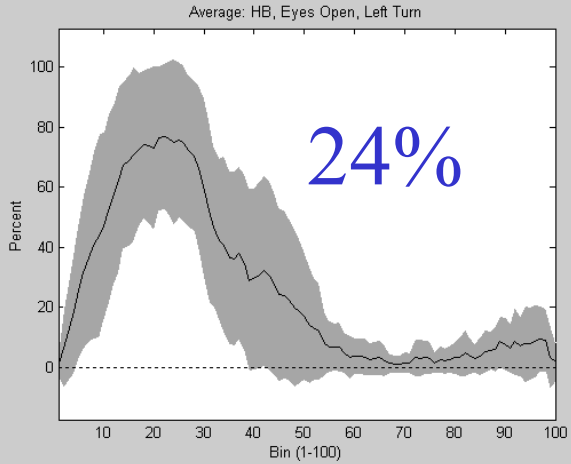


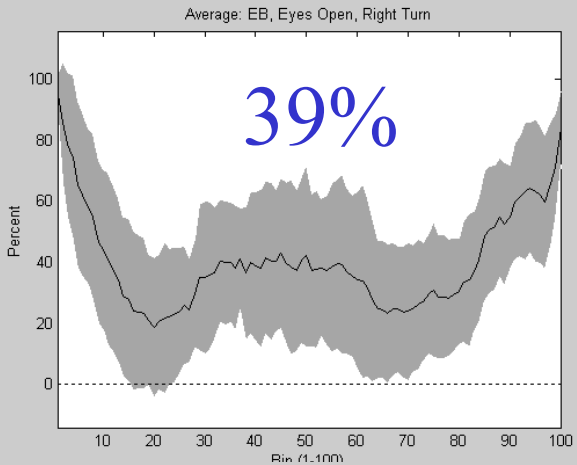


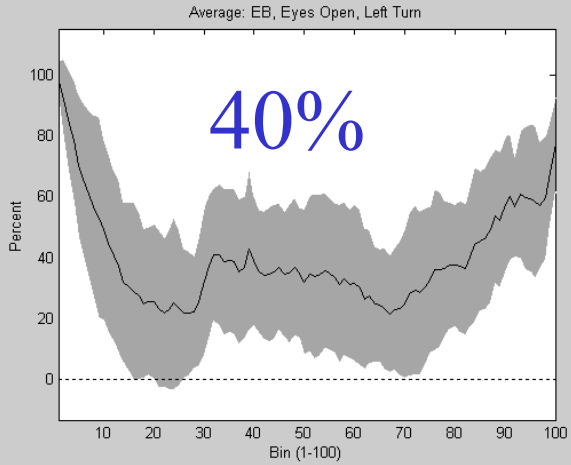
‘head on body’ if head velocity exceeded body velocity by > 10 deg/s

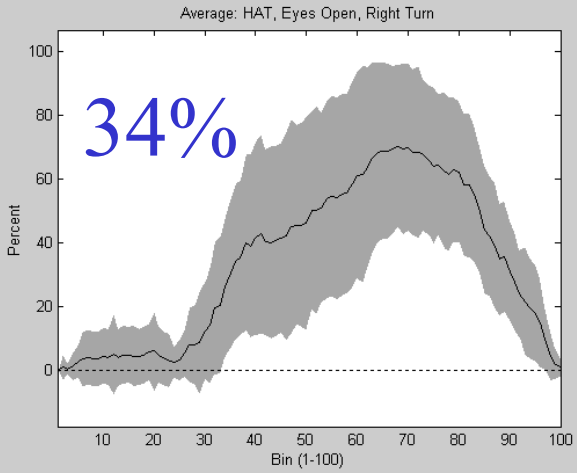
‘stabilization’ if head velocity was lower than pelvis velocity by 10 deg/s or more

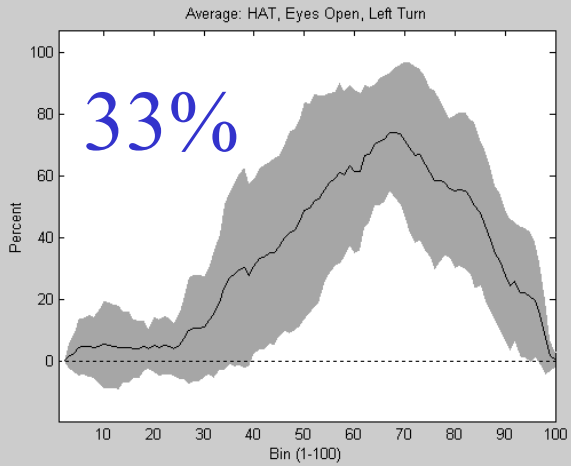






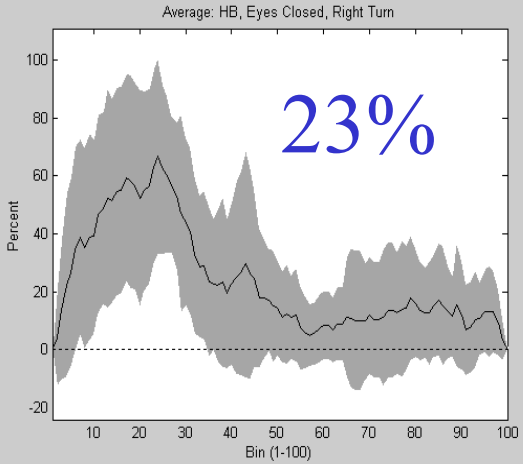


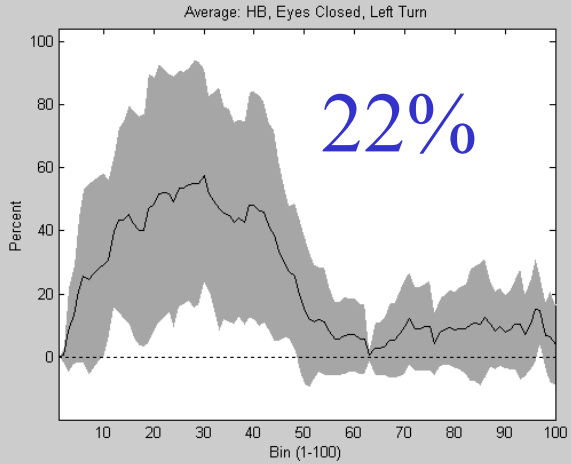


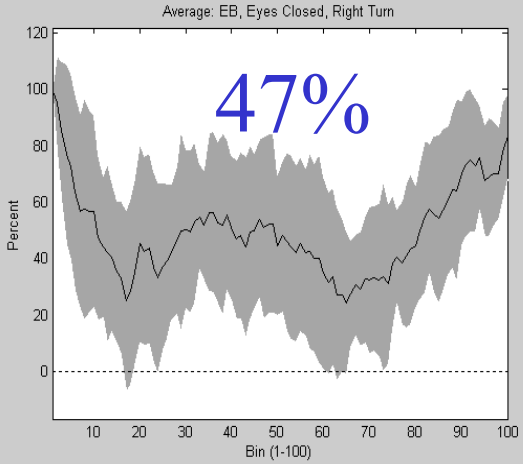


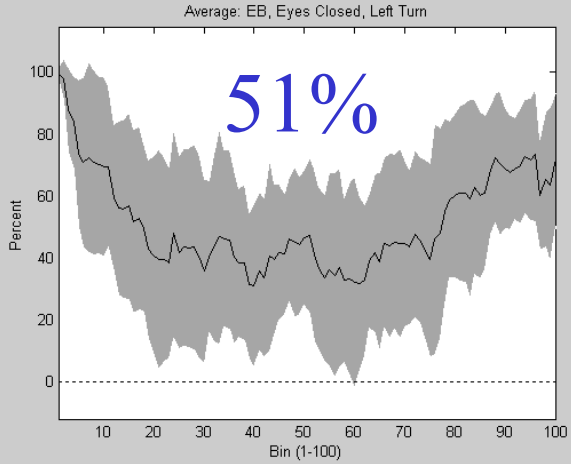
Right and Left pivot turns

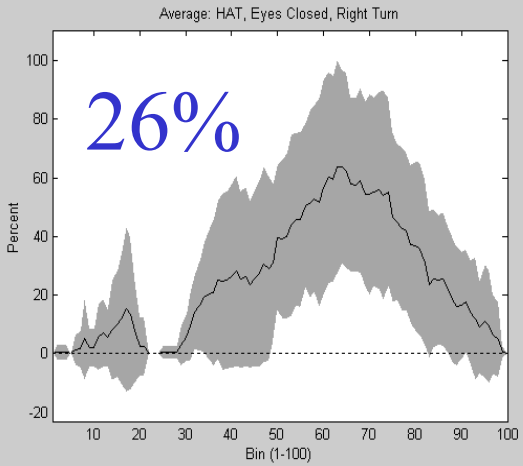
Visible target

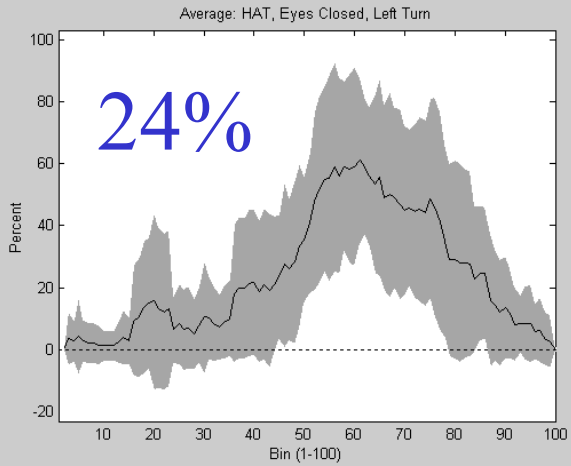












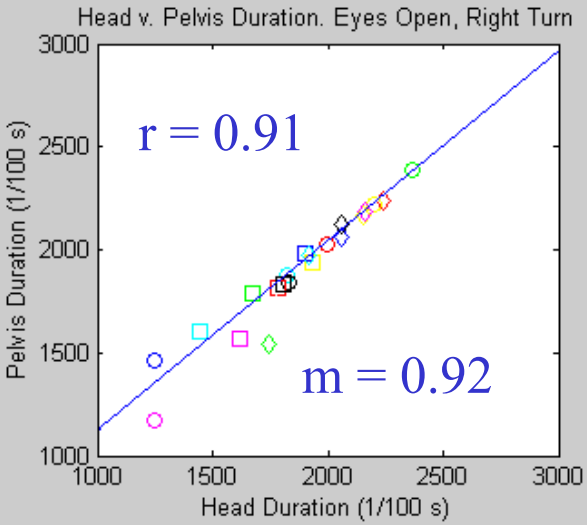
Right and Left pivot turns

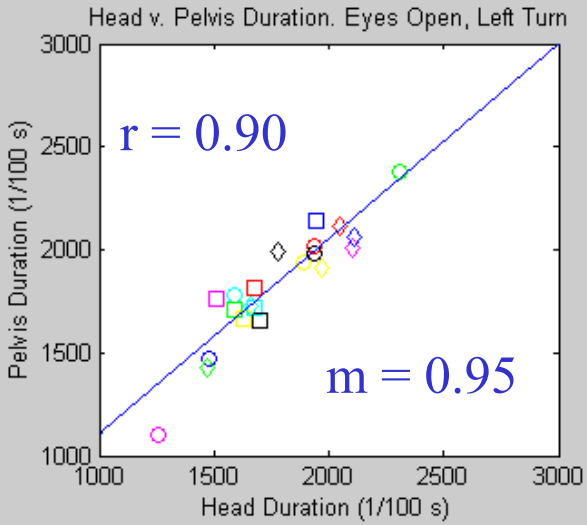
Vision occluded

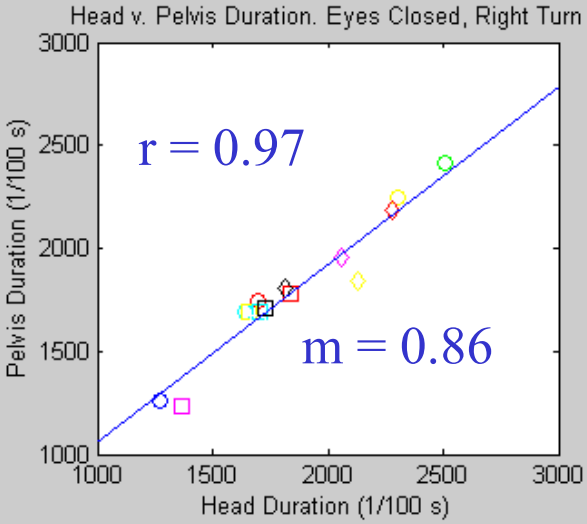
Target visible vs. Vision occluded

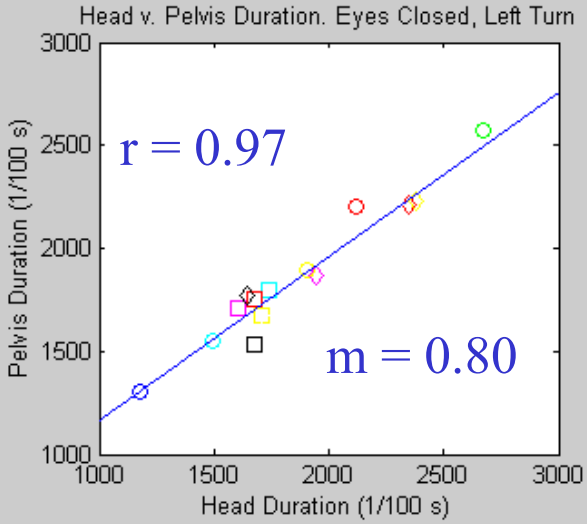
- Greater percentage of turn spent in *en bloc* behavior rather than head stabilization in space
- Pelvis velocity is unchanged, but head in space velocity (and neck movement) is decreased

Duration of Head and Pelvis rotation in space





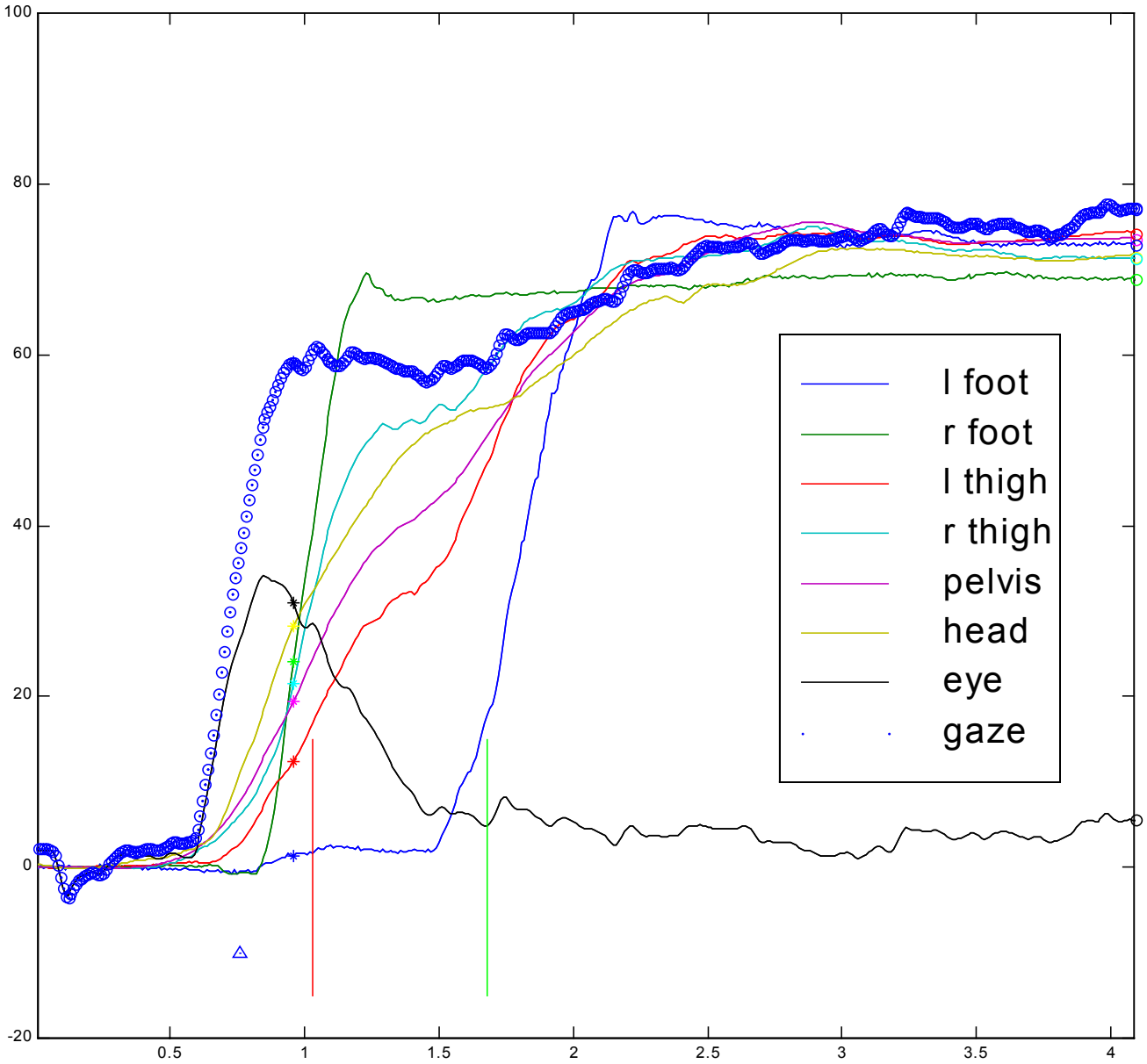




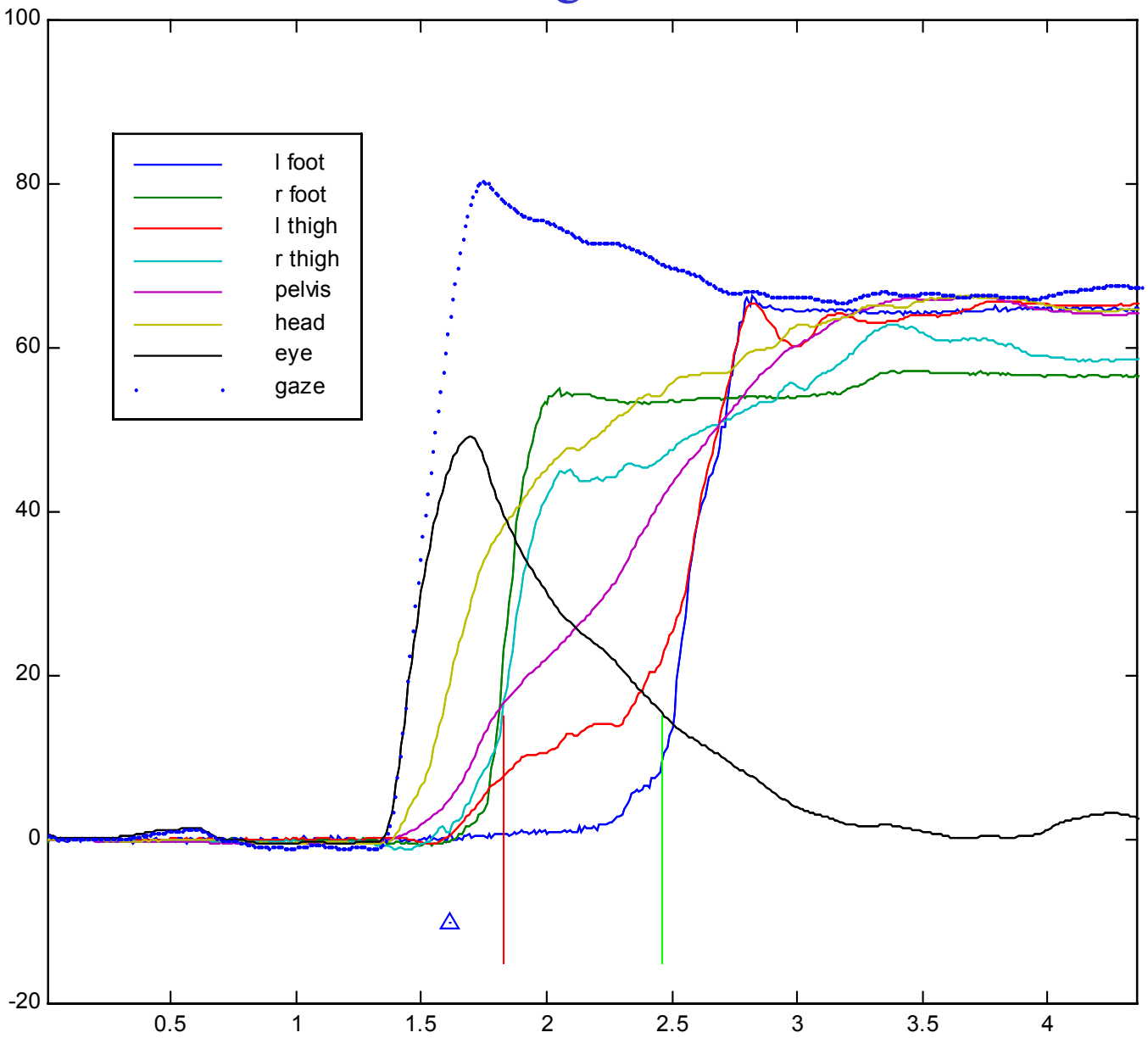
Target visible

Vision occluded

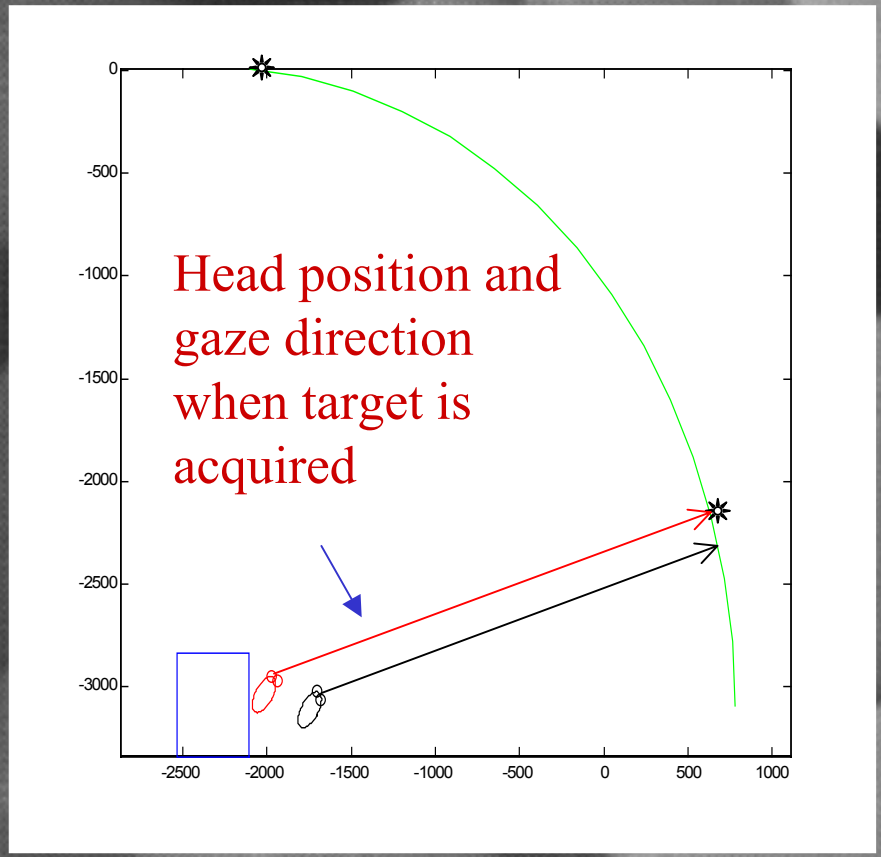
Dark

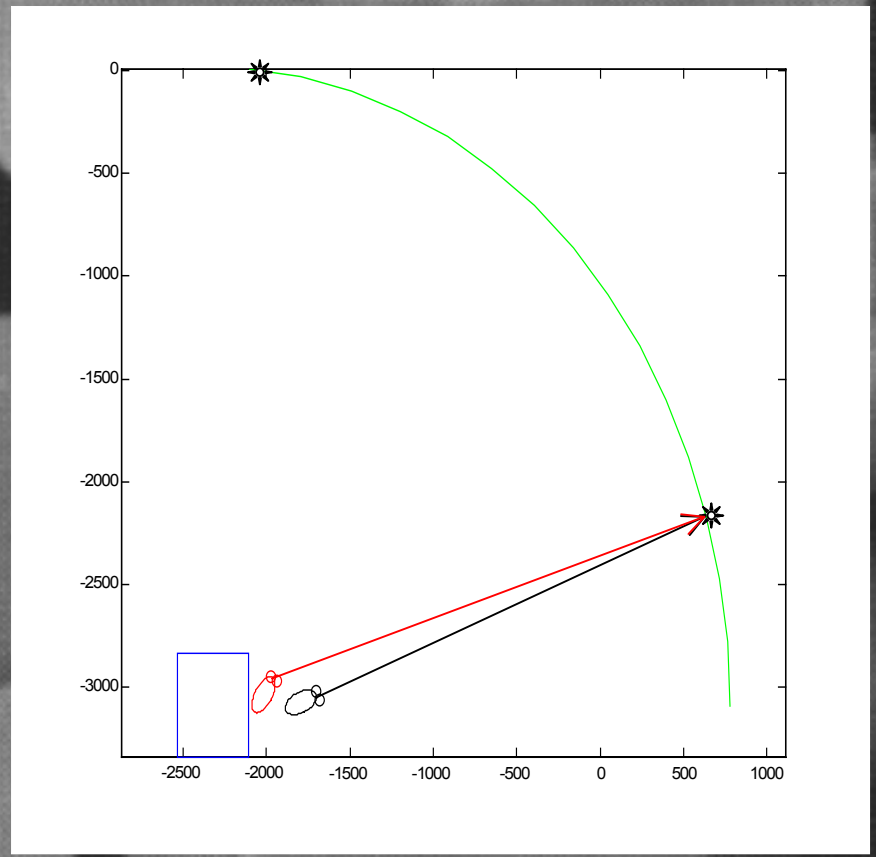

100
80
60
40
20
0
-20
0.5
1
1.5
2
2.5
3
3.5
4
l foot
r foot
l thigh
r thigh
pelvis
head
eye
gaze

Light


100
80
60
40
20
0
-20
0.5
1
1.5
2
2.5
3
3.5
4
l foot
r foot
l thigh
r thigh
pelvis
head
eye
gaze

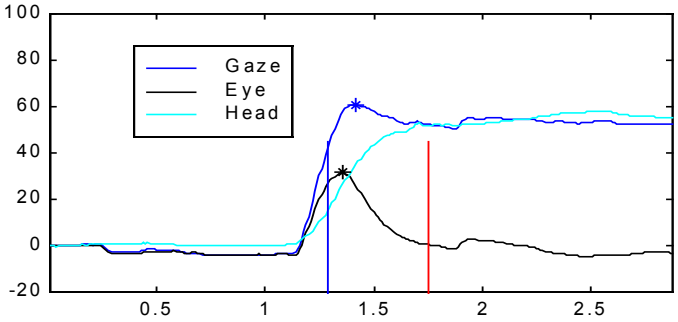
Apparent Overshoot

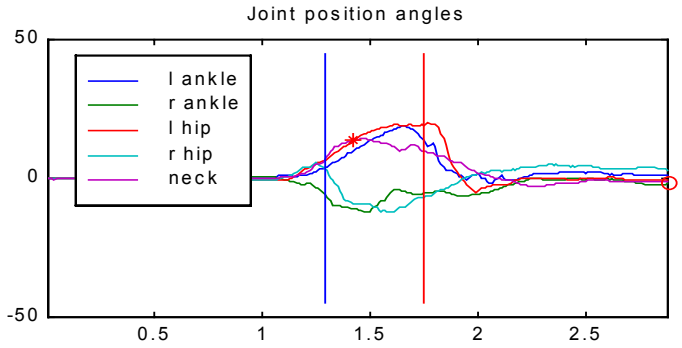


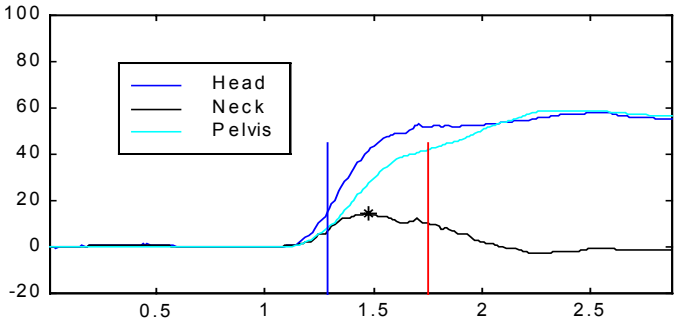


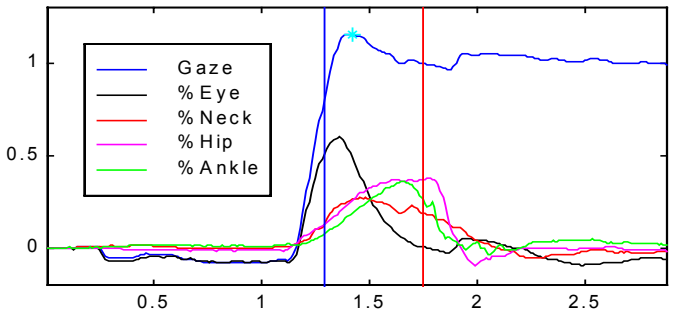
Eye rotation about a fixed axis in space

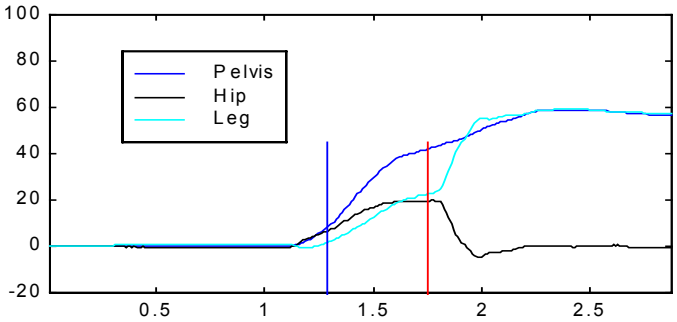
Eye rotation with compensation for translational head motion


Gaze
Eye
Head
100
80
60
40
20
0
-20
0.5
1
1.5
2
2.5

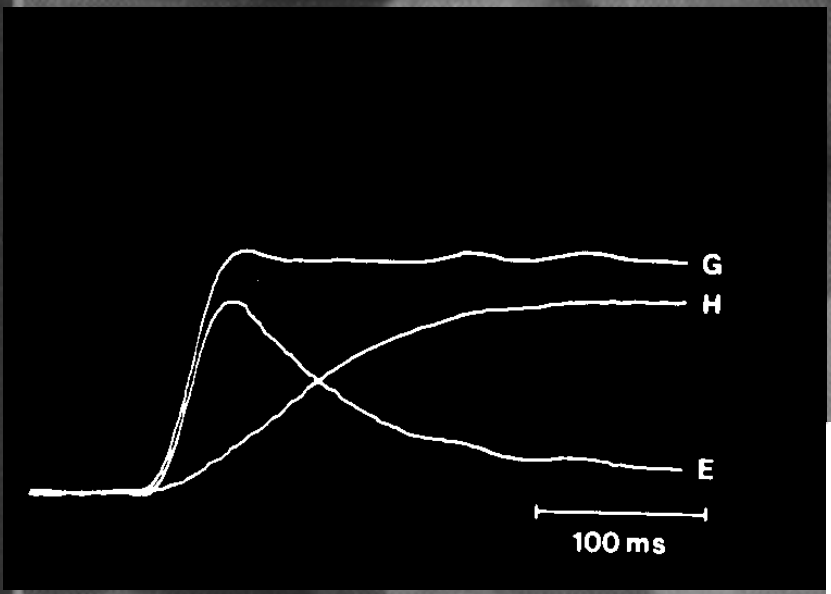

Joint position angles
l ankle
r ankle
l hip
r hip
neck
50
0
-50
0.5
1
1.5
2
2.5


Head
Neck
Pelvis
100
80
60
40
20
0
-20
0.5
1
1.5
2
2.5

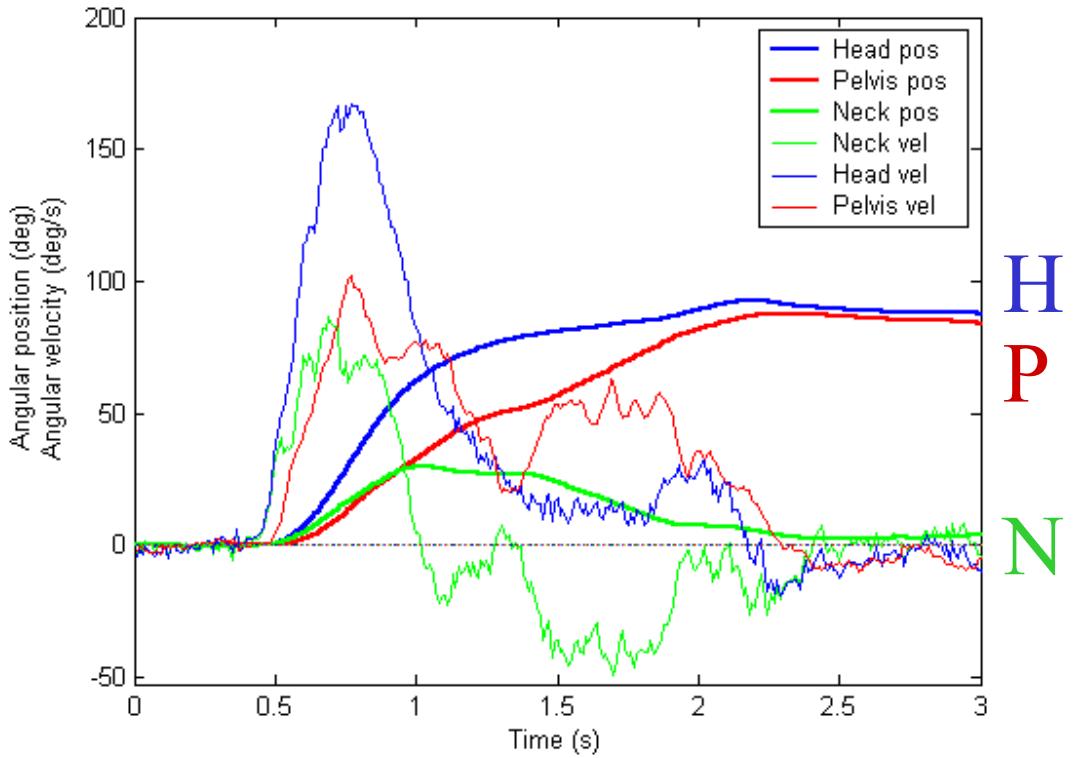

Gaze
% Eye
% Neck
% Hip
% Ankle
1
0.5
0
0.5
1
1.5
2
2.5


Pelvis
Hip
Leg
100
80
60
40
20
0
-20
0.5
1
1.5
2
2.5

Eye-head gaze shift



Whole-body gaze shift



H

P

N

Conclusions

- Head on body rotation during turning is a consistent and significant feature
- Head in space stabilization mechanisms are manifest only during the final portion of the turn

Support

- NIDCD
- Whitaker Foundation
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