Pivot turns as whole-body gaze shifts

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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

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)

light foot
right foot
left thigh
right thigh
pelvis
head

0 0.5 1 1.5 2 2.5 3 3.5
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*

<table>
<thead>
<tr>
<th></th>
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<td>69 ± 27</td>
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- On average, right and left turns were remarkable similar.
- Though some subjects did have significant differences.
### Eyes opened  \( n = 20 \) subjects

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- 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

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<td>105 ± 33 (43-177)</td>
<td>80 ± 26 (34-143)</td>
<td>89 ± 22 (49-143)</td>
<td>42 ±18 (16-104)</td>
<td>11 ± 5 (3-25)</td>
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<td>99 ± 31 (44-173)</td>
<td>75 ± 24 (15-128)</td>
<td>85 ± 20 (48-128)</td>
<td>39 ± 16 (15-112)</td>
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- 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
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- 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

- **Eyes Open, Right Turn**
  - $r = 0.91$
  - $m = 0.92$

- **Eyes Open, Left Turn**
  - $r = 0.90$
  - $m = 0.95$

- **Eyes Closed, Right Turn**
  - $r = 0.97$
  - $m = 0.86$

- **Eyes Closed, Left Turn**
  - $r = 0.97$
  - $m = 0.80$

Target visible

Vision occluded
Dark
Apparent Overshoot

Head position and gaze direction when target is acquired

Eye rotation about a fixed axis in space

Eye rotation with compensation for translational head motion
Eye-head gaze shift

Whole-body gaze shift
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
- University of Pennsylvania Research Foundation
- McCabe Foundation