Dynamic Visual Acuity:  
Measuring a Different Source of Visual Impairment  

Brian Peters  
Jacob Bloomberg  
Ajit Mulavara
Primary Messages

• Seeing clearly requires more than just being able to focus on an object

• Acuity is affected during dynamic activities early postflight

• Dynamic visual acuity is affected by multiple variables
Acuity Formula

Acuity = Accommodation
(ability to focus)
Acuity Formula

Acuity = Accommodation + Gaze Stabilization
(ability to focus) (maintain gaze)
The Vestibulo-Ocular Reflex
Exposure to space flight
Central reinterpretation
vestibular information
Alteration in gaze stabilization

Reduction in visual acuity
during head motion
Drawings of LED target from treadmill-walking subjects
**Dynamic Visual Acuity Test**

- Computer-based test using Landolt C optotypes

- Subjects walk on a treadmill at 1.8 m/s and identify the gap location in the “Cs” presented for 500 ms on a laptop at 4 m

- A threshold-detecting algorithm controls the size of the sequentially-presented optotypes

- Static acuity (seated) is subtracted from the walking acuity
DVA Test Output
Astronauts show reduction in visual acuity during postflight walking due to changes in gaze control

Only 1 of 3 were able to complete the test on R+0

Performance levels for patients with vestibular dysfunction are indicated in red

Target Distance Affects Gaze Task
Required Eye Movements

Translation & Rotation
Plane Intersection
TREM

Sagittal Plane
Horizontal Plane

cm / deg

RHS LHS RHS RHS LHS RHS RHS

5/1 0 0 0 0 0 0 0
-5/-1 -5 -5 -5 -5 -5 -5 -5

4.0 m
Required Eye Movements

3.0 m
Required Eye Movements

2.0 m
Required Eye Movements

1.5 m
Required Eye Movements

1.0 m
Required Eye Movements

Translation & Rotation
Plane Intersection
TREM

Sagittal Plane
Horizontal Plane

0.5 m
Created ability to measure NEAR Acuity

The screen resolutions on typical displays doesn’t allow the clear presentation of small optotypes at short viewing distances

The pictured microdisplay has a resolution of 640 x 480
FAR vs. NEAR DVA Results

Walking at 1.8 m/s

Display Duration: 500 ms

Comparison:
Target Distance
4 m vs. 0.5 m

Walking acuity is worse for NEAR targets

Results Presented in: Peters BT and Bloomberg JJ. Dynamic visual acuity using “far” and “near” targets. Acta Oto-Laryngologica 125:353-357. 2005
Target distance also affects Head & Body movements

<table>
<thead>
<tr>
<th></th>
<th>FAR</th>
<th>NEAR</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical Trunk</strong></td>
<td>5.43 cm ± 0.64</td>
<td>4.85 cm ± 0.44</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Translation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Head Pitch</strong></td>
<td>3.58º ± 0.89</td>
<td>3.96º ± 0.70</td>
<td>0.167</td>
</tr>
<tr>
<td><strong>Lateral Trunk</strong></td>
<td>3.56 cm ± 0.68</td>
<td>3.16 cm ± 0.46</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td><strong>Translation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Head Yaw</strong></td>
<td>2.85º ± 0.68</td>
<td>3.29º ± 0.46</td>
<td>0.112</td>
</tr>
<tr>
<td><strong>Translation</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Improving the DVA Test Sensitivity

LED indicating heel contact
Heel Strike vs. Mid-step DVA Results

Walking at 1.8 m/s

Target Distance = 4 m

Display Duration: 75 ms

Comparison:
  Gait Cycle Phase
  “BETWEEN” vs. “AT” heelstrike

Walking acuity is worse “AT” heelstrike
Passive DVA Test

Because

• 2 of 3 ISS crewmembers couldn’t walk on the treadmill at 1.8 m/s

• “Active” nature of the test could mask deficits (Herdman et al. 2001)

We created a passive DVA test

• vertical oscillations

• frequency & magnitude mimic walking
Passive DVA Test Results #1

Vertical Oscillation (2Hz, 5cm)

Target Distance = 2 m

Display Duration: 75 ms centered around peak velocity

Comparison: Control vs. Patients w/ vestibular dysfunction

*No Difference in DVA Between the Groups*
Passive DVA Test Results #2

Vertical Oscillation (2Hz, 5cm)

Target Distance = 4 m

Display Duration: 75 ms & 500 ms

Comparison: Control vs. Patients w/ vestibular dysfunction

*Difference in DVA only during 500 ms condition*

Conclusion: Control subjects make better use of low velocity portion of perturbation
Conclusions

• Acuity is affected in returning crewmembers because of an inability to stabilize gaze

• Advantages of computer-based acuity test include:
  - randomized optotype orientations
  - NEAR and FAR viewing distances
  - triggered display

• DVA is affected by
  - target distance
  - display timing & duration
  - active vs. passive perturbation