Dynamic Visual Acuity: Measuring a Different Source of Visual Impairment

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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

\[
\text{Acuity} = \text{Accommodation} \\
\text{(ability to focus)}
\]
Acuity Formula

Acuity = Accommodation + Gaze Stabilization
(ability to focus) (maintain gaze)
The Vestibulo-Ocular Reflex

- Head Position in Space
- Eye Position in Space (Gaze direction)
- Eye Position in Head

Extrinsic eye muscles receive signals from the brainstem

Vestibule of the inner ear sends signals to the brainstem

Somatic motor reflexes

Head Position in Space

Eye Position in Space (Gaze direction)

45° Right

45° Left

0°
The Concern

Exposure to space flight

Central reinterpretation vestibular information

Alteration in gaze stabilization

Reduction in visual acuity during head motion
Early Evidence

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
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

4.0 m
Required Eye Movements

Translation & Rotation

Plane Intersection

TREM

3.0 m
Required Eye Movements

Translation & Rotation

Plane Intersection

TREM

2.0 m
Required Eye Movements

1.5 m
Required Eye Movements

1.0 m
Required Eye Movements

Translation & Rotation

Plane Intersection

TREM

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.

U.S. dime
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 Translation</strong></td>
<td>5.43 cm ± 0.64</td>
<td>4.85 cm ± 0.44</td>
<td>0.006</td>
</tr>
<tr>
<td><strong>Head Pitch</strong></td>
<td>3.58° ± 0.89</td>
<td>3.96° ± 0.70</td>
<td>0.167</td>
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<tr>
<td><strong>Lateral Trunk Translation</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>Head Yaw</strong></td>
<td>2.85° ± 0.68</td>
<td>3.29° ± 0.46</td>
<td>0.112</td>
</tr>
</tbody>
</table>
Improving the DVA Test Sensitivity
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