The Source of Viewing Discomfort in 3D Viewing

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Prevalence of Viewing Symptoms

• About 15% of viewers reported some symptoms.
• Although symptoms are well identified, little is known about underlying visual/physical characteristics.
## Ranked 3D Viewing Symptoms

<table>
<thead>
<tr>
<th>Severity (high to low)</th>
<th>Movie (Yang et al., OVS, in press)</th>
<th>Gaming (Yang et al., submitted)</th>
<th>Animated images (Yang et al., completed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Double Vision</td>
<td>Nausea</td>
<td>Disorientation</td>
</tr>
<tr>
<td>2</td>
<td>Neusea</td>
<td>Dizziness</td>
<td>Difficulty concentrating</td>
</tr>
<tr>
<td>3</td>
<td>Dizziness</td>
<td>Headache</td>
<td>Dizziness</td>
</tr>
<tr>
<td>4</td>
<td>Blurred Vision</td>
<td>Difficulty thinking</td>
<td>Difficulty thinking</td>
</tr>
<tr>
<td>5</td>
<td>Pain inside eyes</td>
<td>Double vision</td>
<td>Headache</td>
</tr>
<tr>
<td>6</td>
<td>Pulled eyes</td>
<td>Neckache</td>
<td>Neckache</td>
</tr>
<tr>
<td>7</td>
<td>Eye sore</td>
<td>Blurred vision</td>
<td>Difficulty visually focusing</td>
</tr>
<tr>
<td>8</td>
<td>Neckache</td>
<td>Pain inside eyes</td>
<td>Pulled eyes</td>
</tr>
</tbody>
</table>

**Category:** Motion sickness / Visual / Ocular / Physical / Cognitive
Categories of Viewing Symptoms

- Motion sickness symptoms (dizziness, headache, nausea, disorientation)
- Visual symptoms (double vision, blurred vision, difficulty visually focusing).
- Ocular symptoms (eye sore, eye pain, pulled eye muscle).
- Physical symptoms (neckache, general physical discomfort)
- Cognitive symptoms (difficulty thinking or concentrating)
<table>
<thead>
<tr>
<th>Symptom x Symptom</th>
<th>1% vs. 2D</th>
<th>2% vs. 2D</th>
<th>3% vs. 2D</th>
<th>4% vs. 2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual x motion</td>
<td>.31 *</td>
<td>.30 *</td>
<td>.56 **</td>
<td>.45 **</td>
</tr>
<tr>
<td>Visual x Physical</td>
<td>.53 **</td>
<td>.84 **</td>
<td>.69 **</td>
<td>.40 **</td>
</tr>
<tr>
<td>Visual x Cognitive</td>
<td>.38 **</td>
<td>.78 **</td>
<td>.68 **</td>
<td>.52 **</td>
</tr>
<tr>
<td>Motion x Physical</td>
<td>.50 **</td>
<td>.52 **</td>
<td>.60 **</td>
<td>.35 *</td>
</tr>
<tr>
<td>Motion x Cognitive</td>
<td>.57 **</td>
<td>.65 **</td>
<td>.70 **</td>
<td>.51 **</td>
</tr>
<tr>
<td>Physical x Cognitive</td>
<td>.45 **</td>
<td>.89 **</td>
<td>.83 **</td>
<td>.42 **</td>
</tr>
<tr>
<td>Immersion x Symptom</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>.15</td>
<td>-.17</td>
<td>-.54 **</td>
<td>.17</td>
</tr>
<tr>
<td>Motion</td>
<td>-.09</td>
<td>-.09</td>
<td>-.39 **</td>
<td>-.43 **</td>
</tr>
<tr>
<td>Physical</td>
<td>-.06</td>
<td>-.14</td>
<td>-.56 **</td>
<td>-.00</td>
</tr>
<tr>
<td>Cognitive</td>
<td>.15</td>
<td>-.16</td>
<td>-.51 **</td>
<td>.12</td>
</tr>
</tbody>
</table>

* p < .05; ** p < .01
Accommodative, Convergence & Immersion Findings

• Increased accommodation and convergence responses are found in 3D viewing, especially for young viewers (Yang and Sheedy, 2010).

• At a critical convergence level, symptoms was highly correlated, and negatively correlated to immersion (Yang et al., under revision).

• Convergence is more challenging for those with far eye alignment.

• Physical discomfort and motion sickness are more prevalent than visual/ocular symptoms.
Causes of Visual and Ocular Symptoms

• Sustained pupil constriction.
• Increased accommodation amplitude and frequency.
• Excessive convergence stress re. resting angle.
Causes of ocular discomforts

- Trigemial nucleus (TN) receives ophthalmic input (iris, ciliary body, eye muscle).
- Trigeminal-vascular reflex induces pain perception.
Causes of Cognitive Discomforts

- Trigemial nucleus (TN) send signals to the cingulate cortex (attention), amygdala (emotion) and prefrontal areas (memory and logic thinking).
Causes of Motion Sickness Symptoms

- Conflicts among motion, proprioceptive and visual cues.
- Heightened photosensitivity.
- Ocular stresses (iris, ciliary body, & ocular muscles).
- Facial and scalp pressure.
- Biological circles (day/night cycle, menstruation).
Underlying Motion Sickness Physiology

- Migraine
  - Sensory stimulation + head or neck pain
  - Headache
  - Trigeminal nucleus caudalis

- Pain modulation processes

- Sensory and emotional discomfort
  - Nausea and vomiting
  - Nucleus tractus solitarius
  - Extracranial vasodilatation
  - Neurogenic inflammation

- Motion sickness
  - Sensory conflict
  - Dizziness and vertigo
  - Vestibular nuclei
Unique Symptoms for 3D Viewing?

• 2D viewing report similar symptoms (Yang et al., in press).
• High Illumination causes ocular as well as motion sickness symptoms (Yang et al., revision).
• Similar symptoms occur without motion stimuli (Sowjanya report)
Symptoms-inducing Stimulation in 3D

• Flickering light, overwhelming audio, induced motion perception ...
• Everyone can perceive the symptoms ...

Example of light stimulation and motion sickness (WARNING: COULD CAUSE SEIZURE & MAIGRAINE)
Exacerbating Conditions in 3D

• Enhanced visually-based depth and motion perception (Sowjanya’s report today).
• High luminance stimulation/dark room.
• Flickering images (perceivable or not).
• Wearing 3D glasses (stress on ear/temple/nose; optical aberration).
Hypothesis

• Many, if not most, 3D viewing symptoms reflect over-stimulation and/or stress on general pain and motion sickness mechanisms.

• Improvement of 3D experience can be had by attenuating various sources of stimulation and stress.
Clinical Implications

• Two main sources of sensory stimulation:
  – Visual & Ocular
  – Motion sickness

• Visual symptoms – inability to accommodate, converge; diplopia.

• Ocular symptoms – accommodation, convergence and pupillary stress.

• Motion sickness – sensitivity to motion stimuli, photosensitive migraine, & seizure.

• Clinical screening of 3D suffers with effective tests and stimuli (Yu-chi’s and James’s reports).
Industrial Considerations

• Standards on screen luminance, ambient lighting, and image flickering/contrast.
• Maintain image disparity below a threshold level.
• Light and comfortable 3D eyewear.
• Compressed motion in depth.
Visual Symptoms

A

Visual symptoms

B

Motion sickness symptoms

C

Cognitive symptoms

Disparity ratio

Normalized difference

3D > 2D

2D > 3D

13 - 18

18 - 30

> 30
Convergence Responses

A

Vergence Amplitude (3D - 2D, deg)

1% 2% 3% 4%

B

Vergence Amplitude (3D - 2D, deg)

1% 2% 3% 4%

Diverge
Converge

Esophoria
Exophoria
Near NPC
Far NPC