Symptom experiences viewing 3D displays

Commercial cinema and home theater studies

Support for these studies:
Intel Corporation
Introduction

- Common reports of symptoms
  - Samsung: April 2010
  - Non-controlled surveys
Introduction

• Popular theories include
  • Sensory conflict
  • Unnatural visual demands
  • Immersion
A simple model of sensory conflict: Am I moving?

- Vision
- Vestibular
- Somato-Sensory

YES
A simple model of sensory conflict: Am I moving?

- Vision
- Vestibular
- Somato-Sensory

NO
A simple model of sensory conflict: Am I moving?
A simple model of sensory conflict: Am I moving?
3D movie

Vision

Vestibular

Somato-Sensory

???
Binocular cues for depth: The basics

Natural viewing:
Focal Plane and Vergence Plane are the same
Binocular cues for depth: The basics

3D presentations:
Focal Plane and Vergence Plane mismatch
Sensory and Perceptual Conflicts in 3D Movies
Sensory and Perceptual Conflicts in 3D Movies
Sensory and Perceptual Conflicts in 3D Movies

- Closer viewing distance:
  - ↑ Accommodation-vergence mismatch
  - ↓ “Float” and speed of 3D movement

- Farther viewing distance:
  - ↓ A – V mismatch
  - ↑ “Float” and speed of 3D movement

- Sensory conflict also varies
Recall and stay tuned...

- Dr. Shun-nan Yang’s presentations
2D v 3D Symptom Study
Commercial Theater

Scott C Cooper, OD, MEd, FAAO
Josh A Gietzen BS
John R Hayes, PhD
James E Sheedy, OD, PhD, FAAO
2D v 3D Symptom Study
Commercial Theater

• Purpose: Compare symptom experiences of audiences watching 2D versus 3D versions of the same movie
2D v 3D Symptom Study
Commercial Theater: Methods

- 98 Subjects
  - ≥18
  - No significant eye-disease or abnormality
  - No restriction of ocular motility
  - No photosensitive epilepsy
  - No other reason they should not watch an entire standard or 3D movie
2D v 3D Symptom Study
Commercial Theater: Methods

• Randomly assigned
  • 3D or 2D showing of “How To Train Your Dragon”
  • One of nine seating areas

• Surveys
  • Pre-Movie
  • Immediately Post-Movie
  • Next day email follow up
## Before Movie Survey

**Circle your answers**

Consider how your eyes feel right at this moment. Rate the following descriptions of your eyes.

<table>
<thead>
<tr>
<th>Eye Description</th>
<th>Not at all</th>
<th>Mild</th>
<th>Moderate</th>
<th>Bed</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gritty or sandy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Burning on the surface of the eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eyes itches or feel sore</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain from the inside of your eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strong motion or “pulling” sensation around your eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Considering right at this moment, rate each of the following items.**

<table>
<thead>
<tr>
<th>Item Description</th>
<th>Not at all</th>
<th>Mild</th>
<th>Moderate</th>
<th>Bed</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck ache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shoulder ache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tiredness or sleepiness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazy vision when looking at the theater screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing multiple images (“seeing double”) of these words or images on the theater screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nausea</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling dismantled</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

Consider all the symptoms above. In the past, have you ever experienced any of these...

<table>
<thead>
<tr>
<th>Activity</th>
<th>Never</th>
<th>Occasionally</th>
<th>Sometimes</th>
<th>Usually</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>...at the movies</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...watching television</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>...using the computer</td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>...reading in a moving car</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

*If you indicated sometimes, usually or always, please comment about those symptoms on the other side of this form

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**Last question for now:**

| Have you seen this particular movie before? | YES | NO |
# After Movie Survey

## How did you like the movie?

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The movie was very entertaining</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The special effects added to my enjoyment of the film</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I would definitely recommend this movie to a friend</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Consider how your eyes feel right at this moment. Rate the following descriptions of your eyes.

<table>
<thead>
<tr>
<th>Description</th>
<th>Not at all</th>
<th>Mild</th>
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</thead>
<tbody>
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</tr>
<tr>
<td>Irritated</td>
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<tr>
<td>Gritty or sandy</td>
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<td>Burning on the surface of the eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eye ache or feel sore</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Puts from the inside of your eye</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Strong tension or “pulling” sensation around your eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Considering right at this moment, rate each of the following issues.

<table>
<thead>
<tr>
<th>Description</th>
<th>Not at all</th>
<th>Mild</th>
<th>Moderate</th>
<th>Bad</th>
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</tr>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Backache</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Headache</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Blurry vision when looking at the theater screen</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seeing multiple images (“seeing double”) of those words or images on theater screen</td>
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<td>Nausea</td>
<td></td>
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<tr>
<td>Feeling disoriented</td>
<td></td>
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</tr>
</tbody>
</table>

## Rate the following based on your experience during today’s movie.

<table>
<thead>
<tr>
<th>Description</th>
<th>Not at all</th>
<th>Mild</th>
<th>Moderate</th>
<th>Bad</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any blurry vision</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Any multiple images of the pictures or words</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dizziness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nausea</td>
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<tr>
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<td></td>
<td></td>
<td></td>
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<td></td>
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</tbody>
</table>
Next Day Follow Up Survey

1. Did you experience any eye or other physical symptoms when you stood up or started walking out of the theater?

2. When you arrived home after the movie did you have eye or other physical symptoms from the movie?

3. If you had any symptoms in question #1, did you still experience them the next morning.

4. Describe any symptoms you had when you arrived home and/or continued to experience the next morning.
Analysis: Commercial Cinema

- Each question
- Subscales
  - Internal eye
  - External eye
  - Physical
  - Vision
  - Motion symptoms
- Summary of comments
Cinema Study Summary Points:

- Few, low intensity symptoms were reported in any survey.
- Median response = “no symptom” except after:
  - Dry eyes 2D>3D
  - Eyes ache 3D>2D
Cinema Study Summary Points: Odds Ratio Analysis

• When change occurred, what are the directional odds?
  • Sample size of symptom changes very small
  • Practical view: if difference of log odds ratio $\geq 0.80$ and $\geq 5\%$ of participants needed to change report to equalize odds, flagged as potential trend
Cinema Study Summary Points: Odds Ratio Analysis

- **During 3D worse odds trend**
  - Blurry vision of screen
  - Dizziness
  - Disoriented

- **After 3D worse odds trend**
  - Tension or "pulling"
  - Pain inside eye
  - Disoriented

- **After 2D worse odds**
  - Tired, sleepy
  - Multiple images near or screen
Cinema Study Summary Points: Significant Findings

• Statistically significant during movie:
  • 3D worse:
    • Motion symptoms* (p=.03)
    • Blurry vision (p=.049)

*dizziness, nausea, disorientation
Cinema Study Summary Points: Significant Findings

- Statistically significant after the movie:
  - 2D worse:
    - Dryness (p=.002)
  - 3D better:
    - Tired, sleepy (p=.011)
    - Less tired, sleepy than before (p=.02)
- Note: Motion symptoms after not significant (p=.5)
Cinema Study Summary Points: Significant Findings
Cinema Study Summary Points: Significant Findings

- Statistically significant for seating:
  - Center (not sides)
    - Enjoyed the movie more (p=.003)
    - Less dry eye if in 3D condition (p=.013)
  - First third of the theater
    - More neck pain (p=.04)
    - More blurry vision after (p=.02)
Cinema Study Summary Points: Post-Movie Findings

- Some type of symptom: 14/67 (21%)
- No significant differences 2D vs. 3D
- Specified symptoms
  - motion-related (2)
  - headaches or eye fatigue (4)
  - dry or gritty eyes (3)
  - eye aches or pulling sensations (3)
  - wet eyes (1)
- None remained the following morning
Cinema Study Summary Points:

• Some support for claims of 3D movies inducing more symptoms
  • However:
    • Few experienced them
    • Low intensity change when reported
    • Effect only found during the movie
    • Insignificant reports of symptoms when exiting
Practical point:

- Chances are small that a random person would experience an increase in symptoms due to viewing a 3D versus 2D movie.
- If a change occurred, would likely be small, and not present after the movie.
- Studies of large groups do not rule out that a particular person could have a notable effect, longer than the movie.
Questions raised:
- Modified surveys
- Other, longer movie
- Other 3D entertainment or environment
- Other demographics
- Can people predict if they’ll have a greater effect than others?
- Comparison of 3D rendering methods
Questions raised:
- What about home theater?
Does 3D viewing cause symptoms? Home theater study

Shun-nan Yang, PhD
Tawny Shleiski, MA
Brent Selmins
Scott C Cooper, OD, MEd
Rina Doherty, MS
Philip J Corriveau
James E Sheedy, OD, PhD
Home Theater Symptom Study

- **Design:**
  - 203 teens and adults
  - "Cloudy with a chance of meatballs"
    - Random assignment to 2D or 3D condition
    - Device: Samsung 55" C7000 HD3D LED
      - 240hz (120 each 3D) active shutter
      - Center 6’ from ground
Home Theater Symptom Study
Before Movie Survey

- Pre-movie and Post-movie surveys
  - Same questions as cinema study
  - Reported using mouse and analog scale instead of circling

Consider how your eyes feel right at this moment. Rate the following descriptions of your eyes.

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<thead>
<tr>
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<td></td>
</tr>
<tr>
<td>Wet</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Reddened</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grisy or crusty</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redness of the skin of the eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain from the irritation of your eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensing &quot;pulling&quot; sensation around your eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Consider how right at this moment, rate each of the following items.

<table>
<thead>
<tr>
<th></th>
<th>Not all</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intermittent vision loss</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difficulty focusing on the screen</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling disoriented</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feeling drowsy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Consider all the symptoms above. In the past, have you ever experienced any of these...

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Occasionally</th>
<th>Sometimes</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>watery eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>itching, redness of the skin of the eye</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rubbing the eyes</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sensitivity to bright lights/ daylight</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If you experienced any of the symptoms above, please continue on this page.

Last question for now.

Were you seen this particular movie before?

<table>
<thead>
<tr>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
</table>
After Movie Survey

• Post-movie
  • Added immersion questions
    
    Not at all  |  Mildly  |  Moderately  |  Severely  |  Extremely
    ----------------------------------------

    • The movie was convincing at showing objects moving through space.
    • There was a sense that you were moving around inside the movie.
    • How involved were you in the story?
    • Did the quality of the visual display distract you or interfere with enjoying the movie?
    • Were you involved in the movie to the extent that you lost track of time?

    Derived from Simulator Sickness Questionnaire (Kennedy et al., 1993)
Home Theater Symptom Study

- **Next morning email follow up**
  - Did you experience any eye or other physical symptoms when you stood up or started walking out of the theater?
  - When you arrived home after the movie did you have eye or other physical symptoms from the movie?
  - If you had any symptoms in question #1, did you still experience them the next morning.
  - Describe any symptoms you had when you arrived home and/or continued to experience the next morning.
Home Theater Symptom Study: Results

- Odd Ratio Analysis
  - Pre-Post direction of change
    - Frequency of increase, decrease, no change
    - Those frequencies are basis of determining odds
Home Theater Symptom Study
Odds Ratio Analysis

- Odd Ratio Analysis

![Graph showing symptoms and odds ratio analysis]
Home Theater Symptom Study
Odds Ratio Analysis

- Odd Ratio Analysis

![Graph showing odds ratio analysis for symptoms decreased and increased in 2D and 3D.](image-url)
Home Theater Symptom Study
Covariance Analysis

- Analyses of covariance
  - Dimension: 2D versus 3D
  - Seating position
  - Age (13-23, 24-34, 35-45, 46->46)
  - Gender
  - Interaction of these
Home Theater Symptom Study
Covariance Analysis

- Internal Ocular, External Ocular, Physical Symptoms
  - Internal ocular: Eyes ache, sore, pain inside, pulling sensation
  - External ocular: Dry, irritated, burning
  - Physical: Neck, shoulder, back
  - Visual and motion symptoms served as covariate

- Visual and Motion Symptoms
  - Visual: Blurriness, double vision
  - Motion: Dizziness, nausea and disorientation

- Sense of Immersion
# Home Theater Symptom Study: Covariance Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Analysis</th>
<th>Internal Ocular Symptoms</th>
<th>External Ocular Symptoms</th>
<th>Physical Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Seating Position</strong></td>
<td>Viewing Position</td>
<td>.363</td>
<td>.761</td>
<td>.828</td>
</tr>
<tr>
<td></td>
<td>Dimension (2D versus 3D)</td>
<td><em>01</em></td>
<td>.281</td>
<td>.871</td>
</tr>
<tr>
<td></td>
<td>Dimension and Seating Position</td>
<td>.765</td>
<td><em>028</em></td>
<td>.608</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td>Gender</td>
<td>.997</td>
<td>.232</td>
<td>.328</td>
</tr>
<tr>
<td></td>
<td>Gender and 2D versus 3D</td>
<td>.148</td>
<td><em>045</em> (♀ &gt; ♂ 2D only)</td>
<td>.807</td>
</tr>
<tr>
<td><strong>Age</strong></td>
<td>Age</td>
<td>.399</td>
<td>.920</td>
<td>.622</td>
</tr>
<tr>
<td></td>
<td>Age and 2D versus 3D</td>
<td>.841</td>
<td><em>051</em> (13-24 YO)*</td>
<td>.798</td>
</tr>
</tbody>
</table>

* = 3D stronger symptoms
** = 2D stronger symptoms
## Home Theater Symptom Study Covariance Analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Analysis</th>
<th>Blurry Vision</th>
<th>Double Vision</th>
<th>Dizziness</th>
<th>Nausea</th>
<th>Disorientation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>During Movie</strong></td>
<td>2D versus 3D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viewing Position</td>
<td></td>
<td>&lt;.0001*</td>
<td>.008*</td>
<td>.463</td>
<td>.852</td>
<td>.117</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>.851</td>
<td>.937</td>
<td>.549</td>
<td>.703</td>
<td>.890</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td>.042*</td>
<td>.076</td>
<td>.684</td>
<td>.247</td>
<td>.824</td>
</tr>
<tr>
<td><strong>Variable Interaction(s)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dimension and Age ***</td>
<td>None</td>
<td>Dimension and Age ****</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>After Movie</strong></td>
<td>2D versus 3D</td>
<td>.088 (3D worse)</td>
<td>.205</td>
<td>.503</td>
<td>.836</td>
<td>.268</td>
</tr>
<tr>
<td>Viewing Position</td>
<td></td>
<td>.906</td>
<td>.313</td>
<td>.520</td>
<td>.583</td>
<td>.793</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>.662</td>
<td>.211</td>
<td>.559</td>
<td>.202</td>
<td>.927</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td>.624</td>
<td>.065 (♀ &gt; ♂)</td>
<td>.053 (♀ &gt; ♂)</td>
<td>.014 (♀ &gt; ♂)</td>
<td>.889</td>
</tr>
<tr>
<td><strong>Variable Interaction(s)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>None</td>
<td>None</td>
<td>Dimension &amp; age (.019) #</td>
<td>Position and age *</td>
<td>Dimension and age *</td>
</tr>
</tbody>
</table>

* = 3D stronger symptoms
** = 2D stronger symptoms
*** = 13-23 and 24-34 had greater magnitude of blurry vision than 35-45 YO
**** = 3D, not for 2D

# = 13-23 and 24-34 > in 3D; 35-45 and ≥46 > in 2D
## = ≥46 > 22.5° left 2D; 13-23 > 45° left 3D; 24-34 > 46+ 22.5° left 3D
♀ = 13-23 YO > nausea in side seating (seats 1,2,5)
♀♀ = in 2D, seats 1 and 5 (45° to sides) > nausea; 3D central seating > nausea
Home Theater Symptom Study
Covariance Analysis

- More blurry vision during the movie
  - 3D
  - 13-34 YO than 35-45 YO overall
  - Covaried with age and 2D/3D
- Females
  - Borderline more double vision and dizziness after movie
  - More nausea after movie
- Nausea and seat position
  - 2D: outside seating
  - 3D: central seating
Home Theater Symptom Study: Covariance Analysis

- Variable interaction with age

<table>
<thead>
<tr>
<th>Variable Interaction with Age</th>
<th>Symptom</th>
<th>13–23</th>
<th>24–34</th>
<th>35–45</th>
<th>46+</th>
</tr>
</thead>
<tbody>
<tr>
<td>During</td>
<td>Dizzy</td>
<td>3D only: 45° left</td>
<td>(&gt;46+) 3D only: 22.5° left</td>
<td>NA</td>
<td>2D only: 22.5° left</td>
</tr>
<tr>
<td>2D-3D &amp; Position</td>
<td>Dizzy</td>
<td>Worse in 3D</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D-3D</td>
<td>Dizzy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D-3D</td>
<td>Disorientation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After</td>
<td>Nausea</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Position</td>
<td>Nausea</td>
<td>Both left &amp; 45° right</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>
# Home Theater Symptom Study

## Covariance Analysis

### Immersion

<table>
<thead>
<tr>
<th>Variable</th>
<th>Analysis</th>
<th>Perception of objects moving through space</th>
<th>Perception of viewer moving through space</th>
<th>Involvement in the movie</th>
<th>Display quality and enjoyment</th>
<th>Losing track of time</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D versus 3D</td>
<td></td>
<td>&lt;.0001*</td>
<td>.003*</td>
<td>.398</td>
<td>.937</td>
<td>.105</td>
</tr>
<tr>
<td>Viewing Position</td>
<td></td>
<td>.010**</td>
<td>.694</td>
<td>.058***</td>
<td>.391</td>
<td>.857</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>.735</td>
<td>.573</td>
<td>.719</td>
<td>.602</td>
<td>.136</td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td>.048 (♀ &gt; ♂)</td>
<td>.625</td>
<td>.001 (♀ &gt; ♂)</td>
<td>.536</td>
<td>.143</td>
</tr>
<tr>
<td>Variable Interaction(s)</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>Dimension &amp; position ****</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

* = Greater in 3D
** = Greater in seats #2 and #3 than #5 or #6
**** = Greater in (central, closer) seat #3 than #6
**** = In 2D, #3 and #6 > #1 and #5. In 3D, opposite
# Home Theater Symptom Study

**Correlation Analysis**

- **Immersion and symptom correlations**

<table>
<thead>
<tr>
<th>Immersion</th>
<th>Visual Symptoms</th>
<th>Visual Quality</th>
<th>Motion Sickness</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External</td>
<td>Internal</td>
<td>Physical</td>
<td>During</td>
</tr>
<tr>
<td>Convincing: objects moving through space</td>
<td>-.086</td>
<td>.068</td>
<td>.068</td>
<td>.002</td>
</tr>
<tr>
<td>Self moving through space</td>
<td>.074</td>
<td>-.056</td>
<td>.072</td>
<td>.064</td>
</tr>
<tr>
<td>Involved in the story</td>
<td>-.038</td>
<td>-.023</td>
<td>.020</td>
<td>-.097</td>
</tr>
<tr>
<td>Visual display distractive</td>
<td>-.034</td>
<td>.037</td>
<td>.155</td>
<td>.133</td>
</tr>
<tr>
<td>Losing track of time</td>
<td>.040</td>
<td>.062</td>
<td>.008</td>
<td>-.062</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Immersion</th>
<th>Visual Symptoms</th>
<th>Visual Quality</th>
<th>Motion Sickness</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External</td>
<td>Internal</td>
<td>Physical</td>
<td>During</td>
</tr>
<tr>
<td>Convincing: objects moving through space</td>
<td>-.072</td>
<td>-.108</td>
<td>-.177</td>
<td>-.123</td>
</tr>
<tr>
<td>Self moving through space</td>
<td>.023</td>
<td>.021</td>
<td>-.087</td>
<td>-.191</td>
</tr>
<tr>
<td>Involved in the story</td>
<td>-.312**</td>
<td>-.266**</td>
<td>-.166</td>
<td>-.271**</td>
</tr>
<tr>
<td>Visual display distractive</td>
<td>.220*</td>
<td>.106</td>
<td>.018</td>
<td>.259**</td>
</tr>
<tr>
<td>Losing track of time</td>
<td>-.162</td>
<td>-.174</td>
<td>-.234*</td>
<td>-.201*</td>
</tr>
</tbody>
</table>

* Indicates significant correlation at p < 0.05
** Indicates significant correlation at p < 0.01
### Home Theater Symptom Study

#### Correlation Analysis

**Prior experience and symptoms**

<table>
<thead>
<tr>
<th>Symptom History</th>
<th>Visual Symptoms</th>
<th>Visual Quality</th>
<th>Motion Sickness</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External</td>
<td>Internal</td>
<td>Physical</td>
<td>During</td>
</tr>
<tr>
<td>At movies</td>
<td>.255*</td>
<td>.133</td>
<td>.242*</td>
<td>-.004</td>
</tr>
<tr>
<td>Viewing TV</td>
<td>.341**</td>
<td>.161</td>
<td>.296**</td>
<td>-.014</td>
</tr>
<tr>
<td>Using PC</td>
<td>.421**</td>
<td>.289**</td>
<td>.396**</td>
<td>.325**</td>
</tr>
<tr>
<td>Reading in a moving car</td>
<td>.112</td>
<td>.027</td>
<td>.140</td>
<td>.101</td>
</tr>
<tr>
<td>3D</td>
<td>.086</td>
<td>.161</td>
<td>.215*</td>
<td>.084</td>
</tr>
<tr>
<td>At movies</td>
<td>.188</td>
<td>-.007</td>
<td>.196*</td>
<td>.114</td>
</tr>
<tr>
<td>Viewing TV</td>
<td>.232*</td>
<td>.044</td>
<td>.211*</td>
<td>.084</td>
</tr>
<tr>
<td>Using PC</td>
<td>.128</td>
<td>.095</td>
<td>.133</td>
<td>-.003</td>
</tr>
<tr>
<td>Reading in a moving car</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Indicates significant correlation at p < 0.05

** Indicates significant correlation at p < 0.01
Home Theater Symptom Study

- Follow up: 186 of 205 subjects responded

<table>
<thead>
<tr>
<th>Symptom</th>
<th>2D Viewers</th>
<th>3D Viewers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Any symptoms afterward*</td>
<td>11.0 %</td>
<td>25.2 %</td>
</tr>
<tr>
<td>Symptoms upon leaving*</td>
<td>10.8 %</td>
<td>22.2 %</td>
</tr>
<tr>
<td>Symptoms once home*</td>
<td>4.3 %</td>
<td>14.4 %</td>
</tr>
<tr>
<td>Symptoms next morning</td>
<td>1.1 %</td>
<td>3.3 %</td>
</tr>
</tbody>
</table>

(Similar insignificant trend of fading symptoms post-cinema study)

<table>
<thead>
<tr>
<th>Symptom</th>
<th>2D vs 3D Viewers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eyestrain / Eyes Tired</td>
<td>5 : 11</td>
</tr>
<tr>
<td>Eyes dry, gritty, itchy</td>
<td>3 : 9</td>
</tr>
<tr>
<td>Headache</td>
<td>0 : 7</td>
</tr>
<tr>
<td>Blurry vision</td>
<td>0 : 6</td>
</tr>
<tr>
<td>Dizzy, balance</td>
<td>2 : 6</td>
</tr>
</tbody>
</table>
High Points: Home Theater Symptom Study

- Notes from Odds ratio: Increased odds...
  - 2D viewing:
    - Gritty, sandy symptoms
    - Backache
  - 3D viewing:
    - Pain inside eyes
    - Before and after:
      - Blurry vision
      - Double vision
      - Dizziness
      - Disorientation
    - Less tired / sleepy than before movie
High Points: Home Theater Symptom Study

• Notes from Covariance:
  • 3D > 2D: Internal ocular symptoms
  • 2D > 3D: External ocular symptoms (females only)
  • Age: 13-34 YO
    • Blurry vision during (2D + 3D) compared to 35-45 YO
  • Age: Dizzy during & after; nausea & disorientation after
    • 13-34: worse in 3D
    • 35+: worse in 2D
    • Presbyopia theory?
  • Females: (2D, 3D combined)
    • Borderline significant for double vision & dizziness after
    • Significant for nausea after
    • Greater perception of objects moving through space
High Points: Home Theater Symptom Study

- Notes from Covariance:
  - Perception of objects moving through space:
    - 3D
    - Female
    - Central seating
High Points: Home Theater Symptom Study

- Notes from Covariance:
  - Seating position
    - Perception of objects moving through space
      - 3D
      - Either condition: central seating
  - Nausea:
    - 2D: outside seats
    - 3D: central seats
  - Involvement in movie:
    - Overall: central and closer
    - 2D: central seats
    - 3D: outside seats
High Points: Home Theater Symptom Study

- Notes from correlations:
  - Immersion
    - 3D viewing: greater motion perception, not involvement in movie
  - Involvement in the story
    - Inversely related to internal and external ocular symptoms
    - Inversely related to perception of image quality during and after
    - Similar to “losing track of time”
      - Inversely related to physical symptoms and visual quality during
High Points: Home Theater Symptom Study

• **Notes from correlations:**
  • *Motion sickness afterward in 2D*
    • Perception of self moving through space
    • 2D display distracting
  • **Display distracting:**
    • Correlates with internal ocular symptoms, complaints of visual quality during and after
High Points: Home Theater Symptom Study

- Notes from correlations:
  - Previous symptom history:
    - Symptoms with using a PC
      - All symptom categories during and after in 2D viewing
      - External ocular symptoms and physical symptoms in 3D
    - Any symptom history at the movies, TV or PC
      - Physical symptoms in 2D and 3D viewing
  - History of symptoms in a moving car NOT correlated with any categories in this study
High Points: Home Theater Symptom Study

- **After-effects**
  - **Symptoms of ANY kind**
    - More with 3D at about 2:1 to 3:1 ratio at least until returned home (significant difference)
    - Very few still had some type of report next morning (insignificant difference)
    - Similar trend noticed in Cinema study, but was insignificant
High Points: Home Theater Symptom Study

• **Next related research steps:**
  • How to optimize 3D experience
    • 3D presentation
    • Individual
  • How to identify those susceptible to 3D-related symptoms
  • How to prevent or minimize symptoms for those who experience them
    • How to reduce them more quickly