3D TV Experiences and Preference with Prescribed Active Shutter and Film Pattern Retarding Glasses

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Vision Performance Institute
A research consortium supporting "Quality Sustainable Vision"
PURPOSE

• To compare the visual comfort, perceived immersion, and perceived display quality with active vs. passive prescription 3D spectacles
HYPOTHESIS I

• Compared to clip-on type Shutter glasses (SG), the single-lens-unit curved FPR glasses (cFPR) should result in greater visual comfort, perceived immersion, and perceived display quality, as a function of lens power.
HYPOTHESIS II

• For active SG, further viewing distance and larger viewing angle should result in more negative viewing experiences compared to cFPR.
EXPERIMENTAL DESIGN - Participants

- Pacific University (USA): 45 subjects (18-40 age group)
- Eulji University (S. Korea): 145 subjects (18-60 age group)

• Eligibility Criteria
  - Habitual spectacle wearer
  - Current optical prescription with spherical equivalent power between (+/-) 1.0D and (+/-) 8.00D in at least one eye
  - Far visual acuity of 20/25 or better for each eye
  - No previous diagnosis of visual, ocular, or neurological disorders
  - No previous diagnosis of strabismus (crossed-eyes or wall-eyes), or amblyopia (lazy eye)
EXPERIMENTAL DESIGN - Questionnaires

- Visual and physical discomforts (pre/post movie viewing) : from the Viewing Symptom Questionnaire

<table>
<thead>
<tr>
<th>Range</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Not at all</td>
<td>Mildly</td>
<td>Moderately</td>
<td>Severely</td>
<td>Extremely</td>
</tr>
</tbody>
</table>

1. Do you feel physically uncomfortable in general?
2. Do your eyes feel tired?
3. Do your eyes feel a strain or pulling sensation?
4. Do you have headache?
5. Do you feel dizzy?
6. Do you feel disorientation or vertigo?
7. Does your neck ache?
8. Do you feel tired or sleepy?
EXPERIMENTAL DESIGN - Questionnaires

- Perceived immersion (post movie viewing) :
  from the Simulator Sickness Questionnaire

<table>
<thead>
<tr>
<th>Range</th>
<th>0</th>
<th>25</th>
<th>50</th>
<th>75</th>
<th>100</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
<td></td>
</tr>
</tbody>
</table>

1. Objects felt real as they moved through space.
2. The depth sensation in the movie felt real.
3. I felt like I was part of the movie.
4. The sensation of depth added value to the movie.
5. I was so involved that I felt I lost track of time.
6. I had trouble following the movie.
EXPERIMENTAL DESIGN - Questionnaires

- Display quality (post movie viewing):

<table>
<thead>
<tr>
<th>Range</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

1. The display brightness with the glasses was very good.
2. The colors in the display were good.
3. I saw ghost images during the movie.
4. I saw double images during the movie.
5. The images on the TV appeared jagged (rough edges).
6. The motion of objects was smooth.
7. The 3D glasses were comfortable to wear.
8. The edge of the glasses and frame was visible.
9. I noticed flickering image while watching the movie.
10. I had trouble visually focusing on the scene.
11. I saw multiple images of the scene.
EXPERIMENTAL DESIGN - Movies

- Cloudy with a Chance of Meatballs (Columbia, 2011)
- Despicable Me (Universal, 2011)
- Tangled (Disney Picture, 2011)

- Native 3D format
- Similar genres, and length (90 minutes)
- Dubbed in Korea for Korean participants
- Can be played both active / passive 3D TVs
EXPERIMENTAL DESIGN - Apparatus

• Stereoscopic 3D TVs

- LCD shutter-based 55” Samsung UN55C7000 (Radio Frequency shutter)
- FPR-based 55” LG 55LW6500 (Circular polarization)

The same screen resolution (1920 x 1080 pixels) and vertical refresh rate (240Hz) in 2D mode
EXPERIMENTAL DESIGN - Apparatus

- **Stereoscopic 3D spectacles**

  Two sets of 3D spectacles were prepared for each participant based on their prescription.

  a. Samsung Active Shutter Glasses (SG, SSG-3700CR); flat shutter glasses w/ the Rx optical insert

  b. Curved FPR Glasses (cFPR, lens by SOMO Optical Inc.)

<table>
<thead>
<tr>
<th>Size</th>
<th>Bridge</th>
<th>Diagonal</th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front</td>
<td>21</td>
<td>54</td>
<td>53</td>
<td>29</td>
</tr>
<tr>
<td>Insert</td>
<td>21</td>
<td>49</td>
<td>47</td>
<td>28</td>
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</table>

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<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>18</td>
<td>51.78</td>
<td>51.67</td>
<td>31.22</td>
</tr>
</tbody>
</table>
EXPERIMENTAL DESIGN - Apparatus

• **Visual ability measurements**
  
  – Far Visual Acuity (far VA) using Smart System II 20/20 Basic Visual Acuity System, M&S Technologies, Inc., IL: Park Ridge
  
  – Stereo Acuity (STA) using Stereo Fly chart (Bernell Instruments, Lafayette, IN)
  
  – Phoria using prism lens (by von Graefe Technique)
  
  – Near Point Convergence (NPC) using a focus bead
EXPERIMENTAL DESIGN

Environments set-up

• Up to 3 participants were tested at a time.
• Seat locations
  a. 25°, 2.1m
  b. 0°, 2.6m
  c. 25°, 3.1m
• Horizontal luminance at eye height level: 150 lux
Data Analysis

• Viewing Symptoms : ANCOVA
  (pre-viewing as covariate)

• Perceived immersion & Display Quality : ANOVA
# RESULTS

## Demographics and Visual Characteristics

<table>
<thead>
<tr>
<th>Mean ± SD (Range)</th>
<th>Pacific University (PU)</th>
<th>Eulji University (EU)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td>26.1 ± 4.9 (range 18 ~ 40, n=50)</td>
<td>Group 1: 27.9 ± 6.53 (range 19 ~ 40, n=94)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Group 2: 48.92 ± 5.26 (range 41 ~ 60, n=51)</td>
</tr>
<tr>
<td><strong>Spherical Equivalence Power</strong></td>
<td>-2.13D ± 1.25D (-4.88D ~ +1.38D)</td>
<td>-4.48 ± 1.74D (-8.25D ~ -1.63D)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-3.88 ± 1.92 D (-7.38D ~ +1.69D)</td>
</tr>
<tr>
<td><strong>Binocular Far VA</strong></td>
<td>-0.19 ± 0.6 logMar (-0.3 ~ 0.0 logMar)</td>
<td>-0.07 ± 0.08 logMar (-0.34 ~ -0.02 logMar)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-0.06 ± 0.06 logMar (-0.20 ~ 0.06 logMar)</td>
</tr>
<tr>
<td><strong>Stereo Acuity</strong></td>
<td>23.94 ± 7.63 arcsec (20 ~ 50 arcsec)</td>
<td>39.98 ± 24.89 arcsec (20 ~ 160 arcsec)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41 ± 14.51 arcsec (20 ~ 63 arcsec)</td>
</tr>
<tr>
<td><strong>Near Point Convergence</strong></td>
<td>11.2 ± 6.2 cm (1 ~ 33cm)</td>
<td>7.63 ± 2.11 cm (3.5 ~ 15cm)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.52 ± 7.40 cm (5~ 54cm)</td>
</tr>
</tbody>
</table>

(0.0 logMar = Snellen 20/20)
RESULTS

Perceived Visual and Physical Symptoms

• The main effect of glasses \((F_{1,2872} = 8.595, p=.003)\): SG (Mean = 8.2) > cFPR (Mean = 7.4)

• The main effect of institution \((F=4.92, p=.026)\): EU (mean = 9.1) > PU (mean = 6.7)
RESULTS

Perceived Visual and Physical Symptoms

Mean Discomfort Score

Non-overlapping confidence intervals are significantly different at an unadjusted p<.05.
RESULTS
Perceived Visual and Physical Symptoms

Non-overlapping confidence intervals are significantly different at an unadjusted p<.05.
RESULTS

Perceived Visual and Physical Symptoms

• Symptoms were higher when Near Point Convergence (NPC) was closer (<6 cm) (p= .028)

• Interaction : NPC - Seat position (p=.01)
  – At the closer position (2.1 m; p = .01):
    closer NPC (Mean=8.47) > farther NPC (Mean=6.42)
  – At central position (2.6 m; p = .004):
    closer NPC (Mean=9.44) > farther NPC (Mean=6.77)
RESULTS

Perceived Immersion

- No significant main effect on the spectacle type and immersion ($F_{1,184} = .008, p = .93$)

Non-overlapping confidence intervals are significantly different at an unadjusted $p<.05$. 
RESULTS

Perceived Immersion

• Better STA(=20 arcsec) was accompany by greater overall perceived immersion for SG.
  \( (r = -.23, \ p = .002 \) for SG; \( r = -.13, \ p = .034 \) for cFPR)\)

• “Object felt real as they moved \( (p = .03) \)”
  “I felt like I was part of the movie \( (p = .03) \)”:
  closer NPC had better immersion

• “The depth sensation in the movie felt real”:
  cFPR (mean=77.0) > SG (mean=69.2)
  at the center position (\( F_{2,269}=3.58 \ ; \ p = .03 \))
RESULTS

Perceived Display Quality

• Main effect of glasses ($F_{1,3540} = 56.6, p < .001$): cFPR (mean=77.2) > SG (mean=72.7)

• The interaction between glasses and individual display quality questions was also significant ($F_{10,733} = 4.97, p < .001$).
The display brightness with the glasses was very good

The colors in the display were good

I saw ghost images during the movie (Reversed)

I saw double images during the movie (Reversed)

The images on the TV appeared jagged (rough...)

The motion of the objects was smooth

The 3D glasses were comfortable to wear

The edge of the glasses and frame is visible...

I noticed flickering images while watching the...

I had trouble visually focusing on the scene...

I saw multiple images of the scene (Reversed)

Non-overlapping confidence intervals are significantly different at an unadjusted p<.05.
RESULTS

Perceived Display Quality

- Correlation: STA - trouble focusing
  \((r = -.31, p < .001\) for SG; \(r = -.08, p = .28\) for cFPR)\)
  - STA was a factor for focusing on the image for SG, but not cFPR.
RESULTS

Relationship among Optical Correction, seat position, and Perceived Display Quality

Optical Correction (Average Spherical Equivalence Power)
Less Myopic (> -2D)  More Myopic (<= -2D)

Perceived Display Quality (Positive values are higher)

F = 3.08, p = .047

- 2.1m (25°)
- 2.6m (0°)
- 3.1m (25°)
RESULTS

S3D viewing experiences and Age Groups

• Perceived Visual Discomfort

![Graph showing symptom total score by age group]
RESULTS

S3D viewing experiences and Age Groups

- Perceived Immersion

![Bar chart showing perceived immersion scores for different age groups.](chart.png)
SUMMARY

• Wearing optically corrected cFPR was less tiring visually and physically compared to clip-on SG.
• cFPR glasses with incorporated optical correction afford better resultant display quality than currently available active shutter glasses.
• Low powered optically prescribed 3D spectacle wearers perceived better display quality at the center and closer distances.
• Elder people perceived less visual discomfort and better immersion.
IMPLICATIONS

• Future optically corrected 3D spectacle designs should incorporate the corrective power into the curve of the lens and avoid clip-on or stacked lens systems, which are less comfortable and can impede the view.

NO!
ACKNOWLEDGEMENT

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