The Effects of Visual Attention Factors on Visual Field Testing for Maintenance of Gaze Fixation

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  - Limitation of Existing Perimeters
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Glaucoma

- Glaucoma is a **progressive ophthalmologic disease**, leading a cause of blindness triggered by **visual field defect** that is progressed by optic nerve damage.
- **No obvious symptoms** until the advanced stage → “Silent sight thief”
- **Causes:** high ocular pressure, abnormal blood circulation, high myopia, old age, family history
Quigley and Broman (2006) reported that the prevalence of glaucoma may increase to almost 80 million by 2020 globally.
Exams for Glaucoma

- **Structural test**: Measure the morphological characteristics in the eye
- **Functional test**: Measure the functionality of the retina

⇒ Of the tests, only the visual field test requires psychophysical responses to stimuli for a significant period of testing time (5~10 min./eye)
Detect the locations of damaged optic nerves in the central vision by checking stimuli presented at various locations are recognized while the gaze remains at the central target (Dersu and Wiggins, 2006)

Humphrey® Field Analyzer / HFA™ II-i Series, Carl Zeiss, Germany (considered as gold standard perimetry)
Importance of Gaze Fixation

- If the examinee’s gaze is moved from the central target, the visual field target is presented to a location on the retina different from the optic nerve location to be measured $\Rightarrow$ Inaccurate visual field measurement

$\Rightarrow$ A proper **gaze fixation induction method** is needed for **accurate testing**

![Diagram showing correct and incorrect gaze fixation]

- Gaze: fix on the central target $\Rightarrow$ Correct optic nerve position
- Gaze: move upward $\Rightarrow$ Incorrect optic nerve position

optic nerve position to be measured

Testing target

Central target

Gaze direction
Limitation of Existing Perimeters

- Use a LED light or simple dot as the central target

⇒ Decrease the accuracy of test results due to lack of gaze fixation induction to the central target

<table>
<thead>
<tr>
<th>Central target</th>
<th>White dot</th>
<th>Green dot</th>
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</thead>
<tbody>
<tr>
<td>Model</td>
<td>Easy field</td>
<td>AP-5000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Central target</th>
<th>Yellow dot</th>
<th>Black dot</th>
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<tbody>
<tr>
<td>Model</td>
<td>M700</td>
<td>HVF II-i series</td>
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</tbody>
</table>
Research Goal

Comparison of gaze fixation induction methods for effective gaze fixation induction in visual field testing

- **Gaze fixation performance**: correct fixation rate, 1-blindspot response rate, 1-false positive target response rate
- **Subjective satisfaction**: ease of gaze fixation, eye fatigue, overall satisfaction

⇒ Identification of effective GFIMs

<table>
<thead>
<tr>
<th>Gaze fixation induction method (GFIM)</th>
<th>Performance</th>
<th>Subjective satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black dot (BD)</td>
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<td>Changing color dot (CCD)</td>
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<td>Alphanumeric characters (AC)</td>
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<td>Flashing black dot (FBD)</td>
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<td>Bulls eye &amp; cross hair (BECH)</td>
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</table>
Experimental Design

- Participants: 32 (M:F = 1:1; 20s = 30s = 16, age: 29 ± 4.4 yr)
- Design: Single-factor within-subjects ANOVA
- Homogeneity test of variance: Bartlett’s test
- Post-hoc analysis: Tukey-Kramer test, Dunnett’s T3 test

<table>
<thead>
<tr>
<th>Category</th>
<th>Items</th>
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</thead>
<tbody>
<tr>
<td>Independent variable</td>
<td>• Gaze fixation induction method</td>
</tr>
<tr>
<td>Dependent variables</td>
<td></td>
</tr>
<tr>
<td>Objective Measure</td>
<td>• Correct fixation rate (CFR)</td>
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<tr>
<td></td>
<td>• 1-Blind spot response rate (1-BS_RR)</td>
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<tr>
<td></td>
<td>• 1-False positive target response rate (1-FPT_RR)</td>
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<tr>
<td>Subjective Measures</td>
<td>• Ease of gaze fixation (EGF)</td>
</tr>
<tr>
<td></td>
<td>• Eye fatigue (EF)</td>
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<td></td>
<td>• Overall satisfaction (OS)</td>
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Gaze Fixation Induction Method

- Develop four new GFIMs by applying four visual attentional factors: **color**, **alphanumeric character**, **flashing**, and **shape** (Sanders and McCormick, 1993)

<table>
<thead>
<tr>
<th>Reference</th>
<th>Visual Attention Factor</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Color</td>
</tr>
<tr>
<td>Black dot (BD)</td>
<td>Changing color dot (CCD)</td>
</tr>
<tr>
<td></td>
<td>Alphanumeric characters (AC)</td>
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<tr>
<td>Flashing</td>
<td>Flashing black dot (FBD)</td>
</tr>
<tr>
<td>Shape</td>
<td>Bulls eye &amp; cross hair (BECH; Thaler et al., 2013)</td>
</tr>
</tbody>
</table>
Apparatus

- Eye tracking system, head positioner (Arrington Research, USA), 27” monitor, desktop PC, handheld input button

![Diagram of Apparatus](image)
Experimental S/W

- Visual field testing area: visual angle ≤ 24°
- # of targets: 236 (# of visual field testing targets = 54 × 4 = 216; # of blind spot targets = 10; # of false positive targets = 10) (note) false positive target = beep w/o visual target

Visual field testing panel

Control panel
Procedure

S1. Preparation
- Orientation & informed consent (3 min)
- Adjustment of a head positioner (2 min)
(5 min)

S2. Practice
- Wearing eye patch, positioning the head, adjustment of an eye camera, and calibration of an eye tracking system (1 min)
(5 min)

S3. Main Experiment
- Testing a visual field (5 min)
- Administration of subjective evaluation (1 min)
- Rest: 1 min/GFIM and 7 min/session
(85 min)

S4. Debriefing
(5 min)

Total time: 100 min
2 sessions
Analysis Procedure on Gaze Tracking Data

1. Collect gaze tracking data (sampling rate = 220 Hz)

2. Remove noise data (artifacts due to blinking)

3. Select gaze tracking data during target presentation

4. Analyze gaze trajectories

5. Determine the correct gaze fixation to the central target
Gaze Trajectory Analysis

- Gaze trajectory (GT) is divided into B-S and S-A intervals

0.2 sec. before stimulus presentation (B)

Stimulus presentation (S)

0.2 sec. after stimulus presentation (A)
Determination of Correct Gaze Fixation

Gaze trajectory (GT) is divided into B-S and S-A intervals.

\[ \text{GT}_{B-S} \leq 1^\circ \text{ VF} \]

\[ \text{GT}_{S-A} \leq 1^\circ \text{ VF} \]

**Types of correct gaze fixation**

- **B-S & S-A fixation**
- **B-S fixation**
- **S-A fixation**
- **B-S deviation**
Correct Fixation Rate

- The ratio of the number of targets in which the gaze is located within the visual angle < 1.0° from the central target

- CFR ↑ ⇒ Gaze fixation performance ↑

$$\text{CFR}(\%) = \frac{\sum_{i=1}^{n} F_i}{n} \times 100$$

(Equation 1)

Where, $F_i = \begin{cases} 1, & \text{All gaze locations are within radius 1° from - 0.2 sec to 0.2 sec} \\ 0, & \text{otherwise} \end{cases}$

- or - 0.2 sec to 0.0 sec
- or 0.0 sec to 0.2 sec

$i = 1, 2, 3, \ldots, n$

$n = \text{total number of target} (= 236)$
1-Blind Spot Response Rate (BS_RR)

- BS_RR: ratio of # responses to 10 blind spot targets presented
- 1-BS_RR ↑ ⇒ Gaze fixation performance ↑

\[
1 - BS_{RR}(\%) = 1 - \frac{r}{b} \times 100
\]

- \(r\): the number of responses to the blindspot target presented
- \(b\): total number of the blindspot targets (10 times)

(e.g.) total number of blindspot targets is 10, 2 responses → 1-BS_RR = 80%
1-False Positive Target Response Rate (FPT_RR)

- FPT_RR: ratio of # responses to 10 false positive targets (beeps w/o visual stimuli) presented
- $1 - \text{FPT}_\text{RR} \uparrow \Rightarrow \text{Gaze fixation performance} \uparrow$

$$1 - \text{FPT}_\text{RR}(\%) = 1 - \frac{r}{p} \times 100$$

$r$: the number of responses to the false positive target presented
$p$: total number of the false positive targets (10 times)

(e.g.) total number of false positive targets is 10, 4 responses $\Rightarrow$ $1 - \text{FPT}_\text{RR} = 60\%$
Subjective Satisfaction

- Evaluation of the proposed GFIMs relative to BD using a 11 point-bipolar Likert scale in terms of ease of gaze fixation, eye fatigue, and overall satisfaction.

<table>
<thead>
<tr>
<th>Questionnaire</th>
<th>Type of GFIMs</th>
<th>Ease of gaze fixation</th>
<th>Eye fatigue</th>
<th>Overall satisfaction</th>
</tr>
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<tbody>
<tr>
<td>BD</td>
<td>Normal</td>
<td>Very unsatisfied</td>
<td>Normal</td>
<td>Very unsatisfied</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>CCD</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
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<td>AC</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>FBD</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>BECH</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
<td>-5 -4 -3 -2 -1</td>
<td>1 2 3 4 5</td>
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**Reference**

- **Visual Attention Factor**
  - **Color**
  - **Alphanumeric**
  - **Flashing**
  - **Shape**

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Result: CFR

- **Mean:** All the new GFIMS showed better performance, but not statistically significant, than BD.
- **Variance:** FBD and BECH have significantly lower variance than BD.

⇒ FBD and BECH were preferred in terms of mean and variance of CFR.

Bartlett's Test (normal distribution)
Test statistic = 14.54, p-value = .006

* P < .05 (n = 64)
BD, FBD, and BECH were preferred in terms of 1-BS_RR and 1-FPT_RR.
Results: Subjective Satisfaction

- **BECH** was found most satisfactory compared to the other four methods.

  ⇒ The radial shape of BECH appears to most efficiently induce attention of an examinee.
BECH and FBD are best and second best, respectively, as the performance and subjective satisfaction measures are considered.
For determination of a correct gaze fixation, the trajectory of gaze before and after presentation of the visual field testing target was analyzed.

Minimize the effects of head movements in the gaze trajectory analysis.
BECH and FBD were found proper GFIMs by considering the performance of gaze fixation and subjective satisfaction.

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<tr>
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<th>FBD</th>
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<td>GFIM</td>
<td><img src="image" alt="BECH GFIM" /></td>
<td><img src="image" alt="FBD GFIM" /></td>
</tr>
</tbody>
</table>
| Pros.    | • The radial shape induces the examinee's gaze to the central target **efficiently.**  
• **Lowest false response rate** | • Flashing induces the examinee's gaze to the central target **involuntarily.** |
| Cons.    | • Increased efforts are needed to fix the examinee's gaze to the central target. | • Cause false responses more frequently than BECH. |

⇒ **BECH** is recommended for **people with high attention.**  
**FBD** is recommended for **those with decreased attention.**
Discussion (3/3)

- The participants of the present study were those in 20s and 30s without eye diseases.

- Expand the experiment with participants in various ages (20s ~ 30s; 40s ~ 50s; 60s ~ 70s) and patients with glaucoma.
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