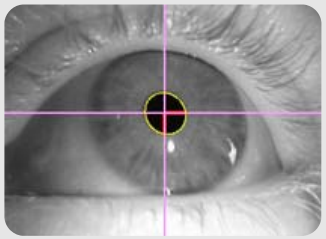
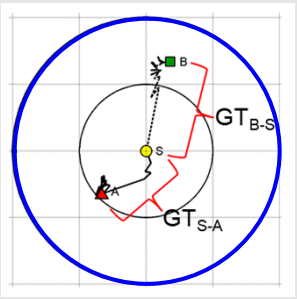
The Effects of Visual Attention Factors on Visual Field Testing for Maintenance of Gaze Fixation



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Contents

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  - ✓ Background: Glaucoma?
  - ✓ Limitation of Existing Perimeters
  - ✓ Research Objectives
- **Methods**
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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

Normal visual field

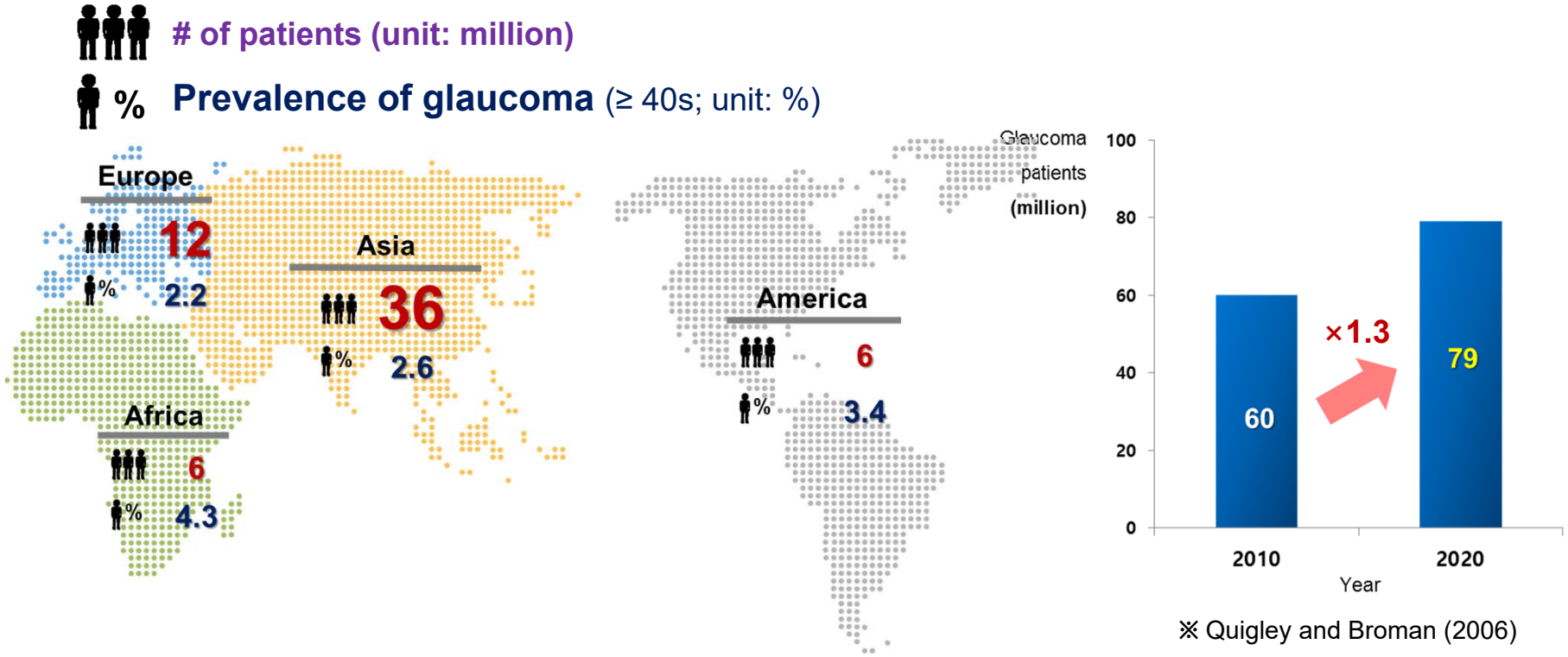
Early stage of glaucoma

Advanced stage of glaucoma

※ American Optometric Association

Patients of Glaucoma in the World

- Quigley and Broman (2006) reported that the prevalence of glaucoma may increase to almost 80 million by 2020 globally.

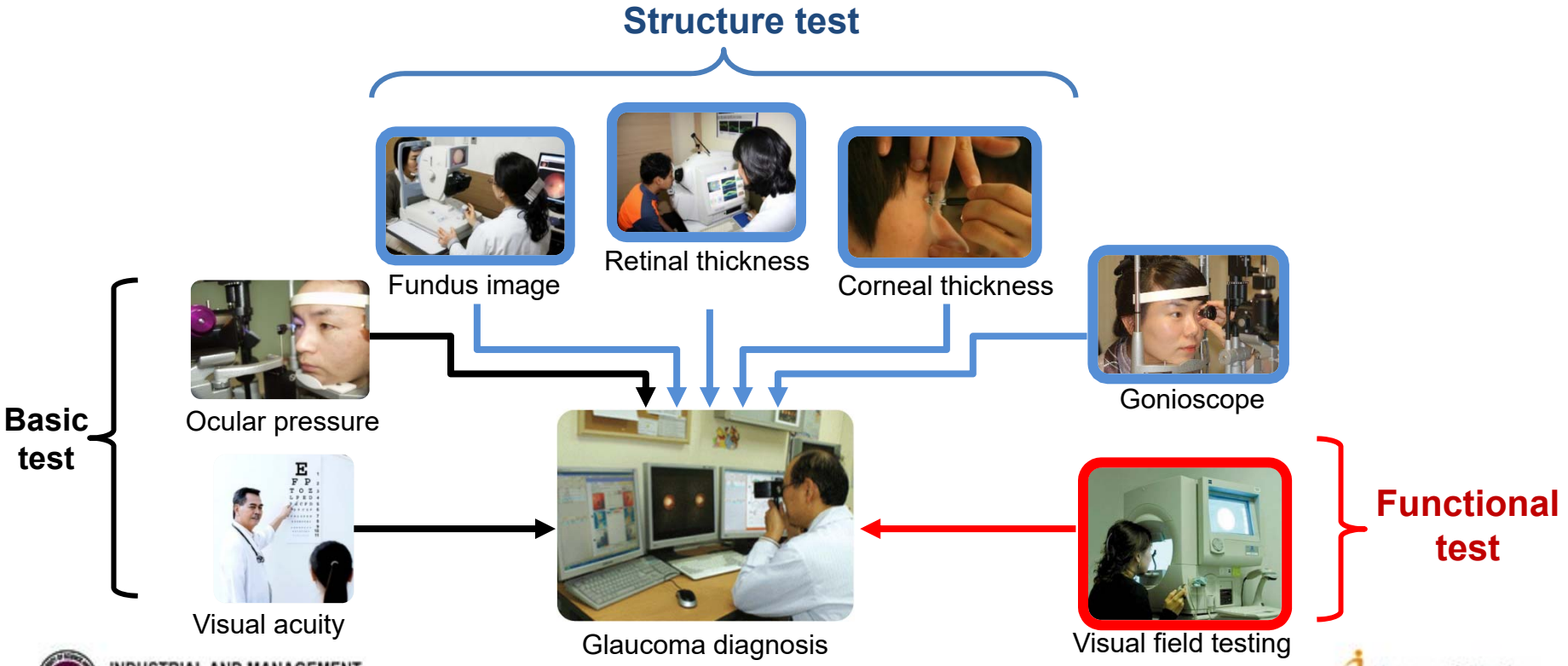


※ Quigley and Broman (2006)

Exams for Glaucoma

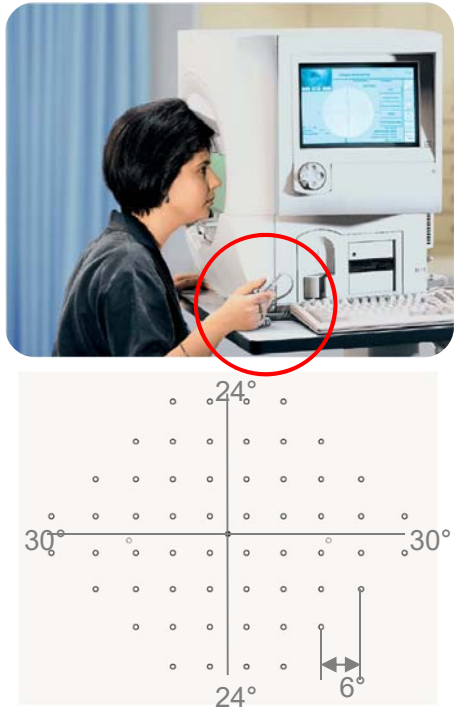
- Structural test: Measure the morphological characteristics in the eye
- Functional test: Measure the functionality of the retina

⇒ Of the tests, only the visual field test requires psychophysical responses to stimuli for a significant period of testing time (5~10 min./eye)



Visual Field Testing

- 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)



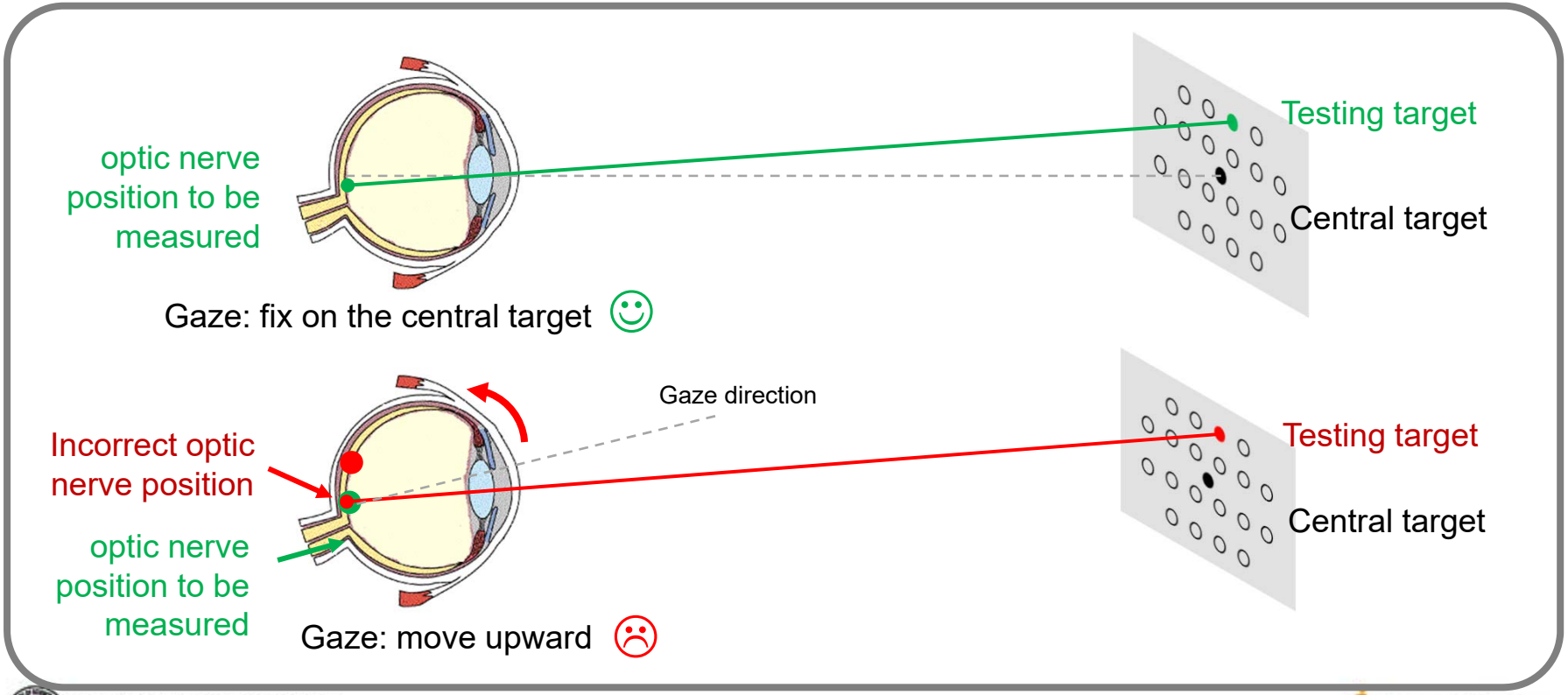
Target location
in central visual field

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 ⇒ Inaccurate visual field measurement

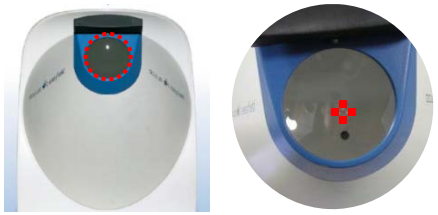
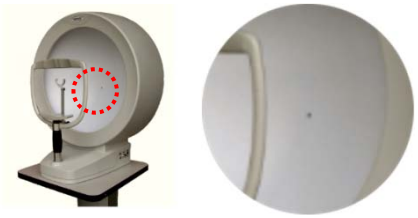
⇒ A proper gaze fixation induction method is needed for accurate testing



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

Central target	White dot		Green dot
Model	Easy field 	AP-5000 	Octopus 900 
Central target	**Yellow dot**		**Black dot**
Model	M700 	HVF II-*i* series 	Humphrey® Matrix™ 

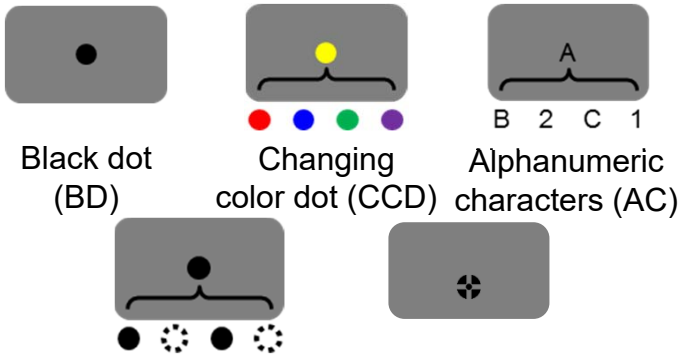
Research Goal

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**

Gaze fixation induction method (GFIM)



Black dot (BD) | Changing color dot (CCD) | Alphanumeric characters (AC)

Flashing black dot (FBD) | Bulls eye & cross hair (BECH)

Performance

Subjective satisfaction

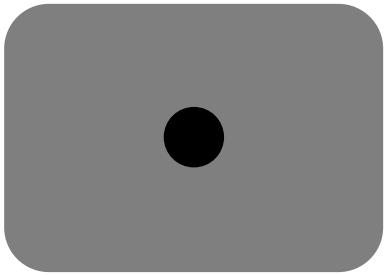
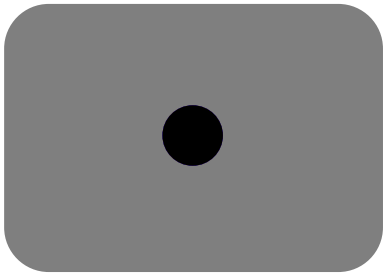
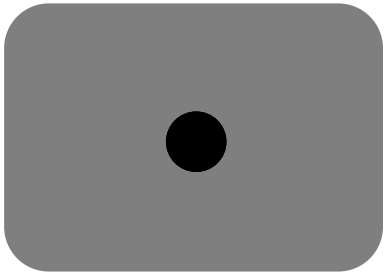
Experimental Design

- 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

Category		Items
Independent variable		• Gaze fixation induction method
Dependent variables	**Objective Measure**	• Correct fixation rate (CFR) • 1-Blind spot response rate (1-BS_RR) • 1-False positive target response rate (1-FPT_RR)
	Subjective Measures	• Ease of gaze fixation (EGF) • Eye fatigue (EF) • Overall satisfaction (OS)

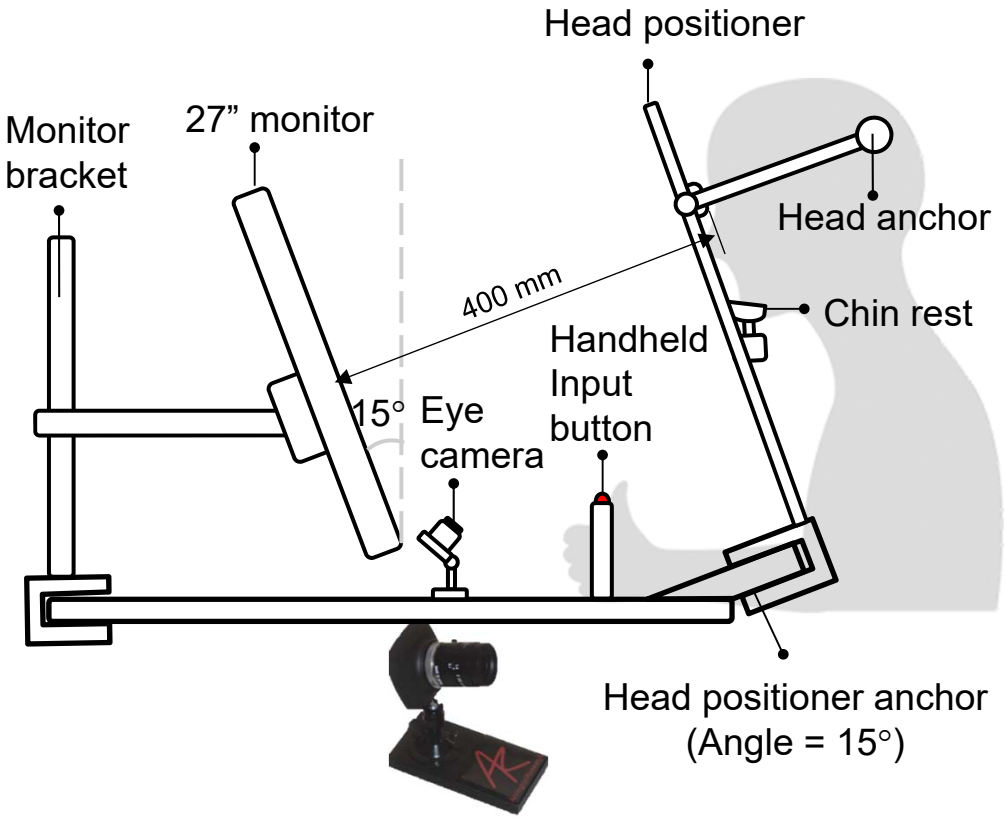
Gaze Fixation Induction Method

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

Reference	Visual Attention Factor	
	Color	**Alphanumeric**
Black dot (BD) 	Changing color dot (CCD) 	Alphanumeric characters (AC) 
	Flashing	**Shape**
	Flashing black dot (FBD) 	Bulls eye & cross hair (BECH; Thaler et al., 2013) 

Apparatus

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

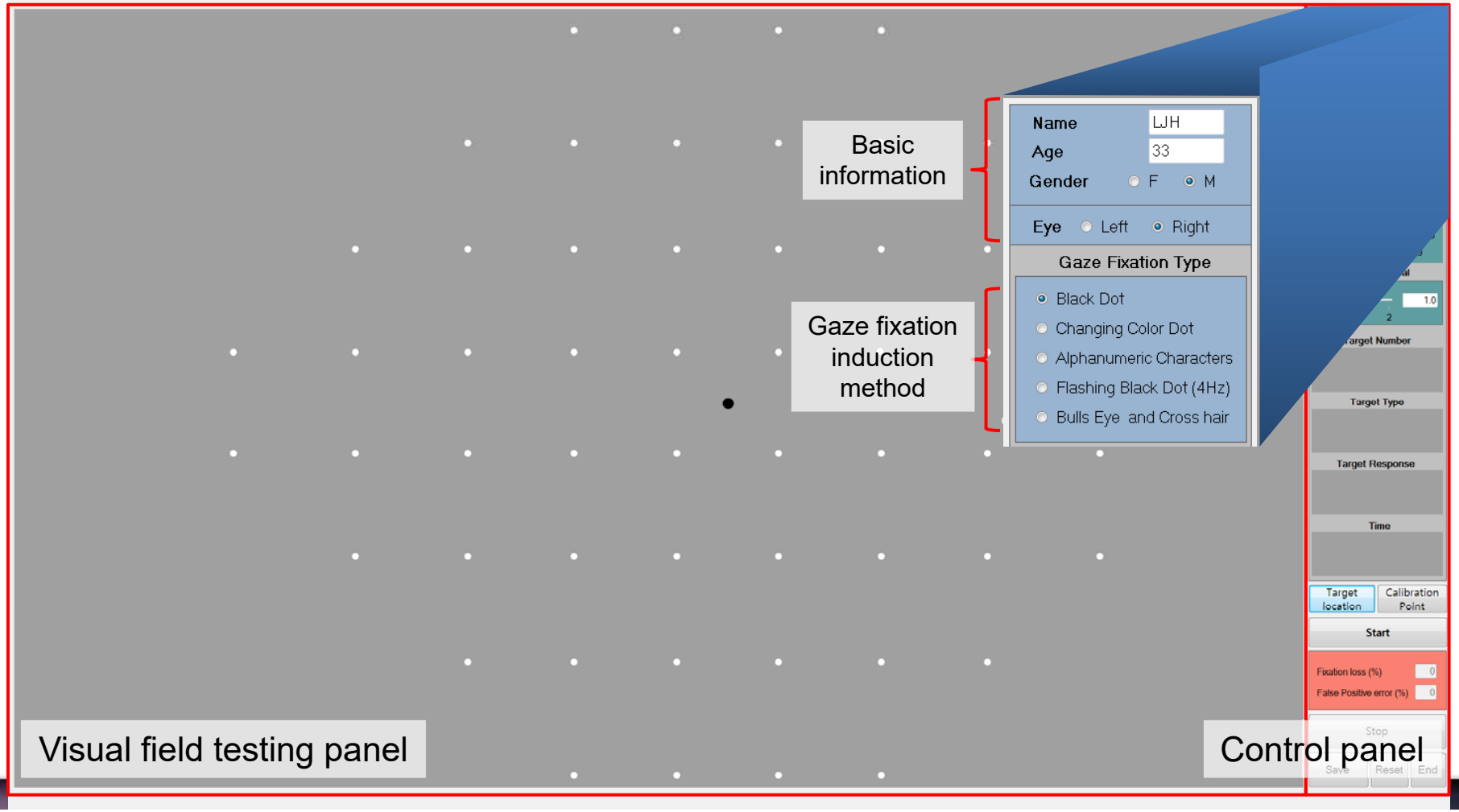


ViewPoint EyeTracker®
(Arrington Research, USA)

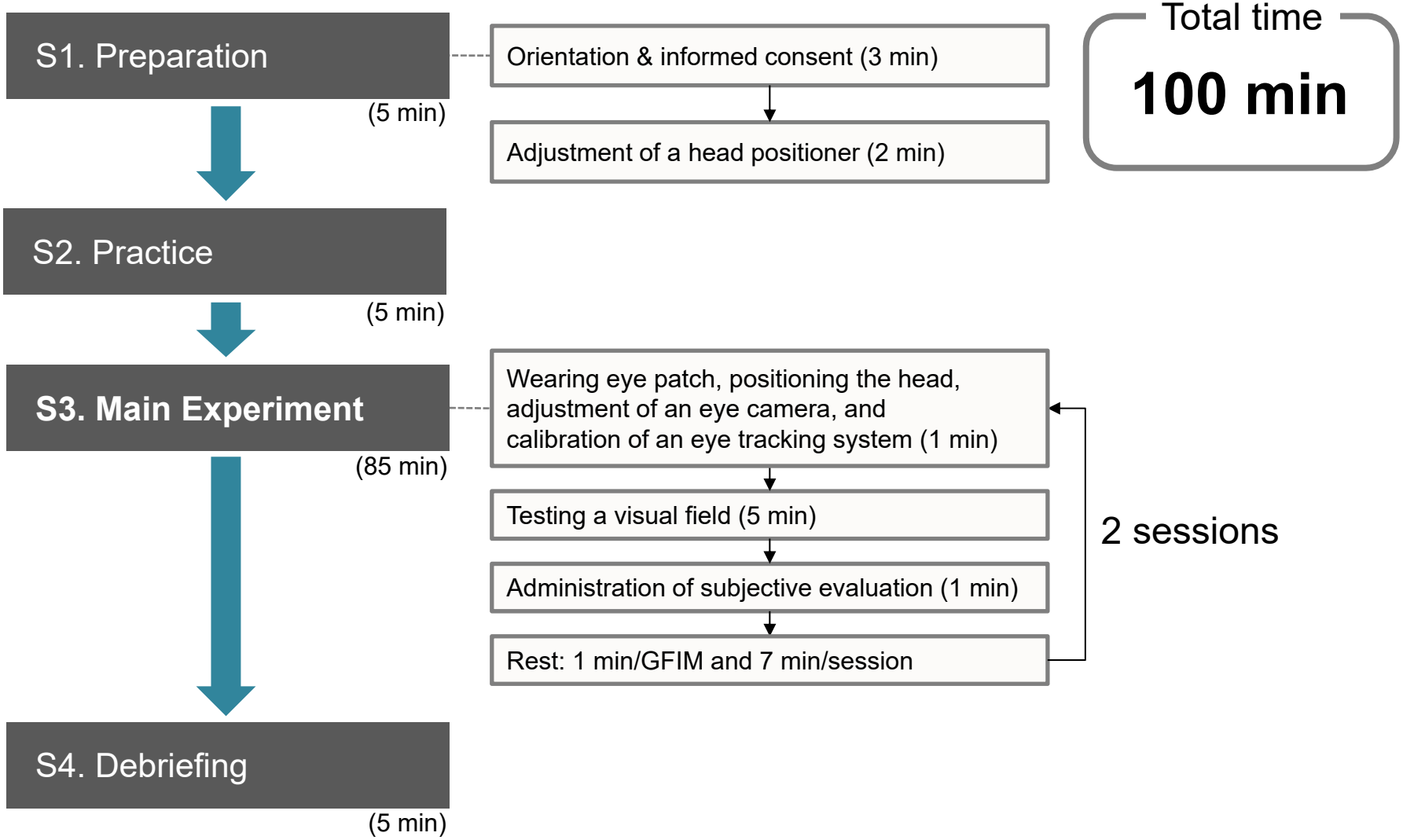
Head positioner
(Arrington Research, USA)

Experimental S/W

- Visual field testing area: visual angle ≤ 24º
- # 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



Procedure


S1. Preparation
(5 min)
Orientation & informed consent (3 min)
Adjustment of a head positioner (2 min)
Total time
100 min
S2. Practice
(5 min)
S3. Main Experiment
(85 min)
Wearing eye patch, positioning the head, adjustment of an eye camera, and calibration of an eye tracking system (1 min)
Testing a visual field (5 min)
Administration of subjective evaluation (1 min)
Rest: 1 min/GFIM and 7 min/session
2 sessions
S4. Debriefing
(5 min)

Analysis Procedure on Gaze Tracking Data

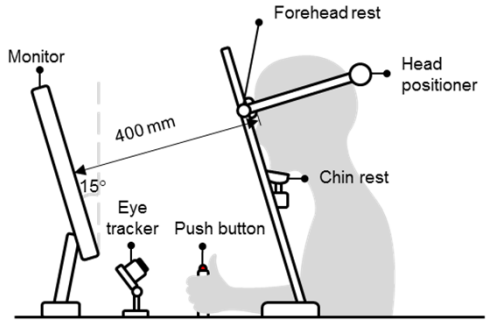
S1. Collect gaze tracking data
(sampling rate = 220 Hz)

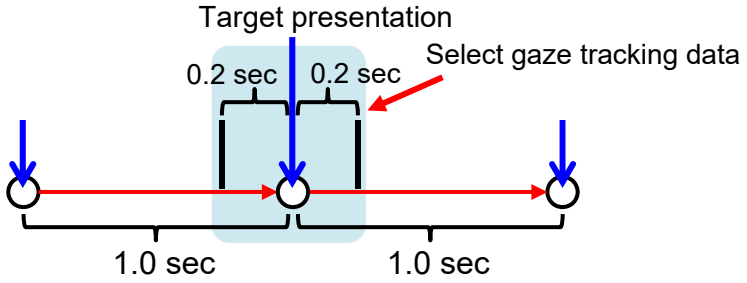
S2. Remove noise data
(artifacts due to blinking)

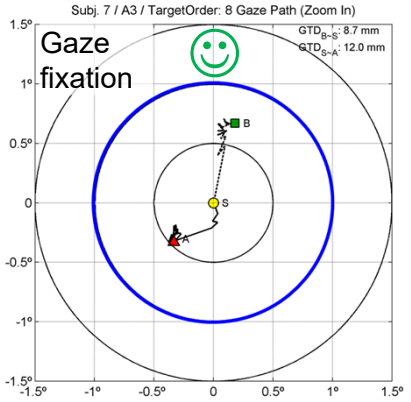
S3. Select gaze tracking data during target presentation

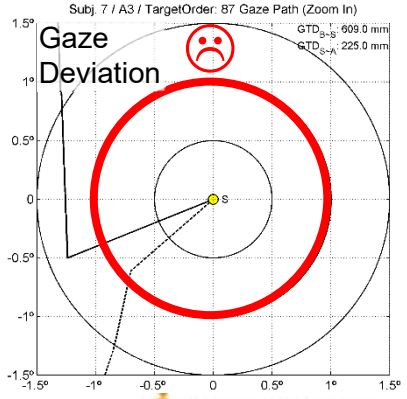
S4. Analyze gaze trajectories

S5. Determine the correct gaze fixation to the central target



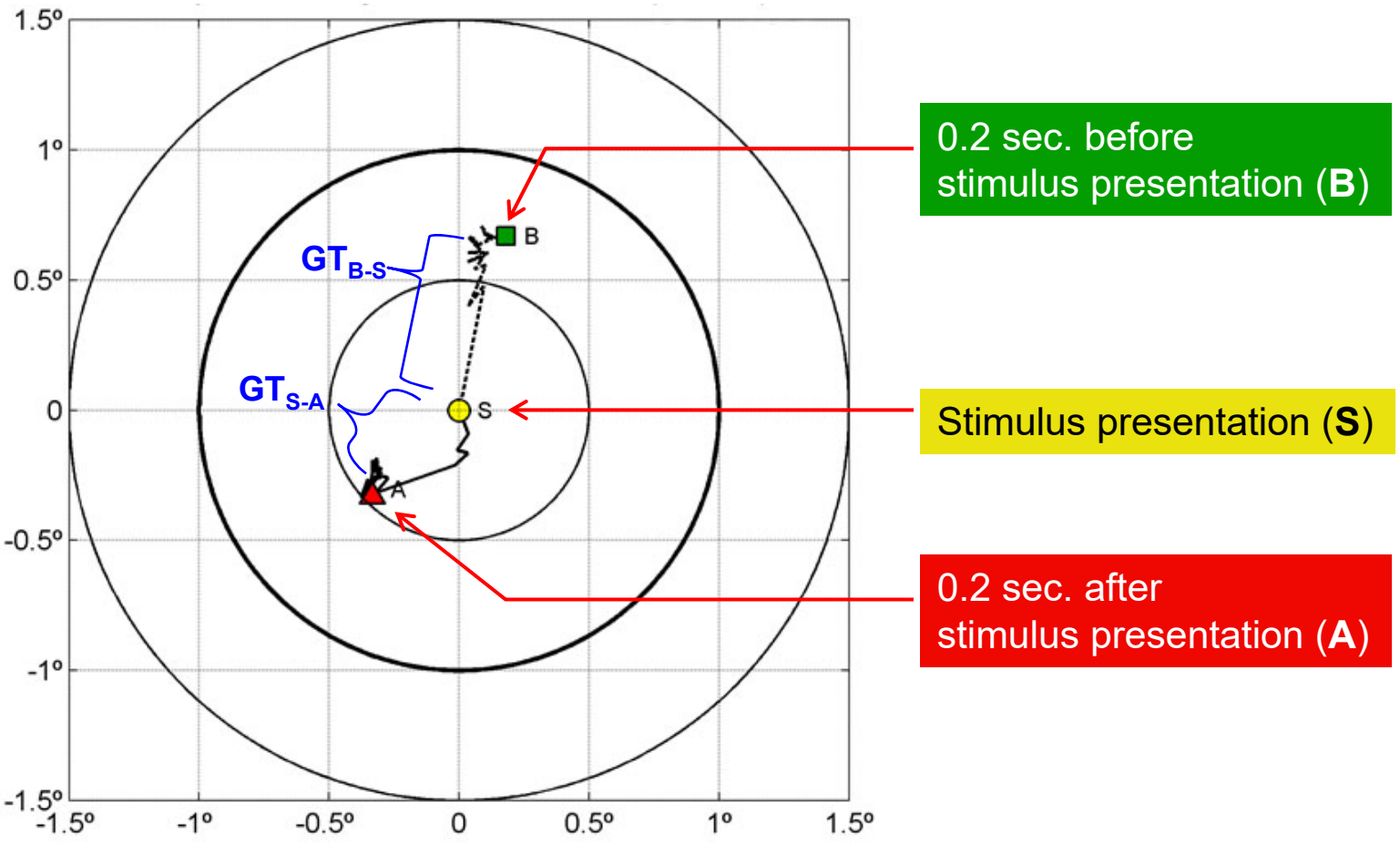






Gaze Trajectory Analysis

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



Determination of Correct Gaze Fixation

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

$GT_{B-S} \leq 1^{\circ}$ VF

No

Yes

$GT_{S-A} \leq 1^{\circ}$ VF

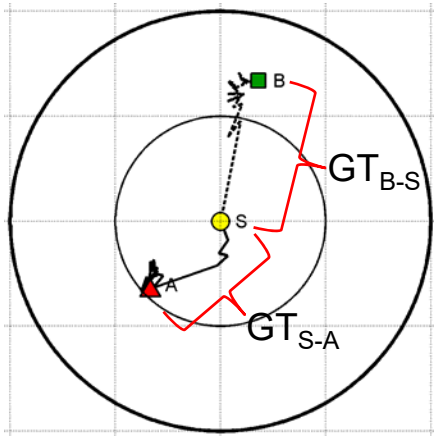
No

Yes

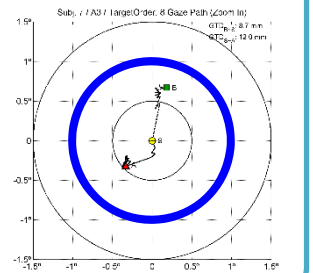
$GT_{S-A} \leq 1^{\circ}$ VF

No

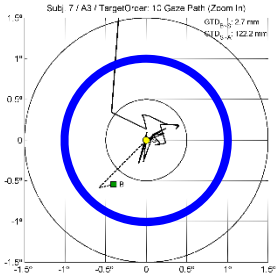
Yes



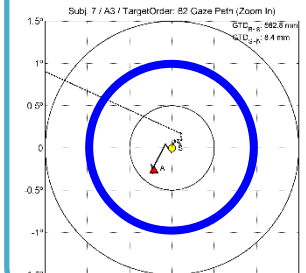
B-S & S-A fixation



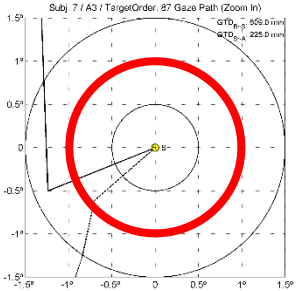
B-S fixation



S-A fixation



B-S & S-A deviation



Types of correct gaze fixation

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 ↑

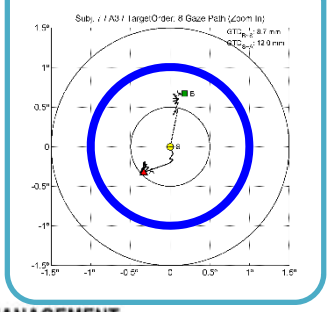
$$\mathrm{CFR}(\%) = \frac{\sum_{i=1}^{n} F_i}{n} \times 100 \qquad \text{(Equation 1)}$$

Where, $F_i = \begin{cases} 1, \ All\ gaze\ locations\ are\ within\ radius\ 1°\ from & -0.2\ \mathrm{sec}\ to\ 0.2\ sec \\ & or\ \ -0.2\ \mathrm{sec}\ to\ 0.0 sec \\ & or\ \ \ 0.0\ \mathrm{sec}\ to\ 0.2\ sec \\ 0, otherwise \end{cases}$

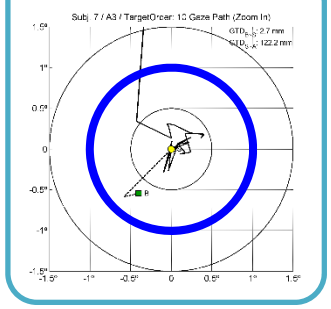
$i = 1, 2, 3, \ldots, n$

n = total number of target (= 236)

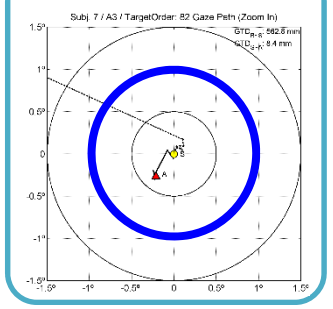
B-S & S-A fixation



B-S fixation



S-A fixation



1-Blind Spot Response Rate (BS_RR)

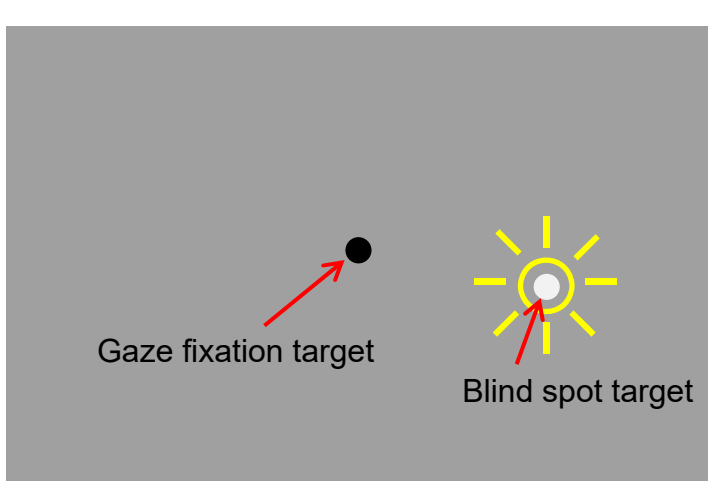
- BS_RR: ratio of # responses to 10 blind spot targets presented
- 1-BS_RR ↑ ⇒ Gaze fixation performance ↑

$$1 - BS\_RR(\%) = 1 - \frac{r}{b} \times 100$$

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)

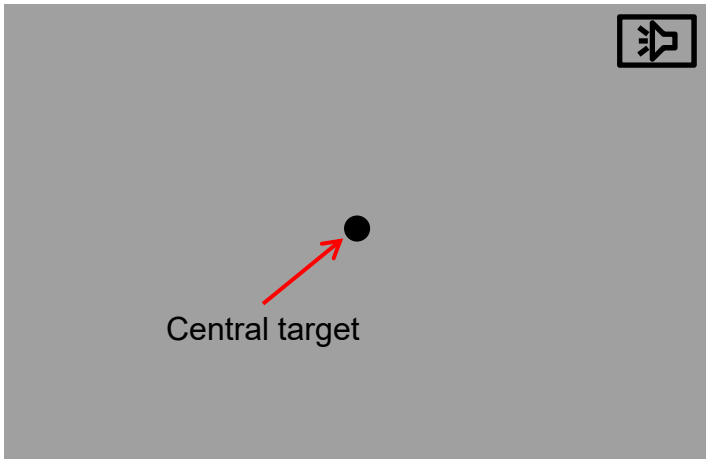
- FPT_RR: ratio of # responses to 10 false positive targets (beeps w/o visual stimuli) presented
- 1-FPT_RR ↑ ⇒ Gaze fixation performance ↑

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

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 → 1-FPT_RR = 60%

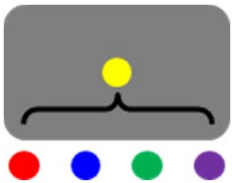
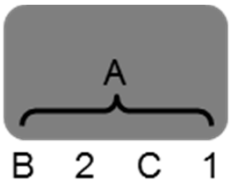


Subjective Satisfaction

❑ 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.

Questionnaire

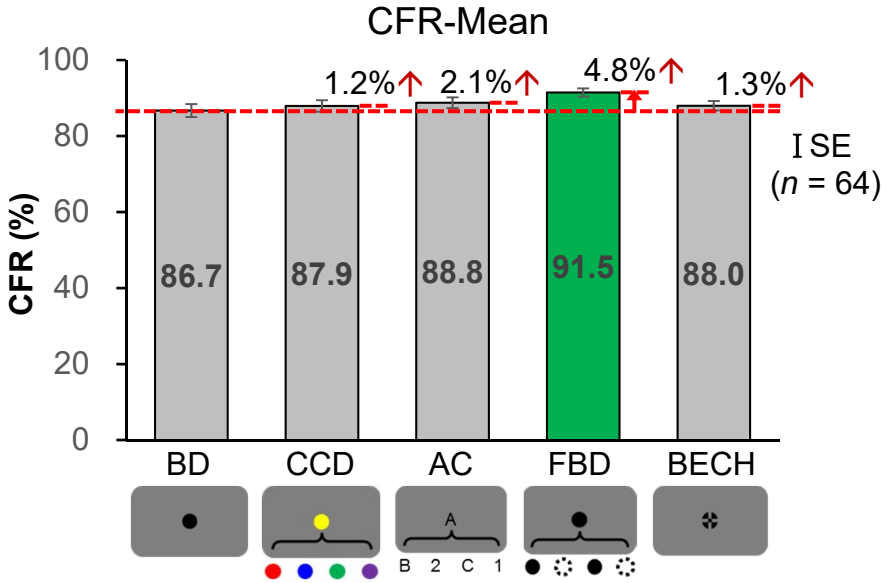
Items	Ease of gaze fixation											Eye fatigue											Overall satisfaction										
Type of GFIMs	Very unsatisfied					Normal					Very satisfied	No fatigue					Normal					The worst fatigue	Very unsatisfied					Normal					Very satisfied
BD						0											0											0					
CCD	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5
AC	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5
FBD	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5
BECH	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5	-5	-4	-3	-2	-1	0	1	2	3	4	5

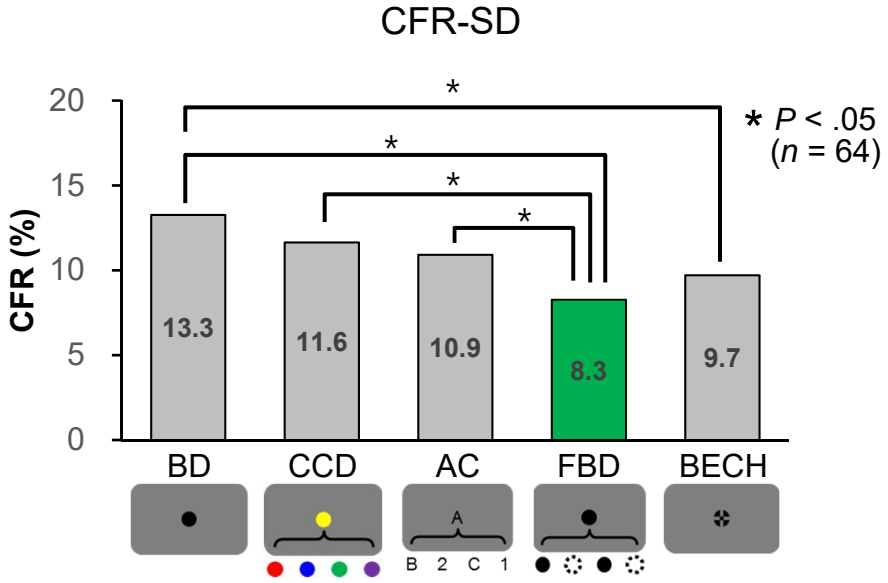
Reference	Visual Attention Factor			
	Color	Alphanumeric	Flashing	Shape
Black dot (BD)	Changing color dot (CCD)	Alphanumeric Characters (AC)	Flashing black dot (FBD)	Bulls eye & cross hair (BECH)
				

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

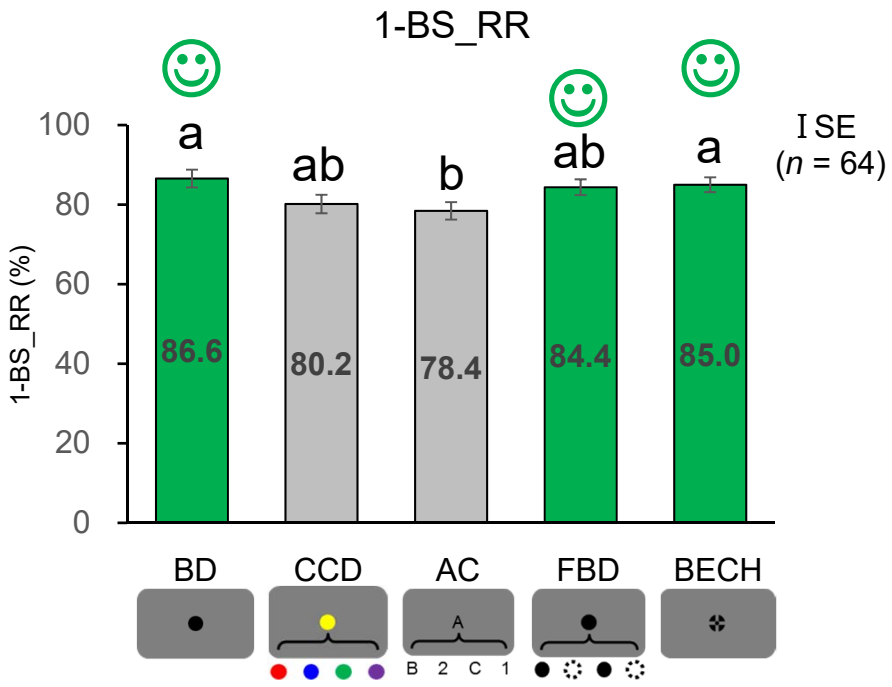


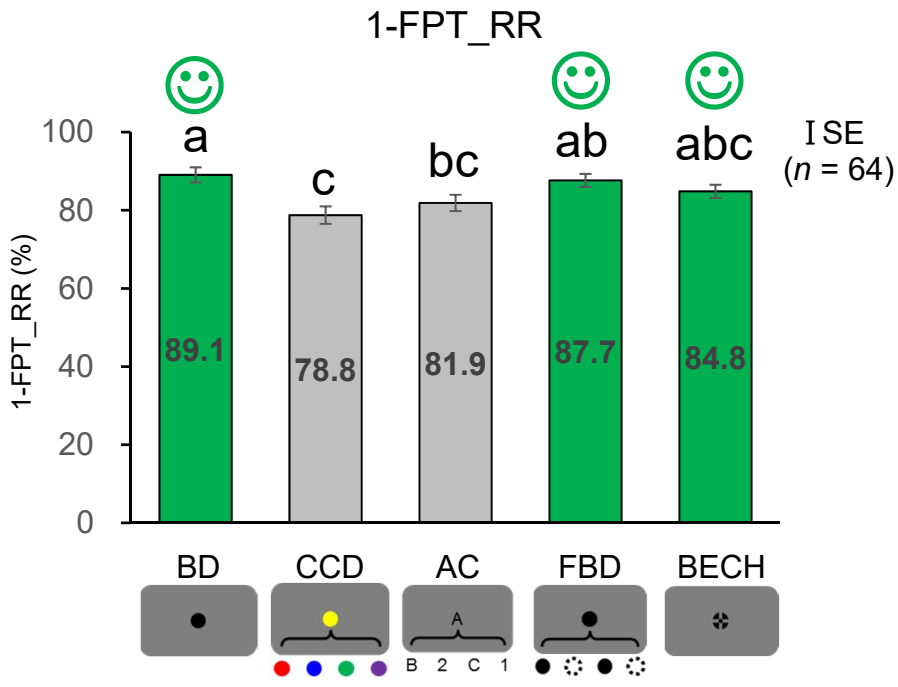


Bartlett's Test (normal distribution)
Test statistic = 14.54, *p*-value = .006

Results: 1-BS_RR & 1-FPT_RR

- BD, FBD, and BECH were preferred in terms of 1-BS_RR and 1-FPT_RR.

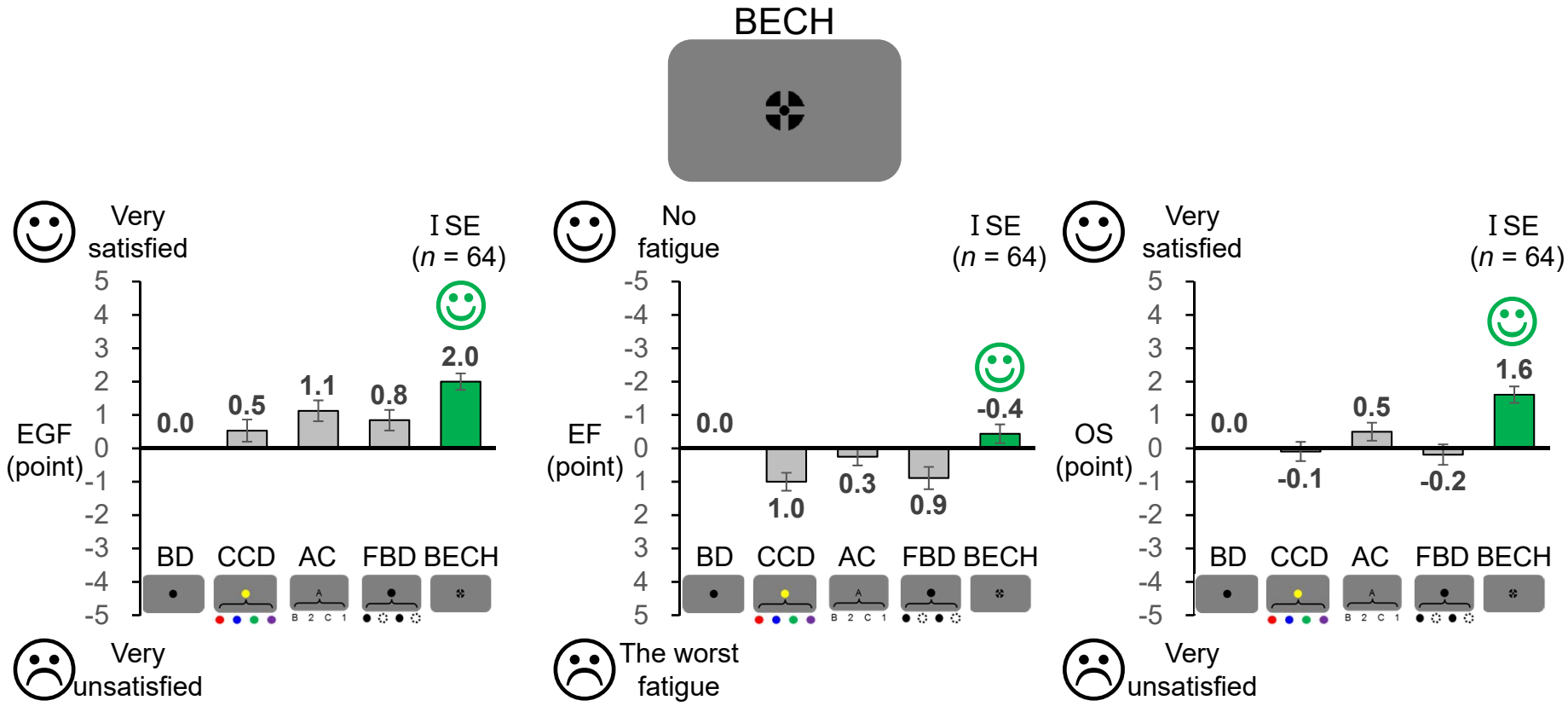




Results: Subjective Satisfaction

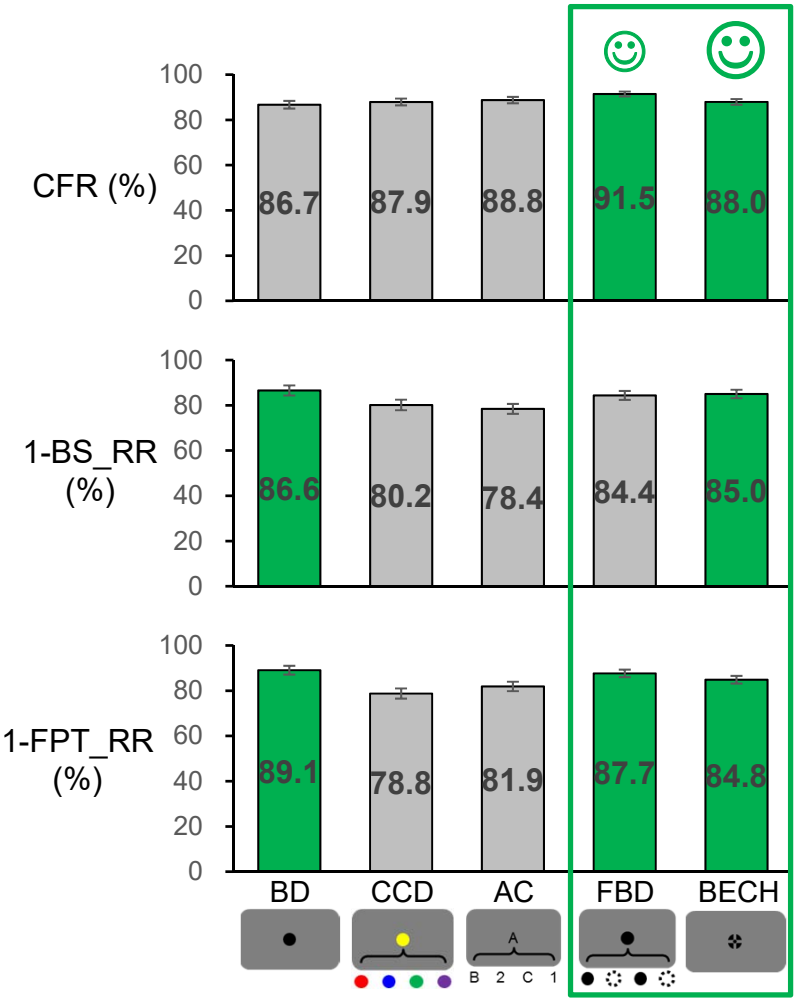
- BECH was found most satisfactory compared to the other four methods.

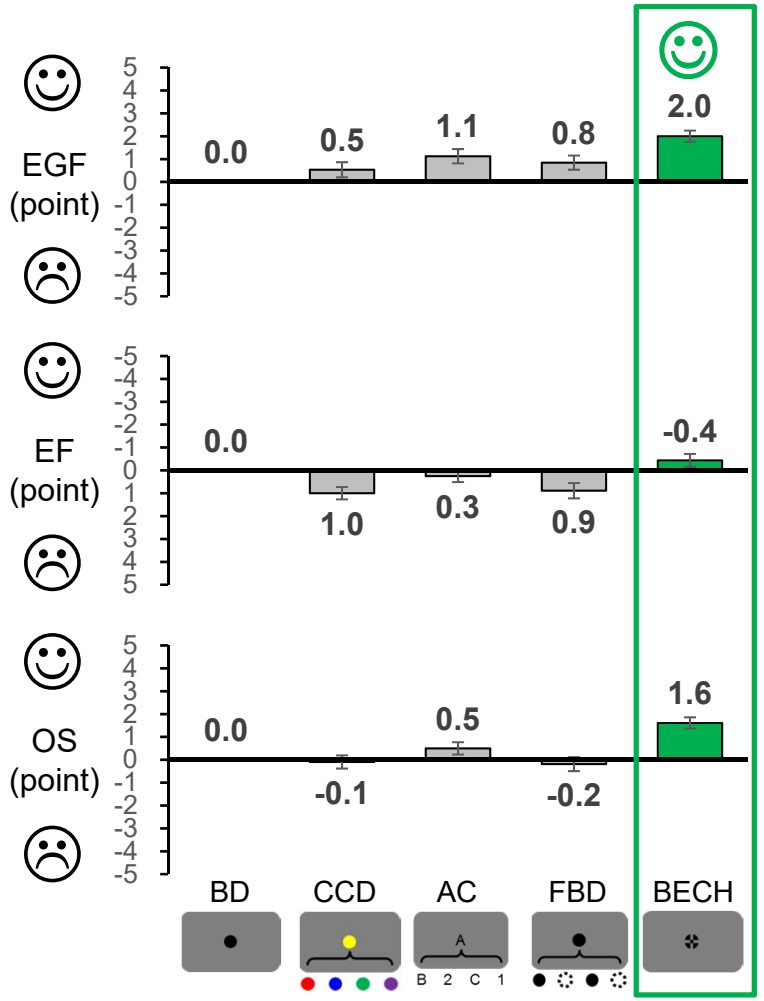
⇒ The radial shape of BECH appears to most efficiently induce attention of an examinee.



Synthesis: Performance & Satisfaction

- BECH and FBD are best and second best, respectively, as the performance and subjective satisfaction measures are considered.

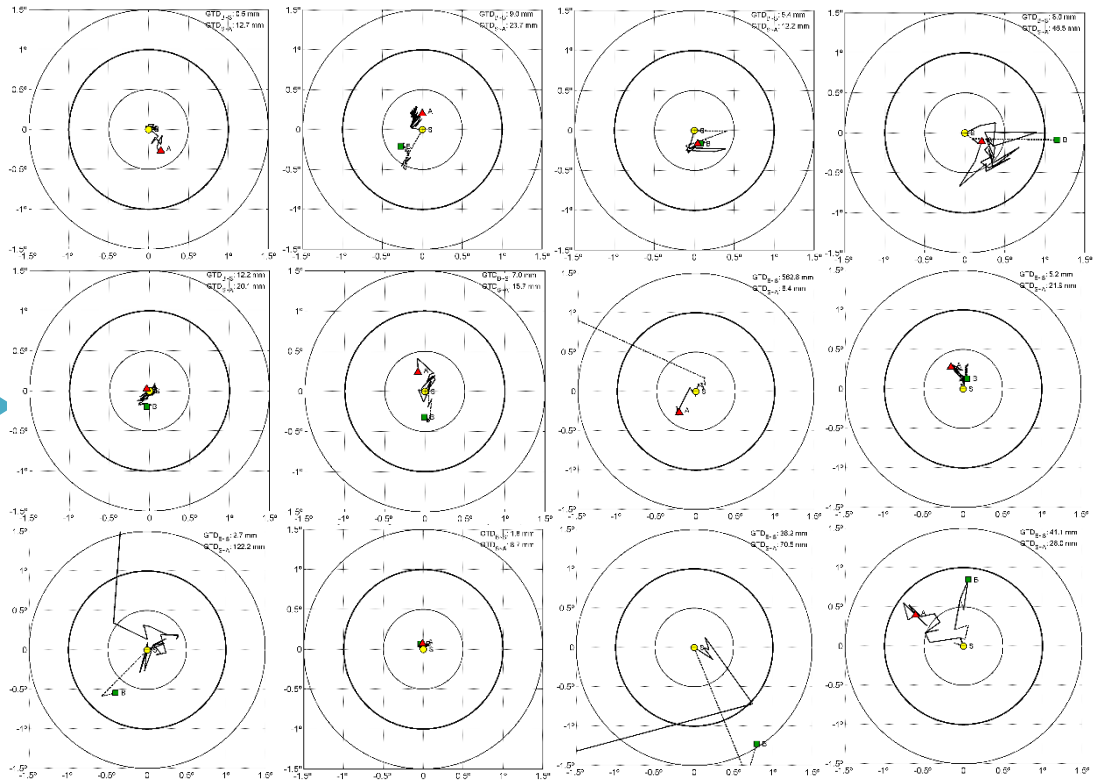




Discussion (1/3)

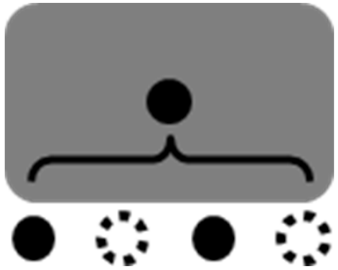
- For determination of a correct gaze fixation, the trajectory of gaze before and after presentation of the visual field testing target was analyzed.

⇒ Minimize the effects of head movements in the gaze trajectory analysis



Discussion (2/3)

- BECH and FBD were found proper GFIMs by considering the performance of gaze fixation and subjective satisfaction

Category	BECH	FBD
GFIM		
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

Q & A

THANK YOU FOR YOUR ATTENTION

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