

# Experimental data

## 3D and the human visual systems

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1. Introduction

2. Naturalness

3. Visual comfort

4. Visual fatigue

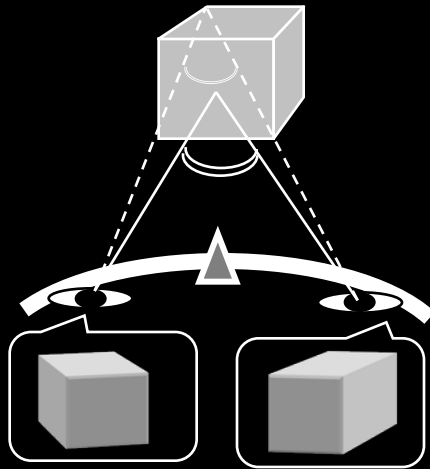
5. Conclusion

# 1. Introduction

## Major factors in perception of depth

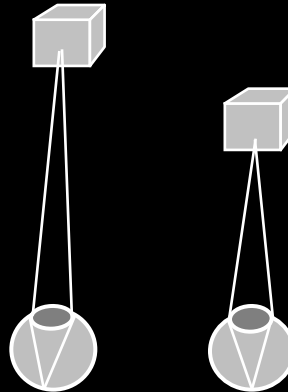
### **Vergence :**

Angle of visual lines.



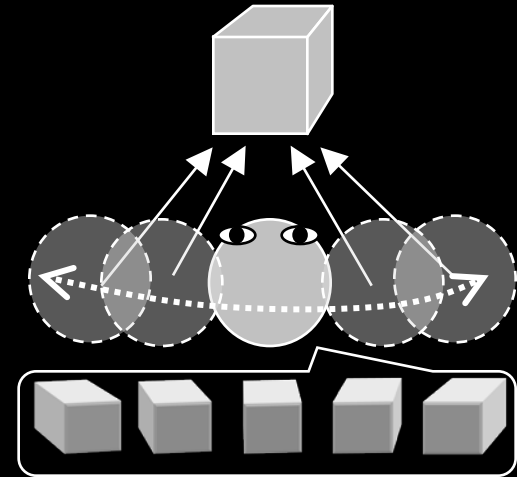
### **Binocular Disparity :**

Image difference caused by viewpoint difference.



### **Accommodation :**

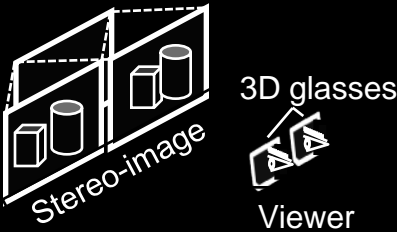
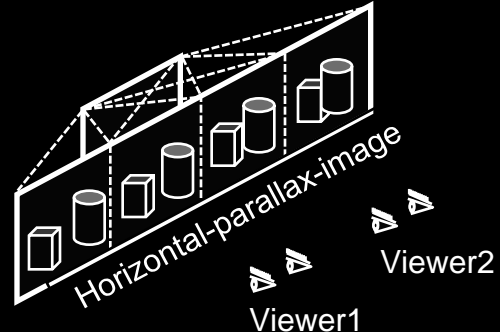
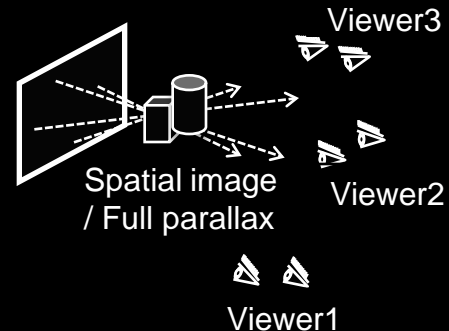
Focusing of the lens  
Reflects distance to object.



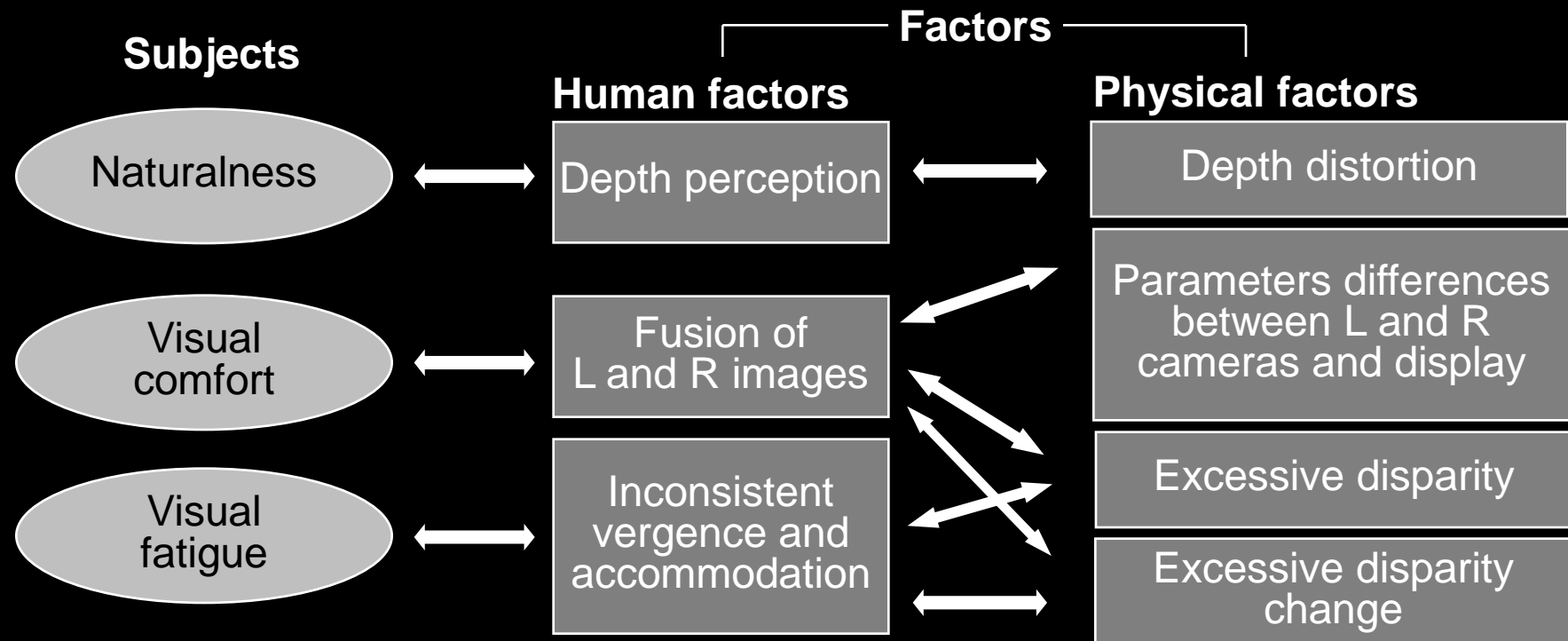
### **Motion Parallax :**

Image difference according to the change of a viewpoint.

## Three-dimensional display technology

	<u>Stereogram</u>	<u>Parallax panoramagram</u>	<u>Spatial imaging</u> (Integral 3-D display)
<u>Vergence</u>	✓	✓	✓
<u>Binocular disparity</u>	✓	✓	✓
<u>Motion parallax</u>		✗ (Horizontal parallax only)	✓ (Full parallax)
	 <p>Stereo-image 3D glasses Viewer</p>	 <p>Horizontal-parallax-image Viewer1 Viewer2</p>	 <p>Spatial image / Full parallax Viewer1 Viewer2 Viewer3</p>

## Human factors in Stereoscopic 3DTV



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1. Introduction

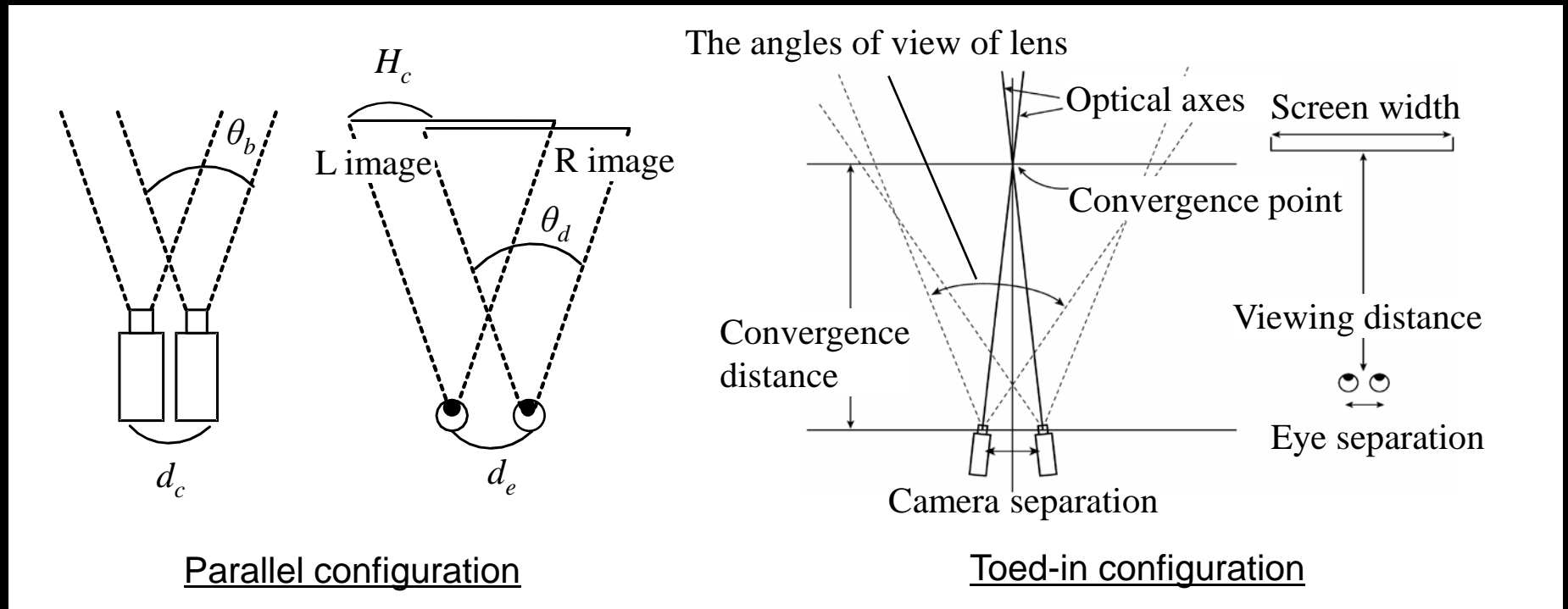
**2. Naturalness**

3. Visual comfort

4. Visual fatigue

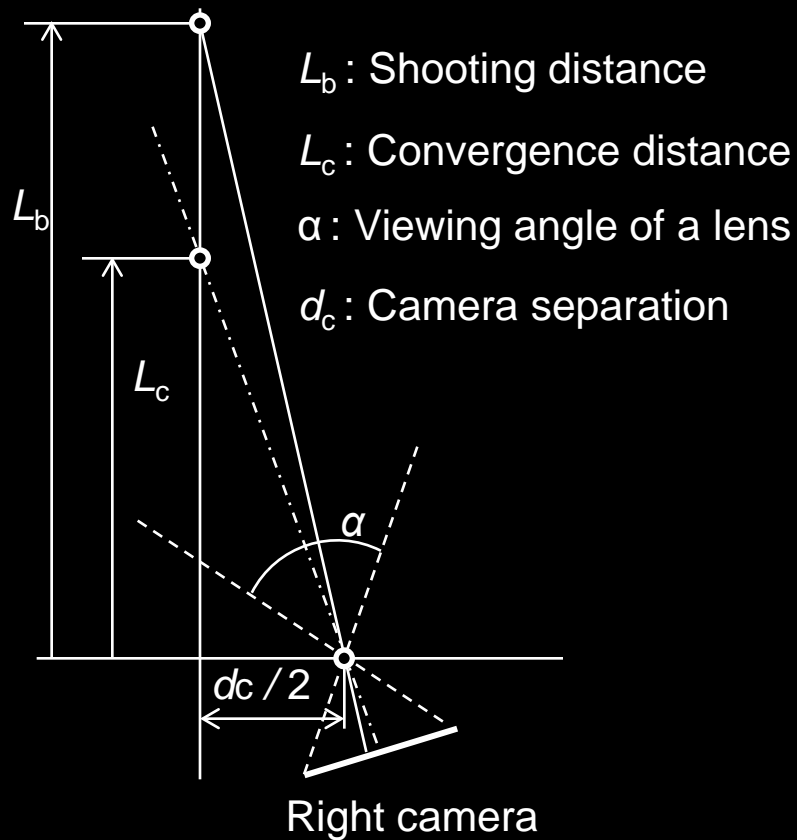
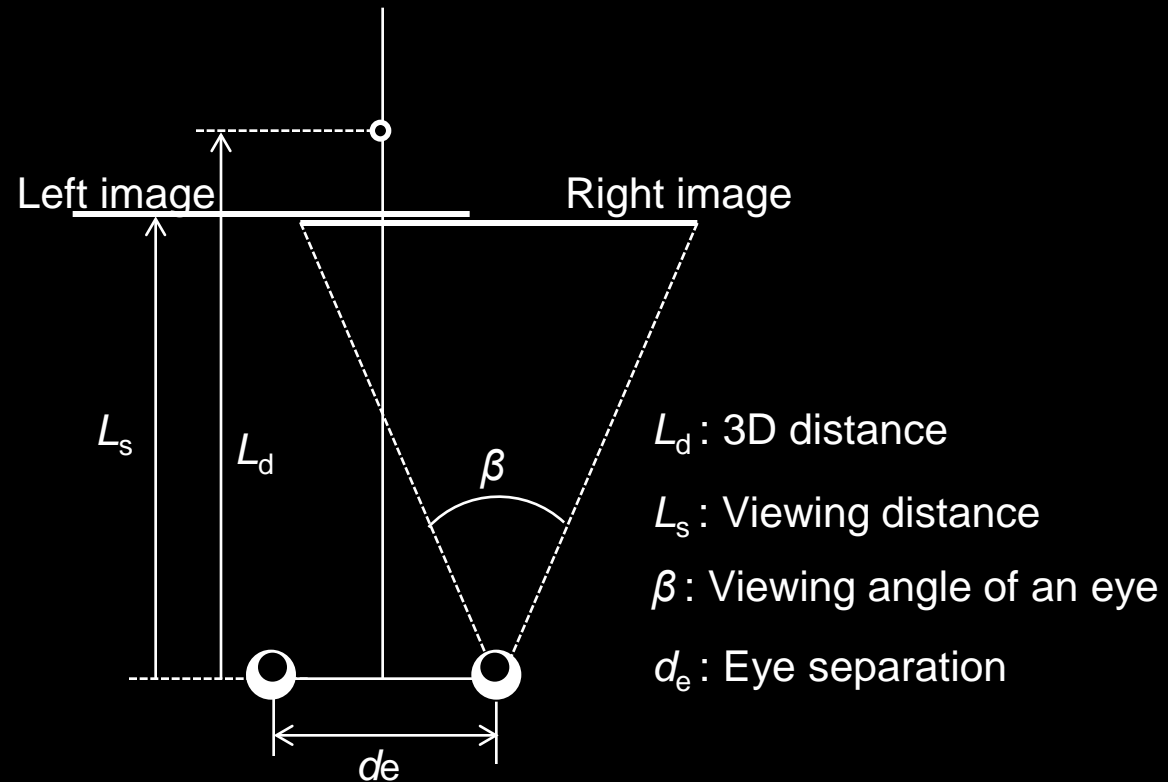
5. Conclusion

## 2. Naturalness



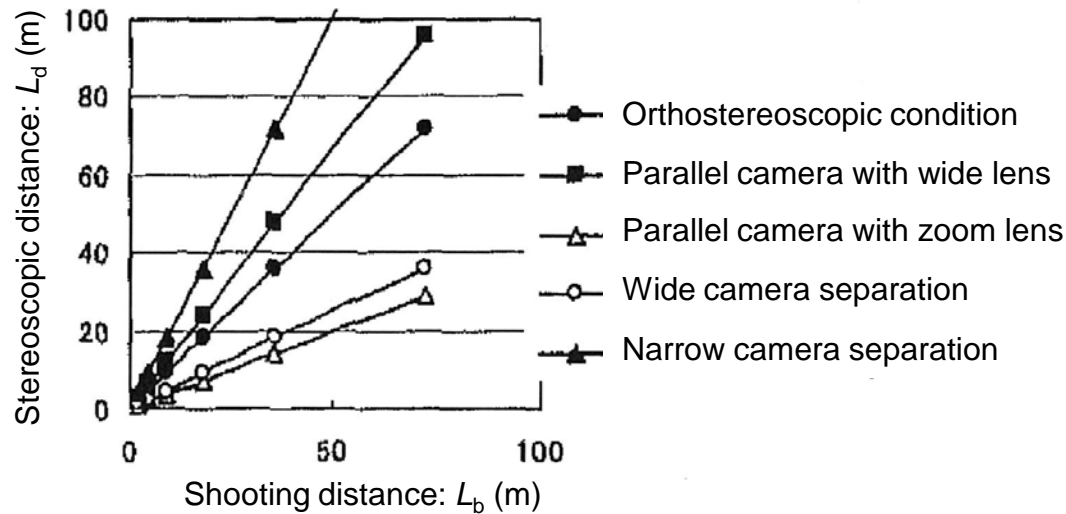
Orthostereoscopic condition

$$\begin{cases} d_c = d_e = H_c \\ \theta_b = \theta_d \end{cases}$$

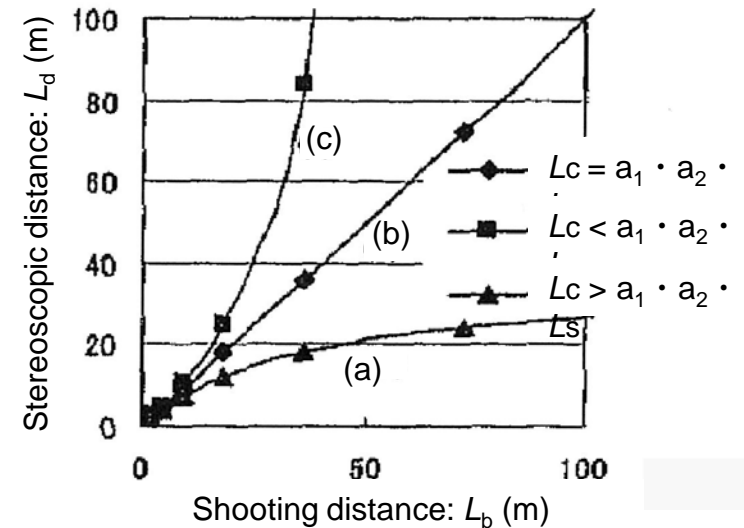
Shooting conditionDisplay condition



### Stereoscopic distance and shooting distance



(i) In the case of parallel configuration



$$a_1 = d_c / d_e \quad a_2 = \tan(\beta/2) / \tan(\alpha/2)$$

(ii) In the case of toed-in configuration

(a) Cardboard effect : Effect in which objects looks unnaturally thin.

(c) Puppet theater effect : Effect in which objects in foreground looks unnaturally small.

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### 3. Visual comfort

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#### ◆ Geometrical distortions

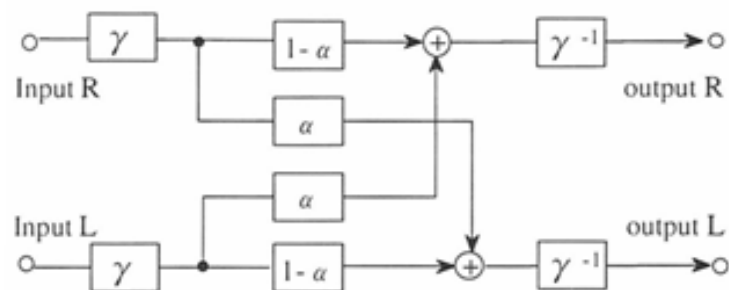
Detection limit and tolerance limit for discrepancies  
between left and right images

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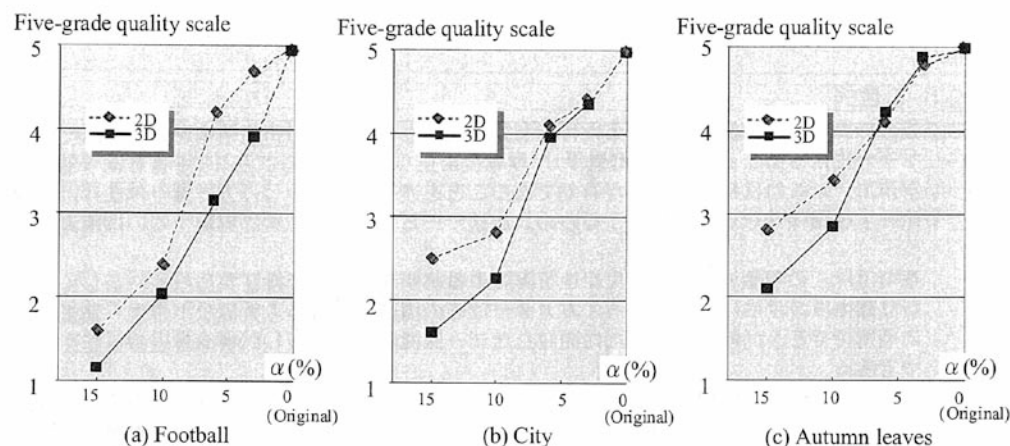
Factor	Detection limit	Tolerance limit	Note
Size	1.2%	2.9%	Taking size of one image as 100%
Vertical displacement	0.7%	1.5%	Taking image height as 100%
Rotation	0.5deg.	1.1deg.	Angle of rotation about image center

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# ◆ Cross talk



Block diagram of making images with cross talk



Results of subjective evaluation for the degree of disturbance caused by cross talk.

## Degree of disturbance

- 5 : Imperceptible
- 4 : Perceptible, but annoying
- 3 : Slightly annoying
- 2 : Annoying
- 1 : Very annoying

Detection limit : 1~2%

Tolerance limit : 5~10%

## ◇ Parallax distribution

### Conditions of subjective evaluation test of parallax distribution

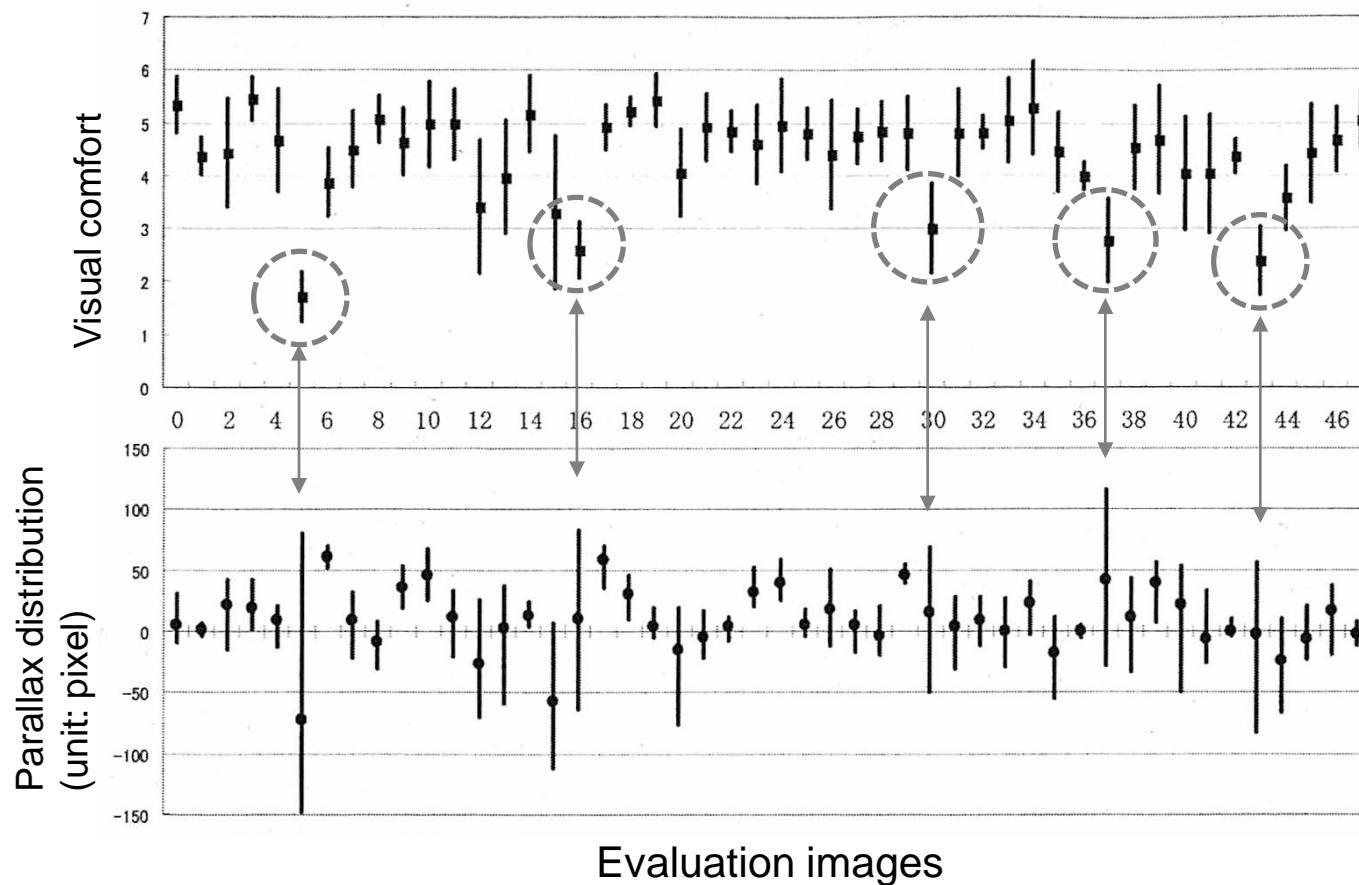
Images used in test	48 still images (including a standard pattern)
Subject	24 adult males and females (not expert)
Repeat test	10 sec viewing of 2D image (for reference), following by 10 sec viewing of 3D image (for evaluation)
Display system	3D HDTV using polarizing glasses
Screen size	90 inches
Viewing distance	about 3 H (3.33 meters)
Peak brightness	15cd/m <sup>2</sup>
Method of evaluation	Relative evaluation on a scale of seven, based on 2D image

### Scale of evaluation

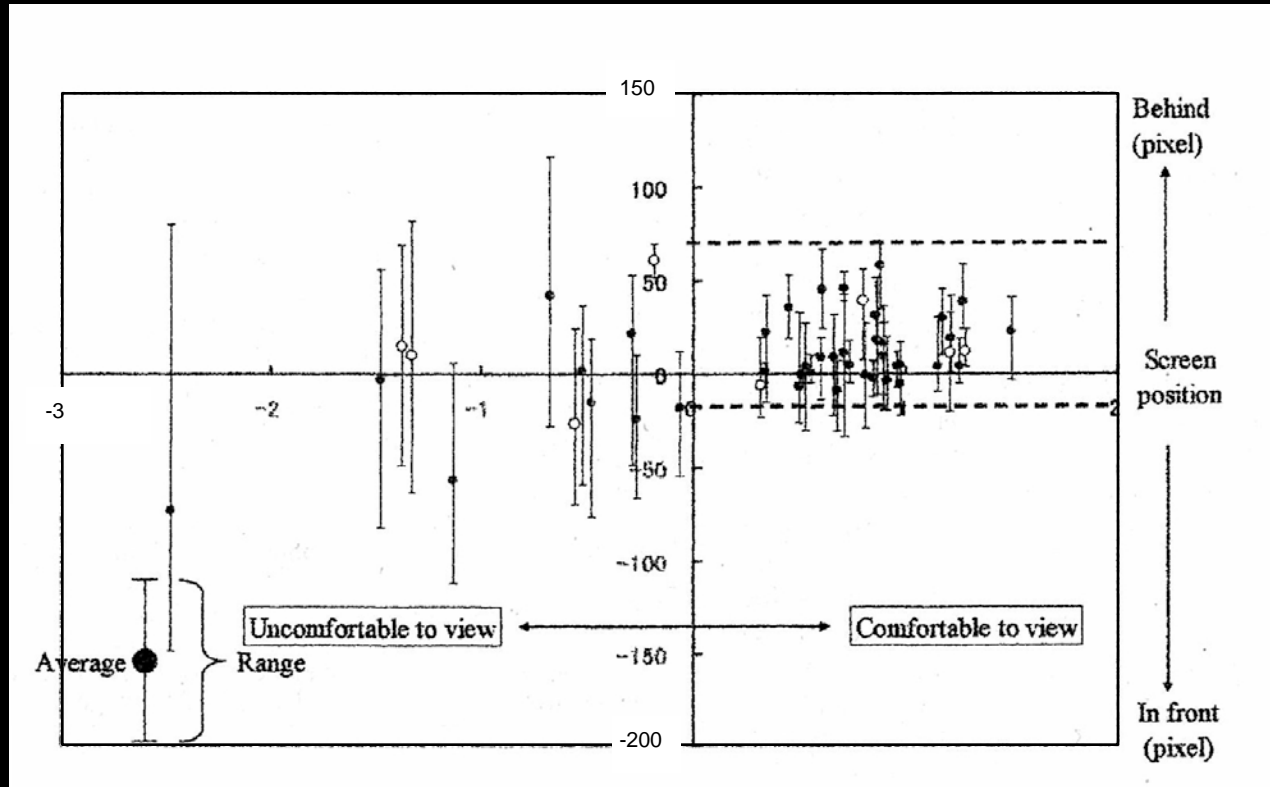
#### Visual comfort

- 7 : Much better
- 6 : Better
- 5 : Slightly better
- 4 : The same
- 3 : Slightly worse
- 2 : Worse
- 1 : Much worse

Results of evaluation test and parallax measurement  
on 48 evaluated stereoscopic HDTV images



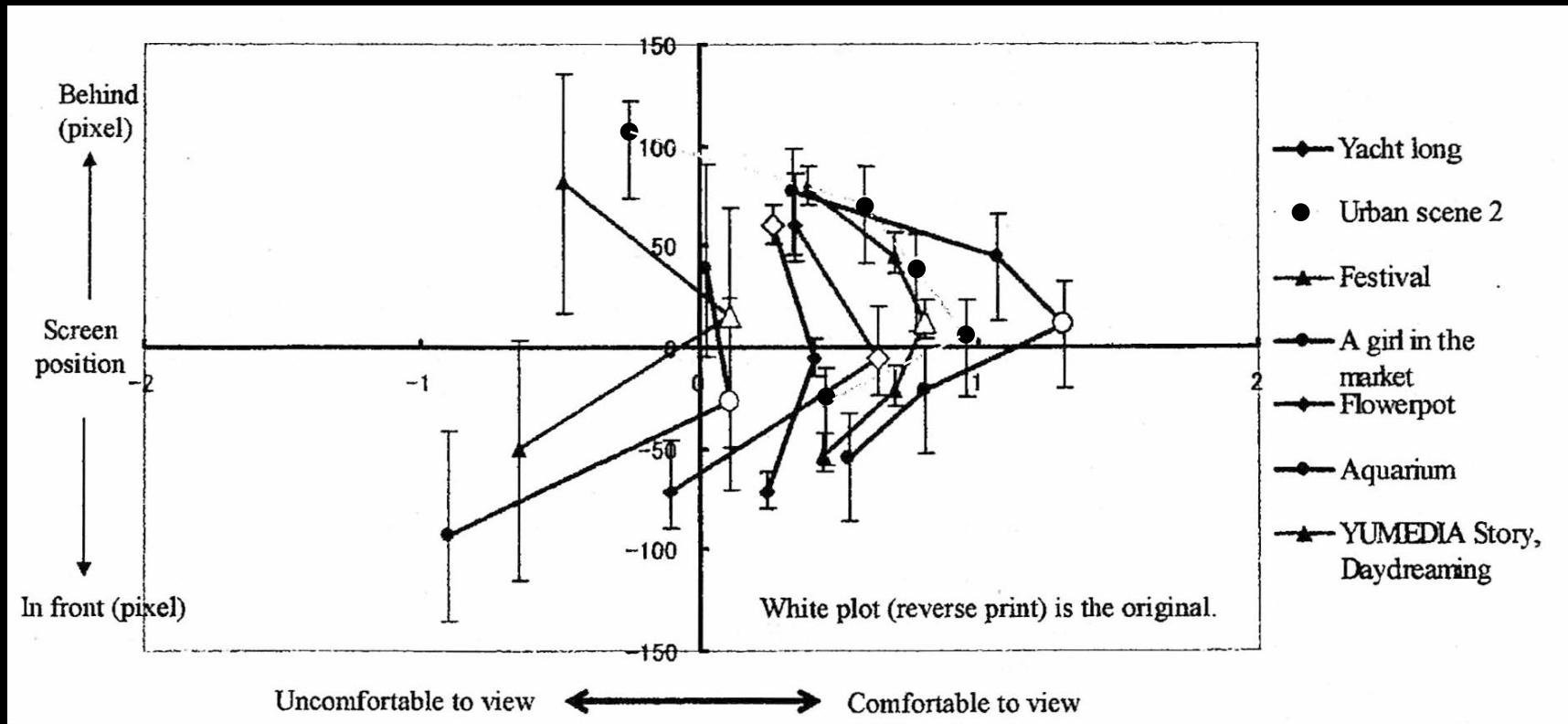
## Relationship between parallax distribution and visual comfort



### Comfortable to view

- Parallax distribution ranges of less than 60 minutes.
- Parallax distribution ranged from 30 minutes in front of the screen to 65 minutes behind the screen.

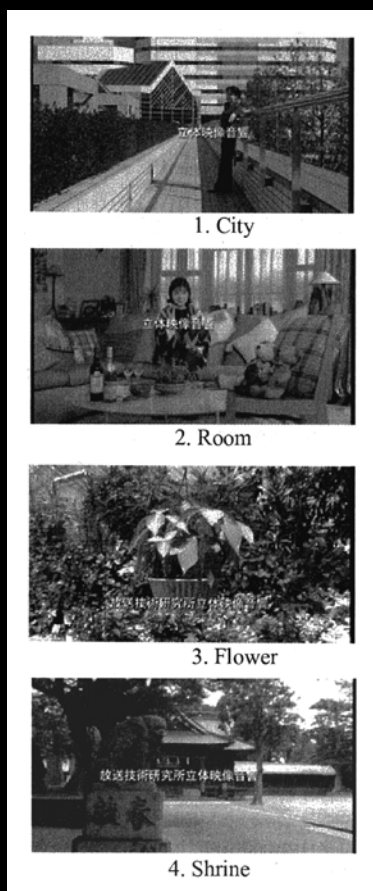
Preferable average value of the parallax distribution of  
presented stereoscopic images





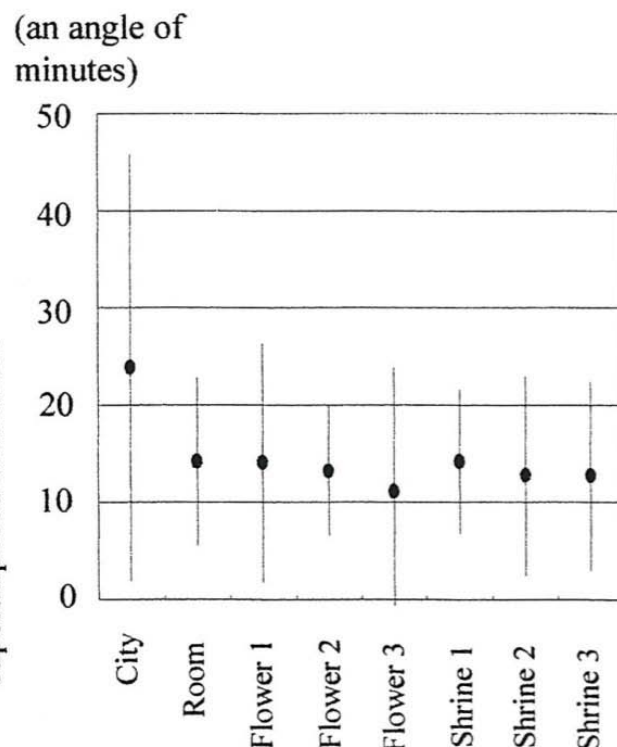
# ◆ Depth position of superimposed characters

## Preferable depth position of superimposed characters over stereoscopic natural images.



Test images

Parallax between the closest depth position of background image and the depth position of the superimposed characters

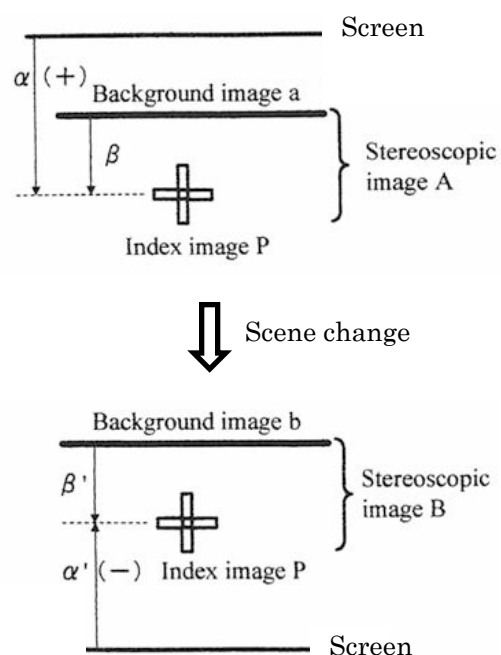


Characteristics of Parallax in evaluation images

Evaluated images	Convergence angle (min) at closest background image	A range of parallax distribution (min) of background image
City	38	48
Room	53	10
Flower 1	72	28
Flower 2	78	40
Flower 3	120	60
Shrine 1	72	16
Shrine 2	84	31
Shrine 3	84	50

# ◆ Scene changes

## Evaluation of visual comfort/discomfort due to scene changes.



The change in the depth position of P :  $\Delta \alpha = \alpha - \alpha'$

The change in the thickness of the stereoscopic image:  $\Delta \beta = \beta - \beta'$

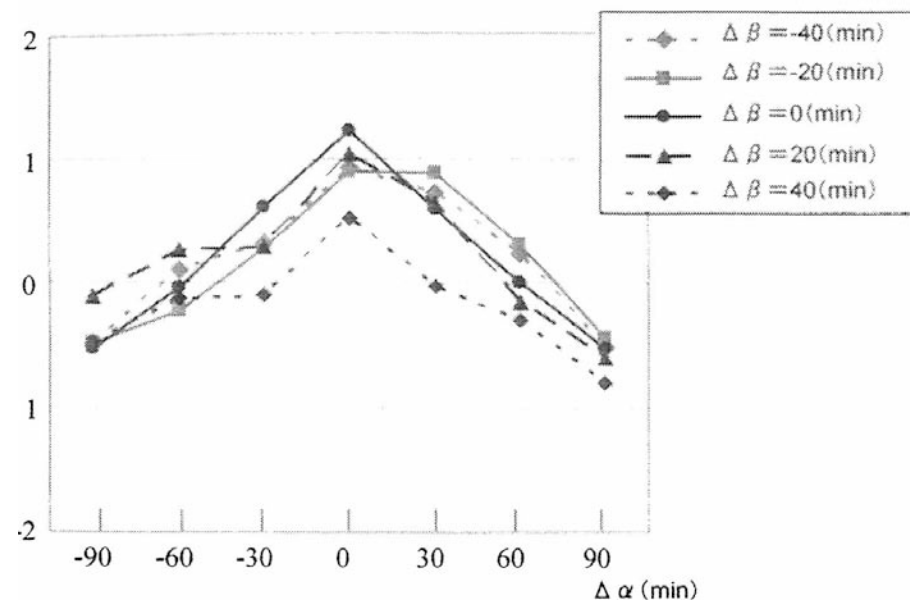
Comfortable to watch

Somewhat comfortable to watch

Not sure

Somewhat uncomfortable to watch

Uncomfortable to watch

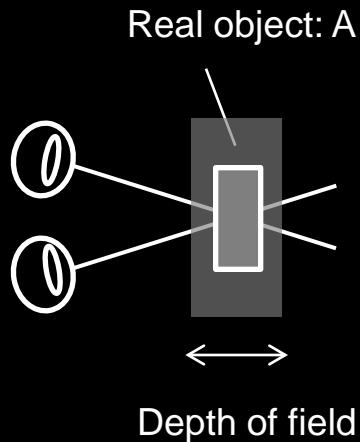


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# 4. Visual fatigue

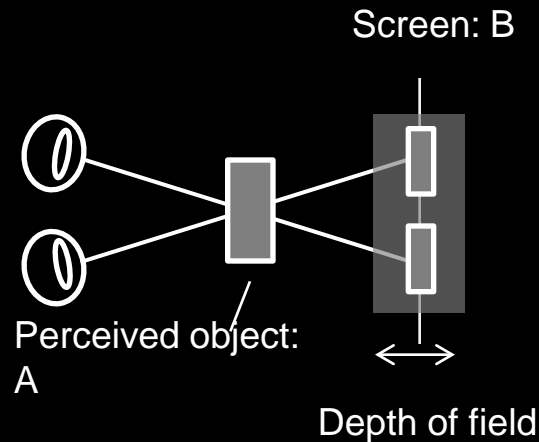
## Vergence and accommodation

Vergence  
= Accommodation  
= A

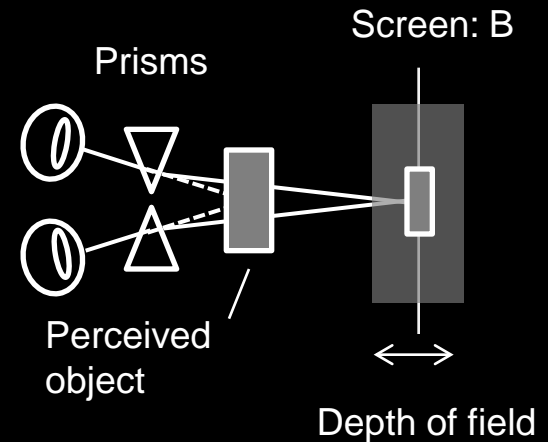


**A real object**

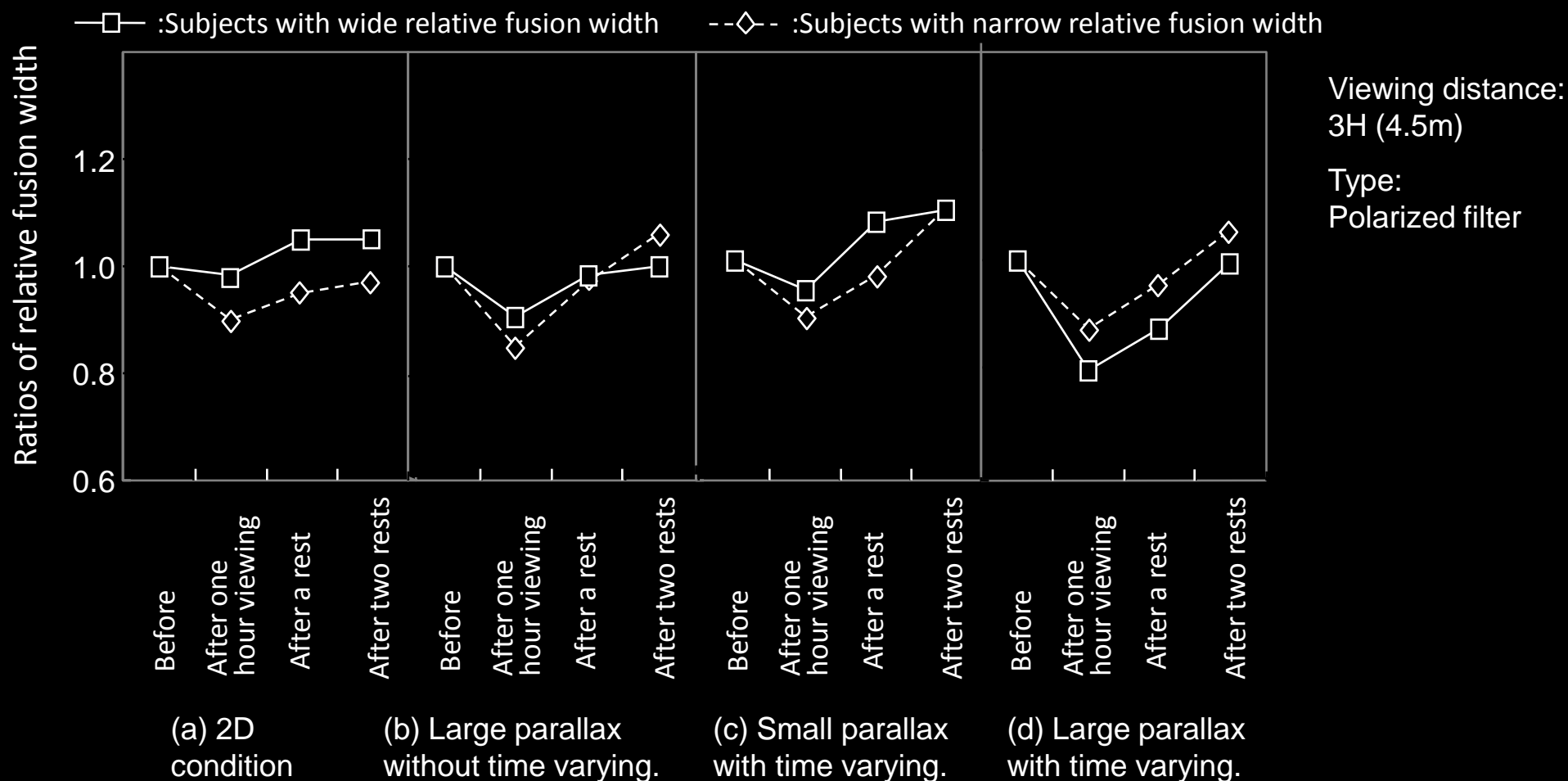
Vergence=A  
Accommodation= B



**Stereoscopic images**

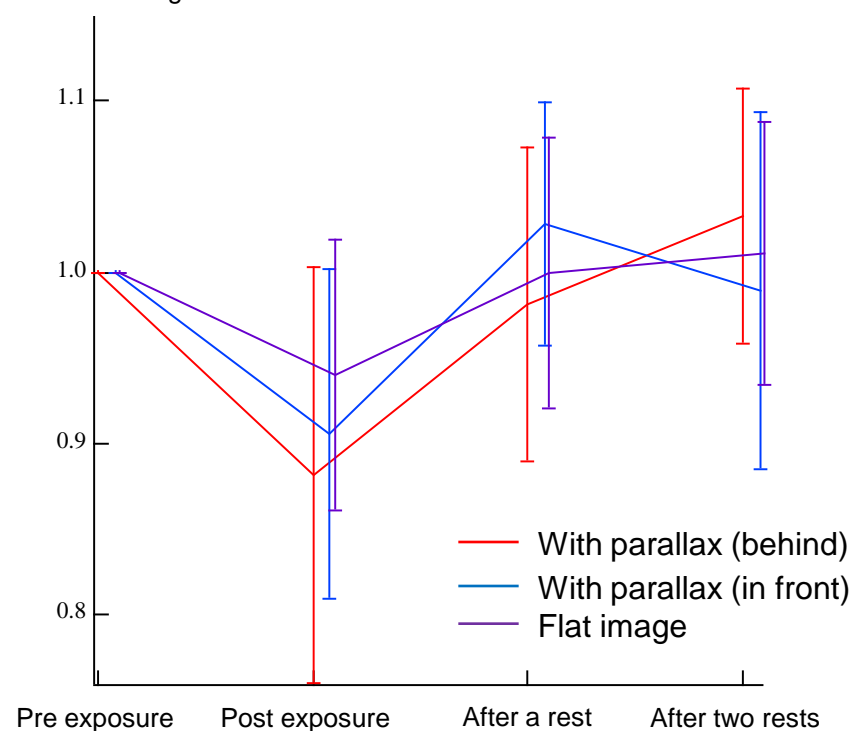


**A image through prisms**



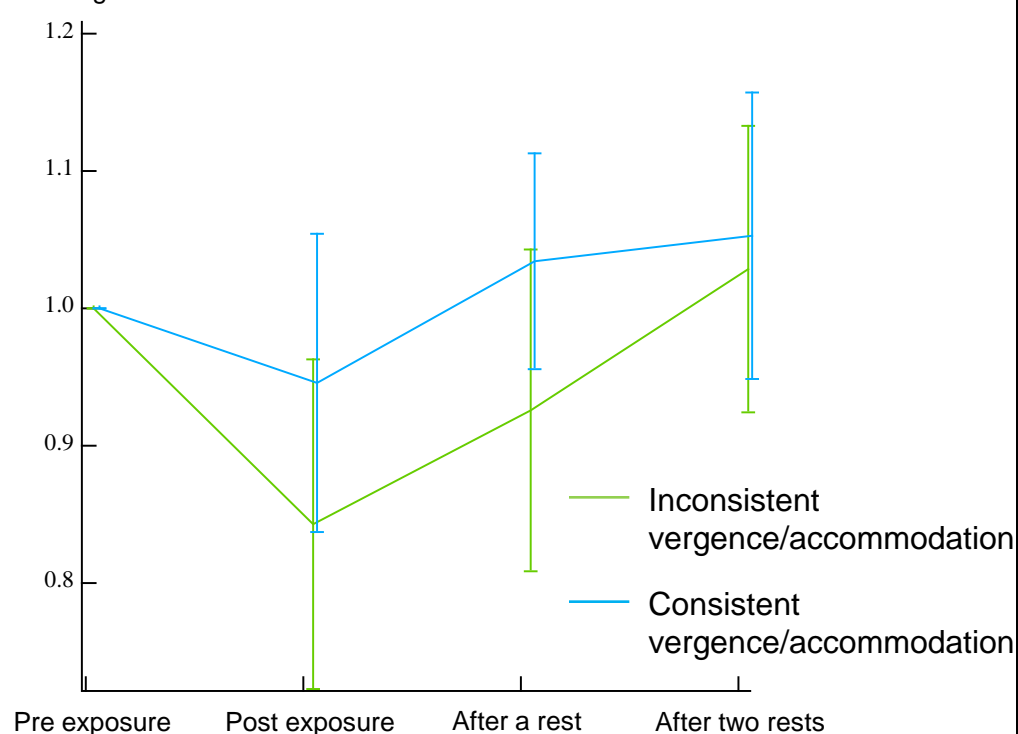
### Fusional amplitude after viewing image with large binocular parallax

Ratios of relative range of convergence

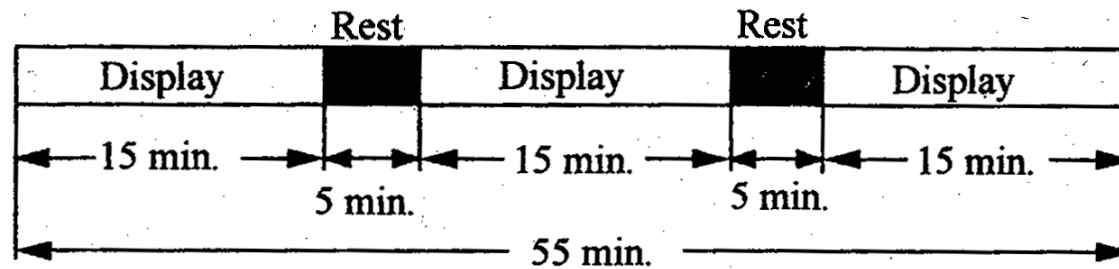


### Fusional amplitude after viewing image with time fluctuations in binocular parallax

Ratios of relative range of convergence



## ◇ Accommodation response



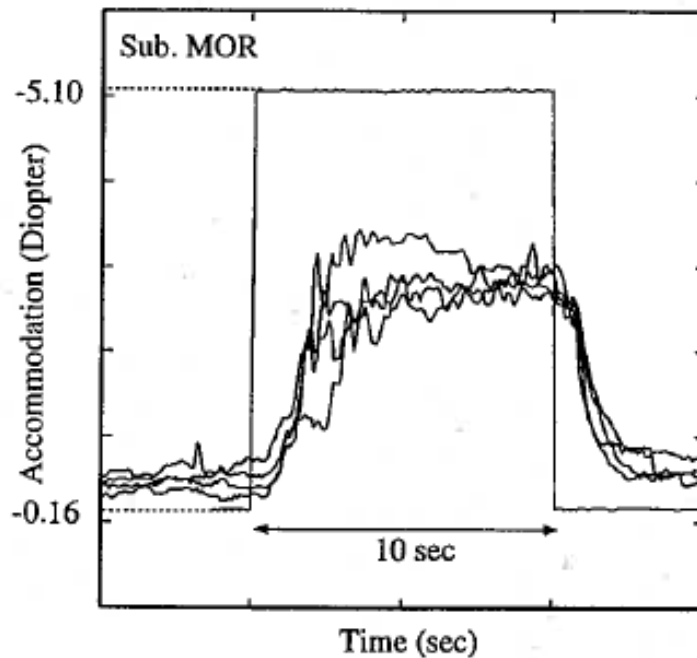
Display sequences of stereoscopic video

Screen size: 120inch (diagonal)

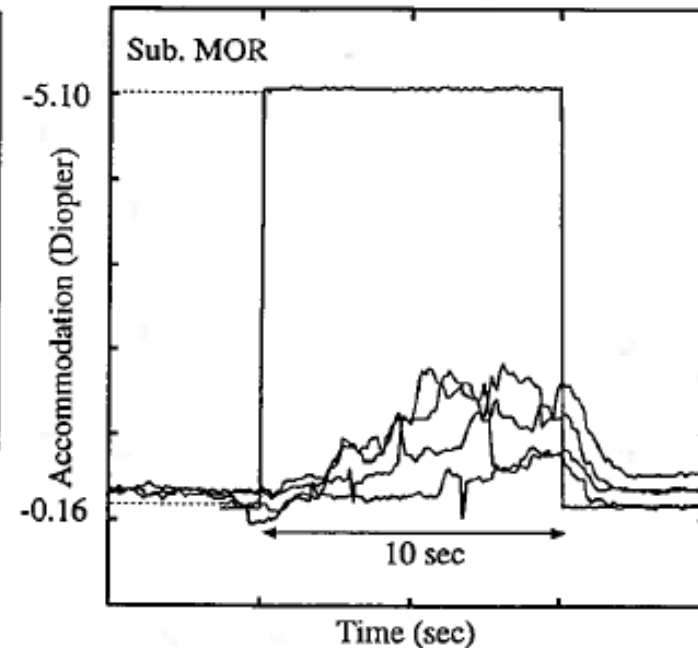
Viewing distance: 3H (4.5m)

Type: Polarized filter

## An example of the accommodation response of the eyes



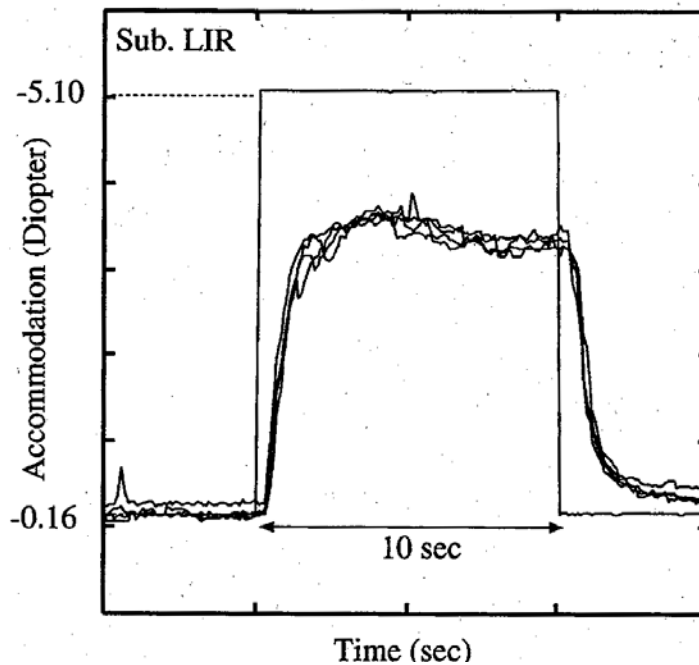
Before viewing stereoscopic images



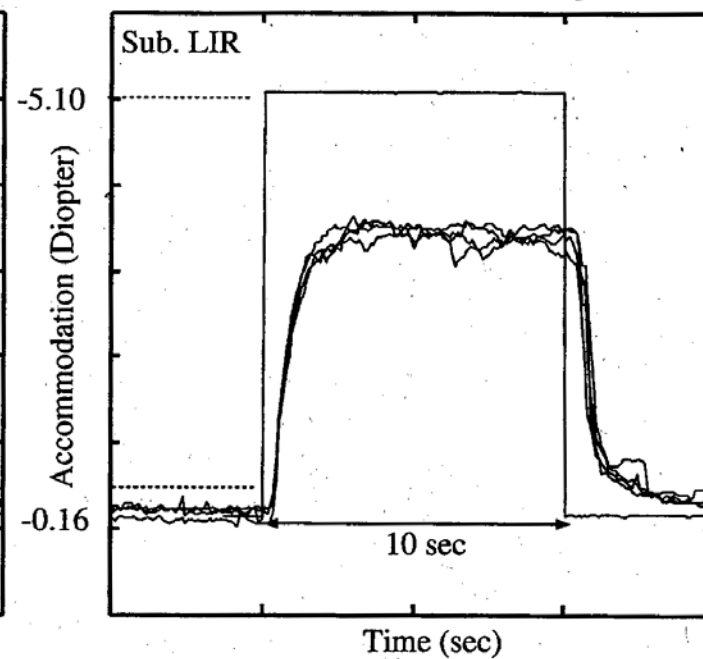
After viewing stereoscopic images



## An example of the accommodation response of the eyes

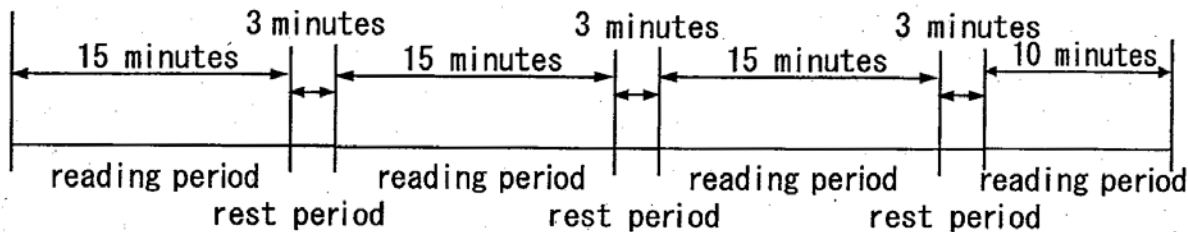


Before viewing stereoscopic images



After viewing stereoscopic images

## ◆ Subjective evaluation



Display sequence of stereoscopic video

Screen size: 28inch (diagonal)

Viewing distance: 3H (108cm)

Type: LCD shutter glasses

### Scale of evaluation

#### Eye fatigue

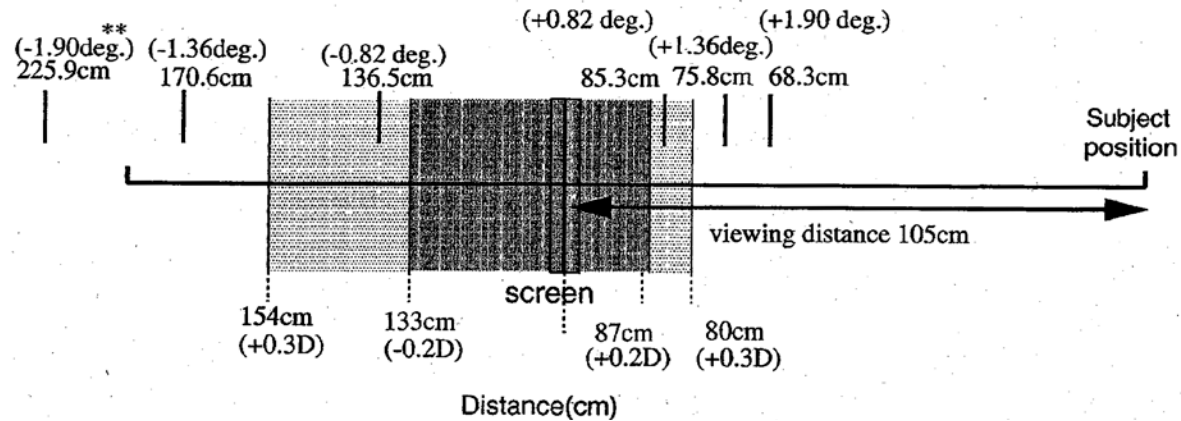
5: Not tired

4: Almost not tired

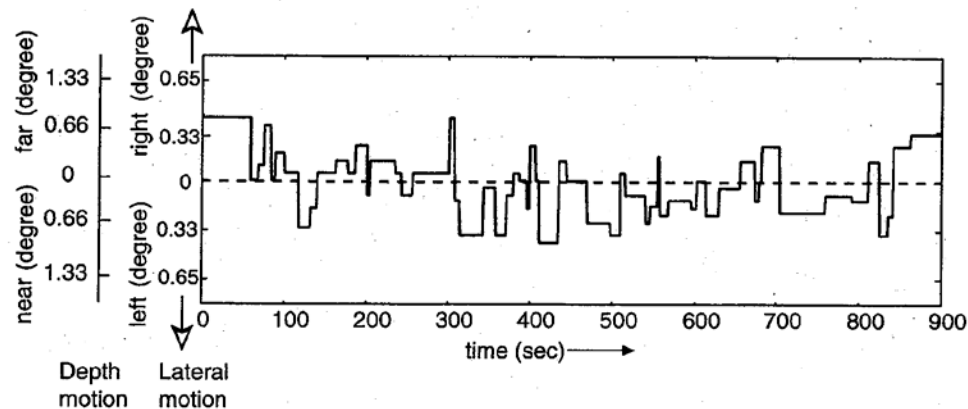
3: A little tired

2: Tired

1: Severely tired

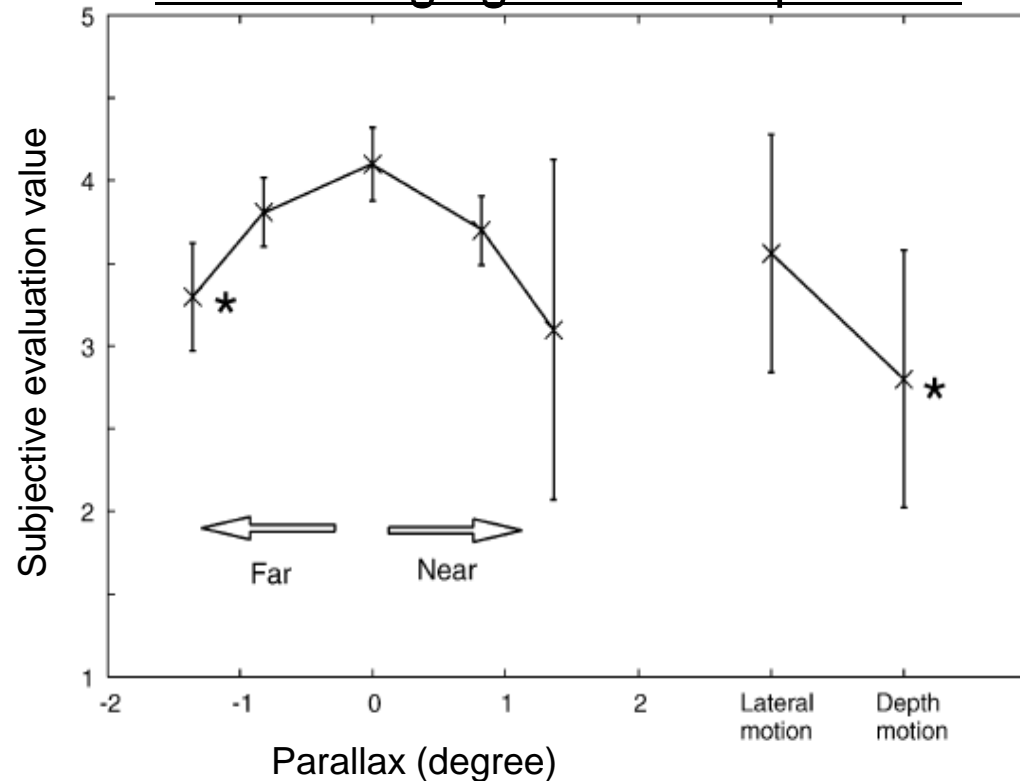


Target position for still stereoscopic image



Relationship between motion magnitude and scene change timing

Subjective evaluation of visual fatigue  
while changing amount of parallax



Stationary objects

Moving objects

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# 5. Conclusion

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- **Human factors** in Stereoscopic 3DTV
  - Naturalness   - Visual comfort   - Visual fatigue
- **Composite factors** in perception of stereoscopic 3D images
  - Programme production techniques   - Display devices
  - 3D glasses   - Viewing condition   - Viewer characteristics
- **All parties concerned with stereoscopic 3DTV systems**  
need to understand the characteristics of stereoscopic 3D images
- **Viewers** should be well informed of satisfactory conditions for viewing stereoscopic 3D images