Video Analysis (Videoverarbeitung)

LV 188.329 (1 VO), WS 2016/17

3D Movie Making

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FAKULTÄT FÜR !NFORMATIK

Faculty of Informatics

Acknowledgement

These slides were developed by Matej Nezveda for the course in 2015/16. We wish to thank Matej for making the slides available for further use.

Red-cyan glasses required in order to see content in 3D

LECTURE'S CONTENT:

The theory behind stereo perception, camera work and how to create 3D imagery.

Outline

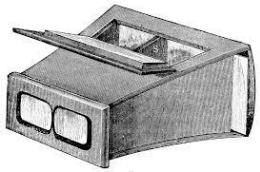
1. 3D History and Motivation
2. Stereoscopic Vision
3. Basics of Stereoscopic Imaging
4. 3D Cinematography Fundamentals
5. 3D Cinematography Advanced
6. 3D Movie Design

1

- **3D evolution & popularity of 3D movies**
- **3D cinematographic language**

3D Evolution

1851
Brewster stereoscope introduced in London



1891
Anaglyph format invented

1952
First feature length 3D movie

Today
3D TV broadcast

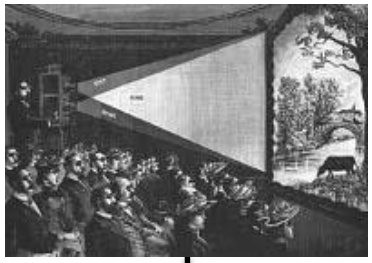
1820 1840 1860

1838
Wheatstone explains stereopsis

1928
Baird demonstrates 3D TV

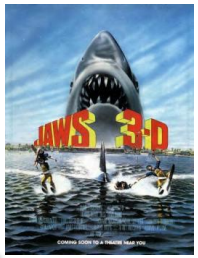
1996
First IMAX 3D fiction movie

Popularity of 3D Movies

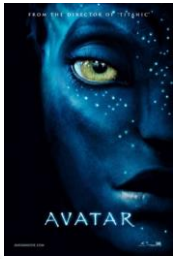


1920's
Introduction

1950's
Golden Area



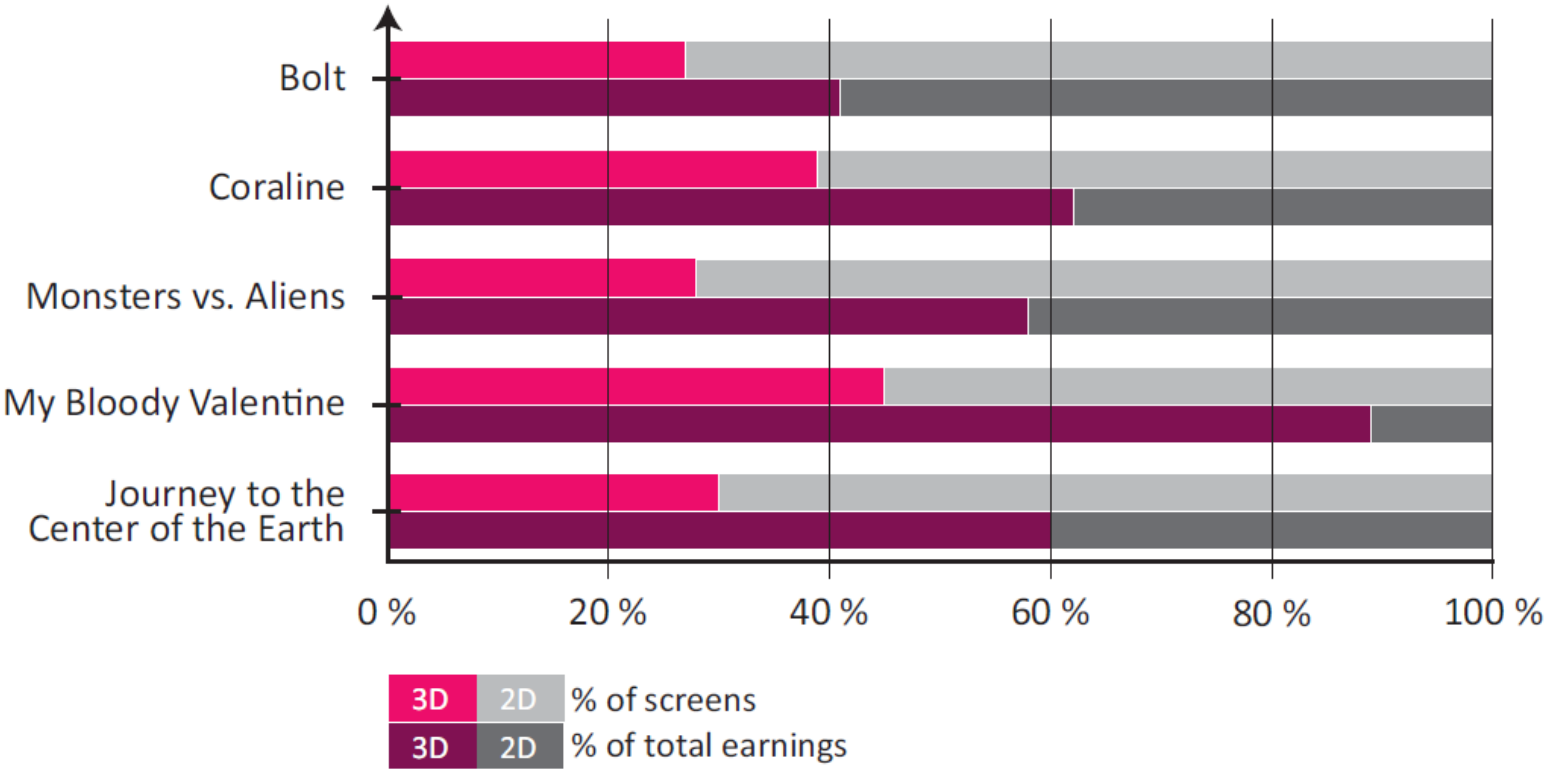
1980's
Rebirth



2010's
Renaissance

2D vs 3D:

Number of screens and total earnings for North America



Future of 3D

- **What is the future of current 3D?**
  - Are we prepared to completely switchover to 3D?
  - Shall we consider 3D as passing hype like in 1950s?

- **Differences with 1950s golden age:**
  - **Advances in technology …**
    - Shooting technology
    - Post-production technology
    - Display technology
  - **… as financial viability …**
    - Enough interest and tickets sale
    - Enough cinemas using the technology
  - **… give 3D biotope it needs to thrive**

“There will be no 3D cinema without these two elements: stories really benefiting from 3D and fully developed 3D cinematography“

Bernard Mendiburu

2

- **What are monoscopic and stereoscopic depth cues?**
- **How does brain use stereoscopic vision to provide us with depth impression?**

Depth Perception

Human perception of depth relies on:

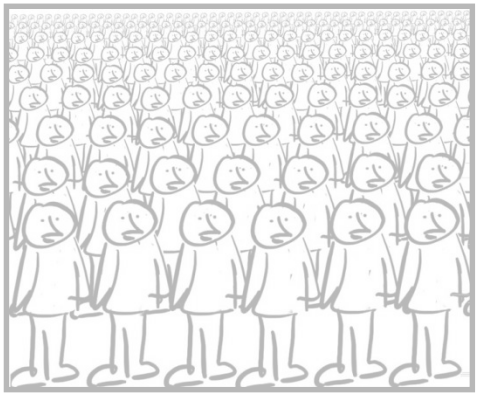
- **Monoscopic depth cues**
  - Depth information extracted from a single 2D view
- **Motion-based depth cues**
  - Depth information extracted from a single viewpoint
- **Stereoscopic depth cues**
  - Depth information extracted from two different perspectives of a scene

Monoscopic Depth Cues Pt. I

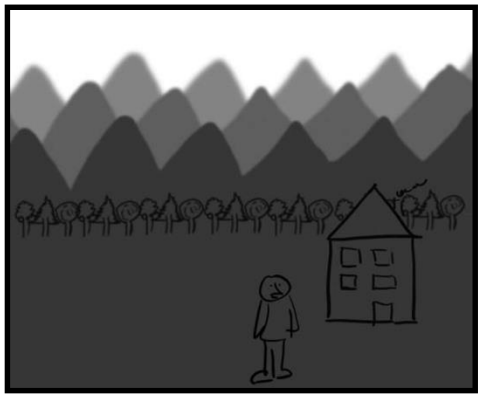
Relative size

Occlusion

Texture gradient

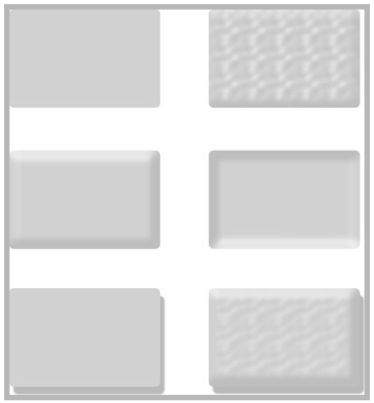


Atmosphere blur, saturation, and color shift



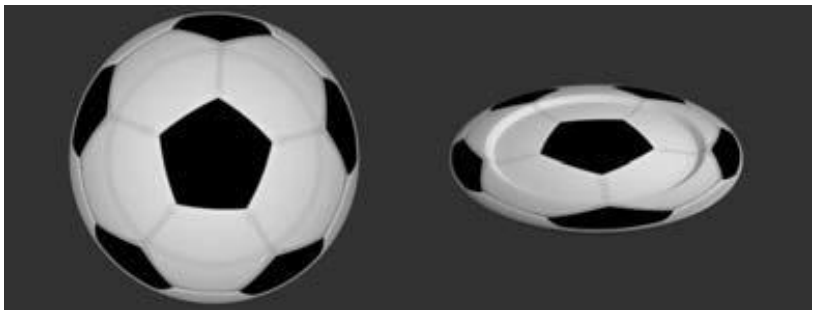
Monoscopic Depth Cues Pt. II

Cast shadows and specular highlights



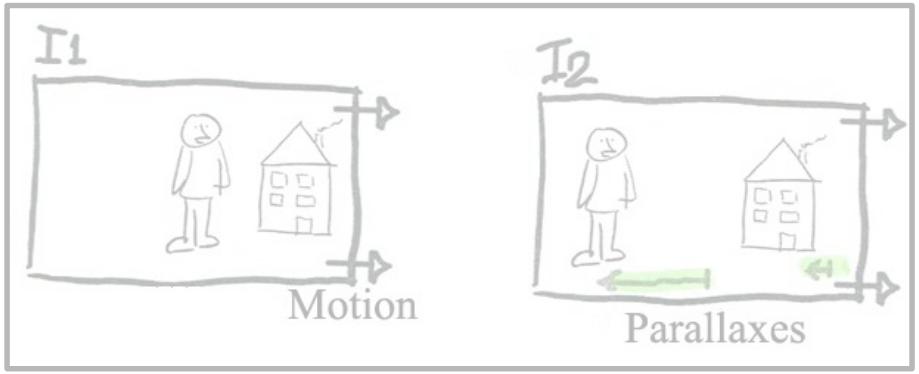
Position relative to the horizon

Previous knowledge of shapes

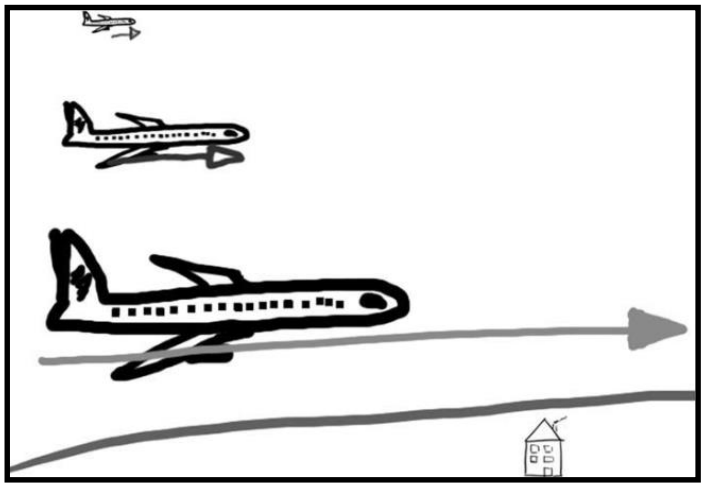


Parallax:
Relative position of an object‘s image in a set of pictures

Point-of-view motion parallax:
Distance in the frames between two positions of the same objects

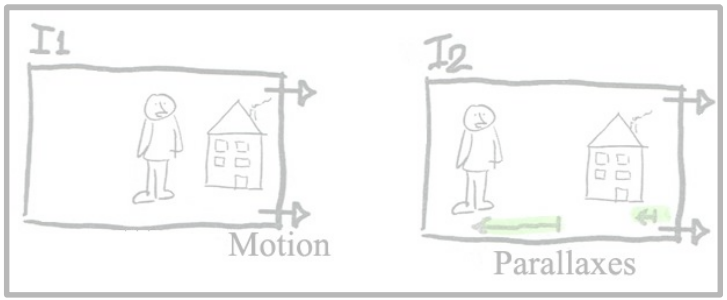


Object‘s movement parallax:
The further away the slower it seems to move

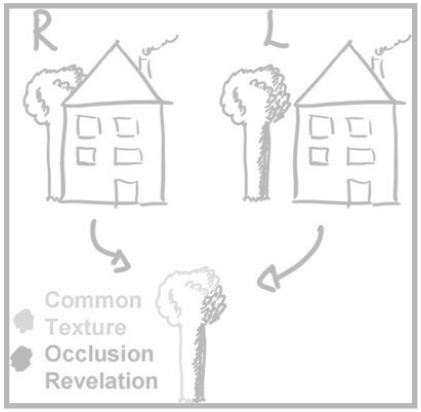


Stereoscopic Depth Cues

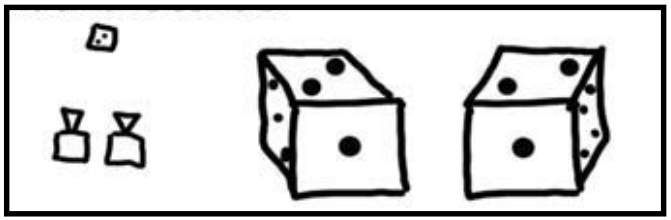
Stereoscopic parallax:
Position of images on retina



Occlusion revelations:
What only one eye sees



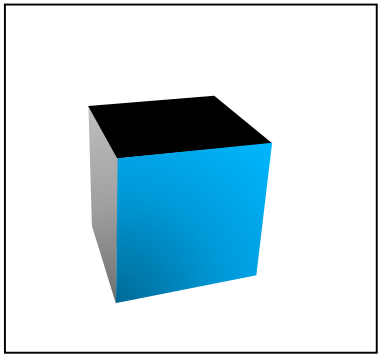
Shape change:
Fine depth structure of objects

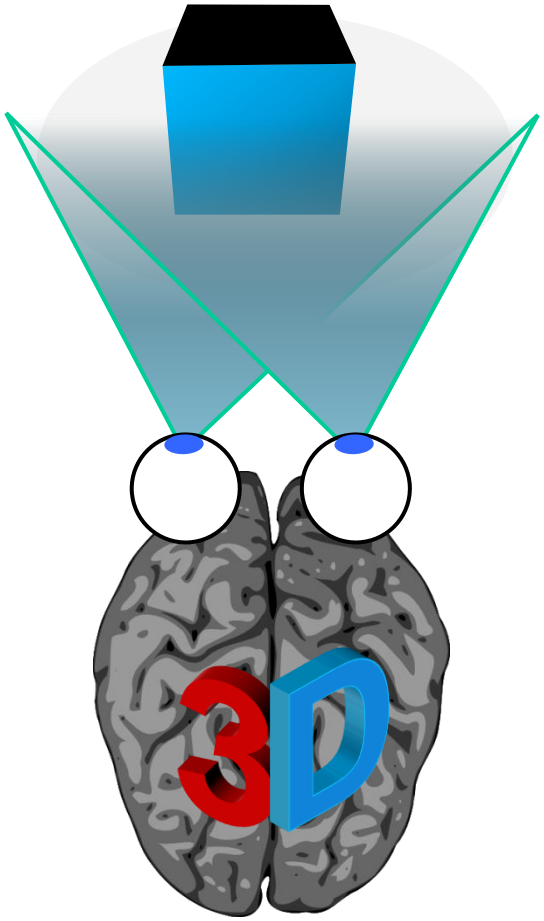


Binocular Stereopsis

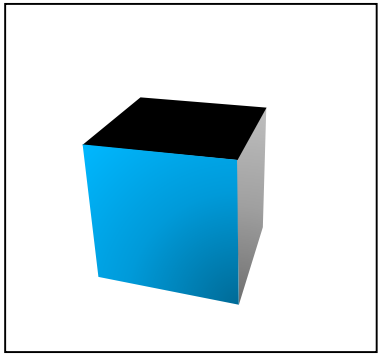
original view

left eye's view





right eye's view



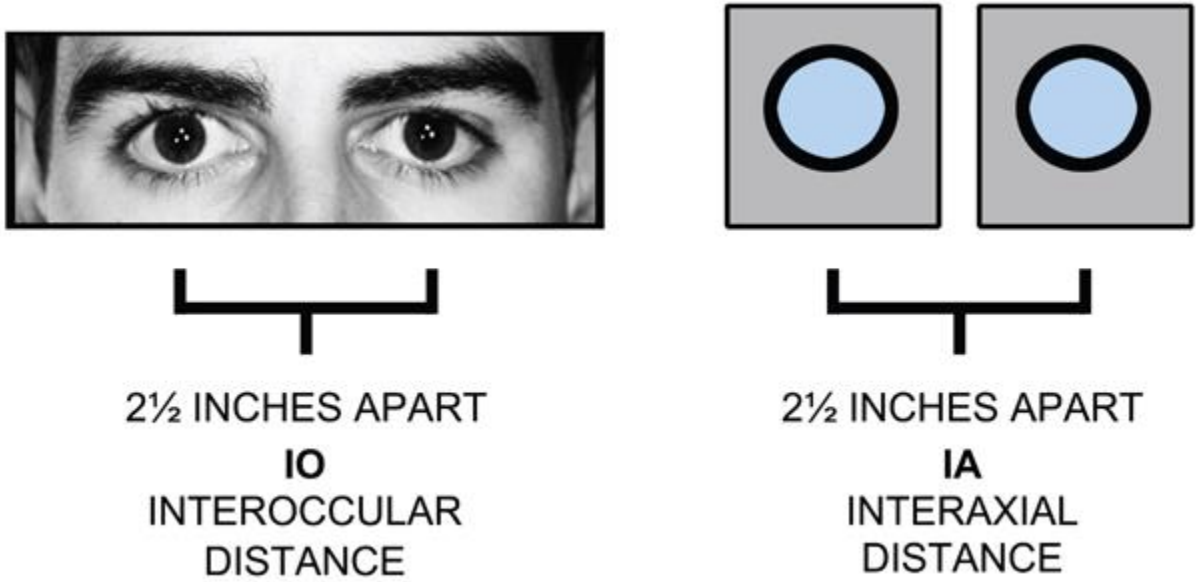
our brain creates the 3D

3

- **Accommodation and convergence reflex**
- **Limits of stereoscopic depth perception**
- **Parallax as conceptual tool for 3D cinematography**

From Stereopsis to Stereoscopy

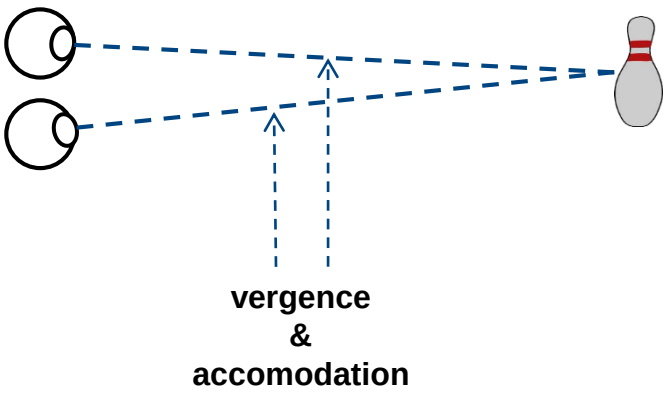
- **2 eyes = 2 different images (stereopsis)**
- **2 lenses = 2 different images (stereoscopy)**



Accommodation and Convergence

Accomodation and convergence are coupled when we see the world in 3D:

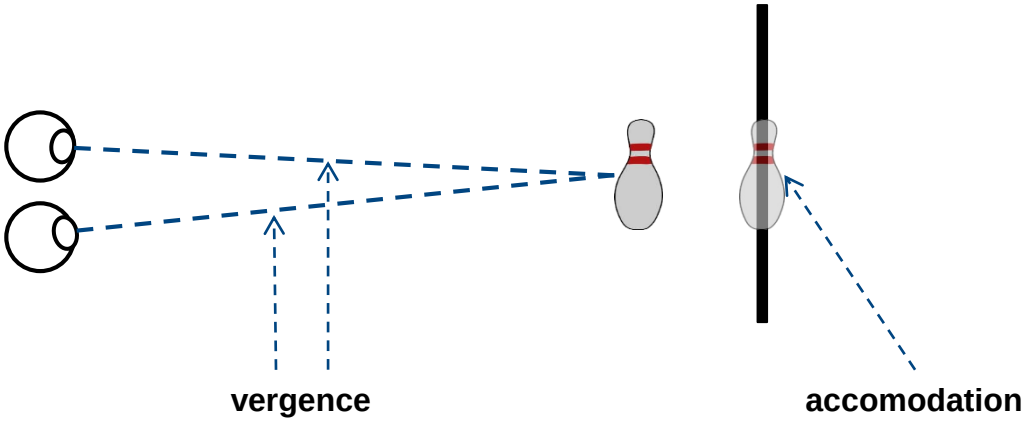
- Accomodation: Eyes lens focus on the object
- Convergence: Eyes sight crossing on the object



Accommodation and Convergence

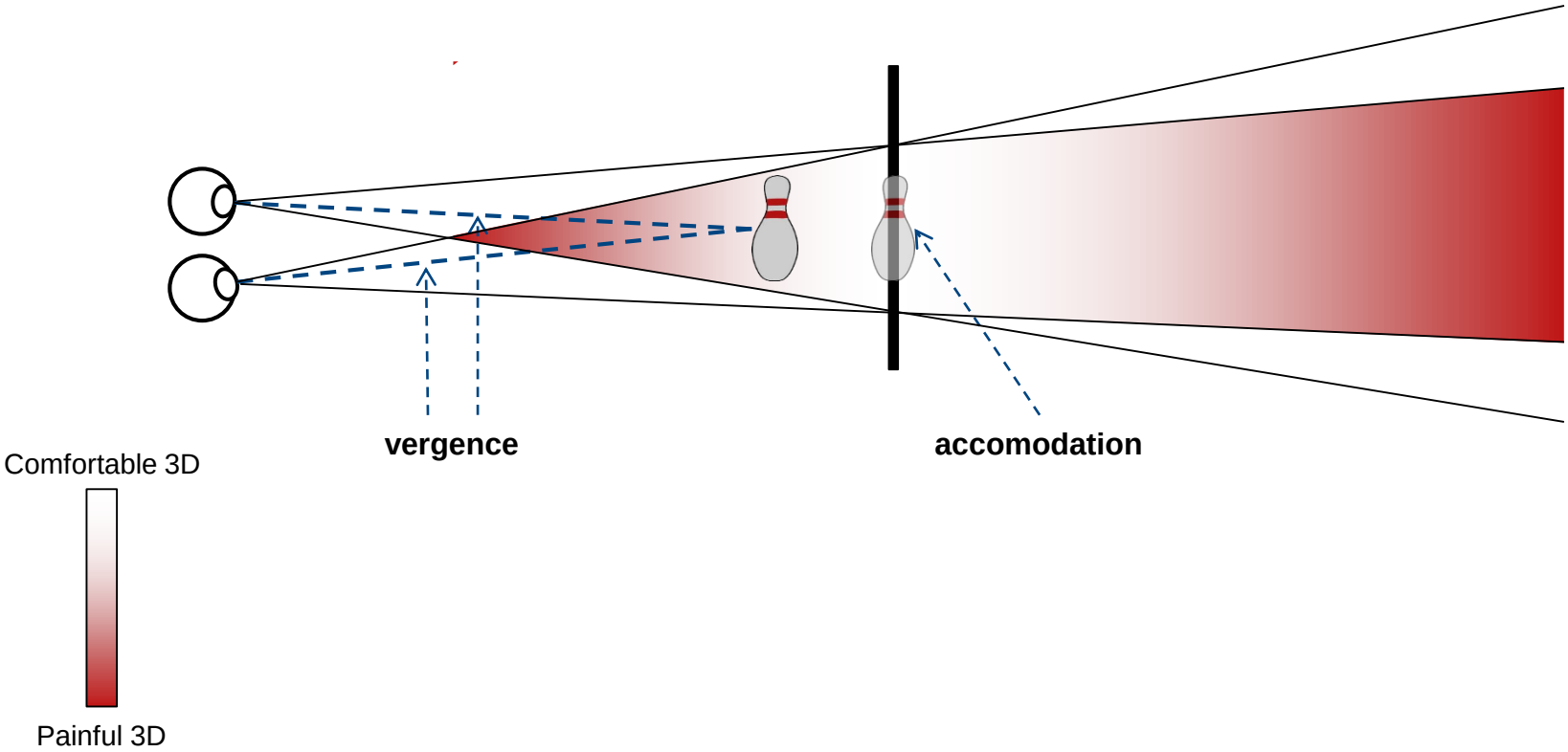
Accomodation and convergence are decoupled when we watch movies in 3D:

- Accomodation: Eyes lens focus on the screen
- Convergence: Eyes sight crossing on virtual object



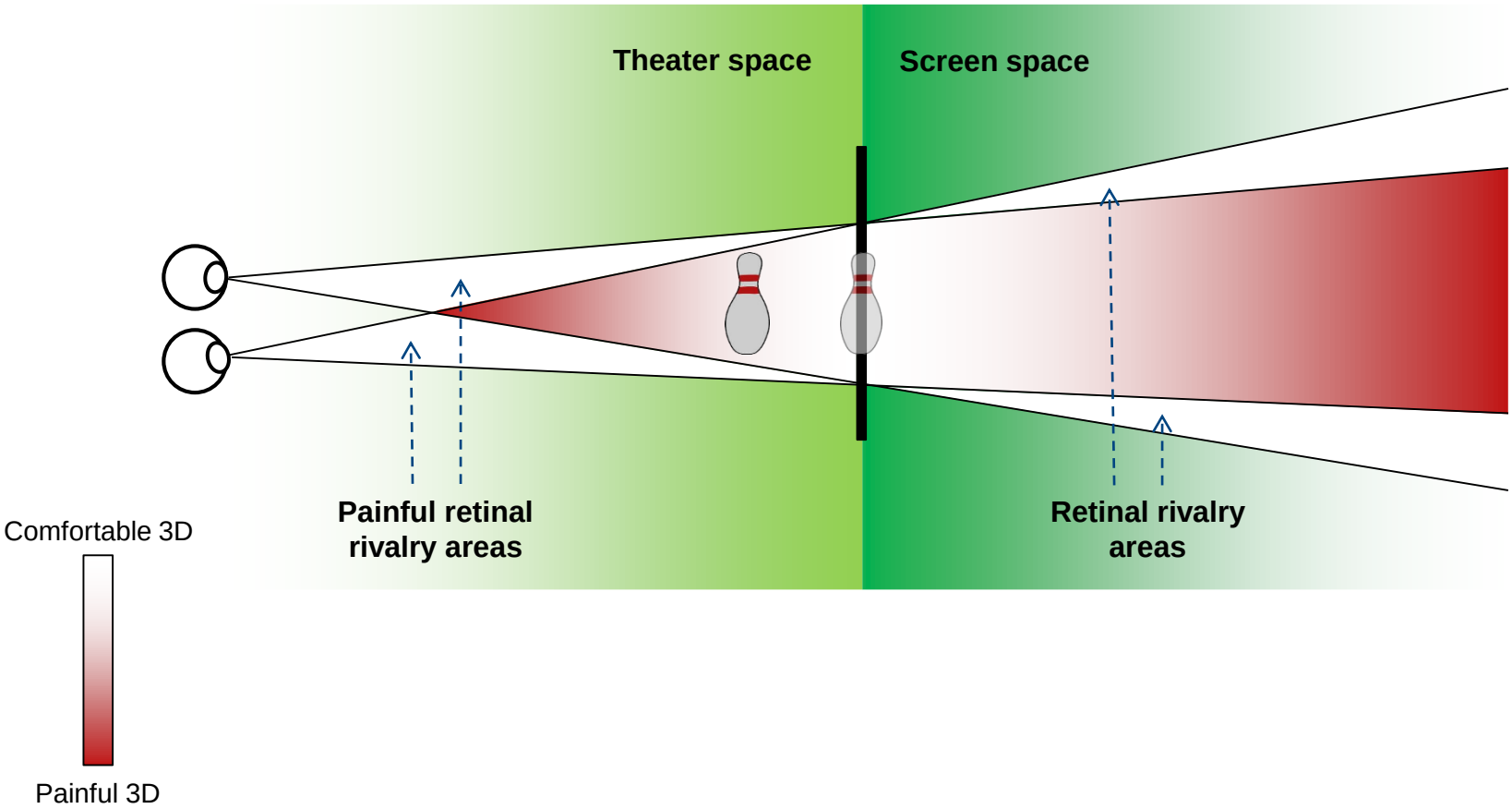
Accommodation and Convergence

Decorrelation of accommodation/convergence is not natural and can be painful



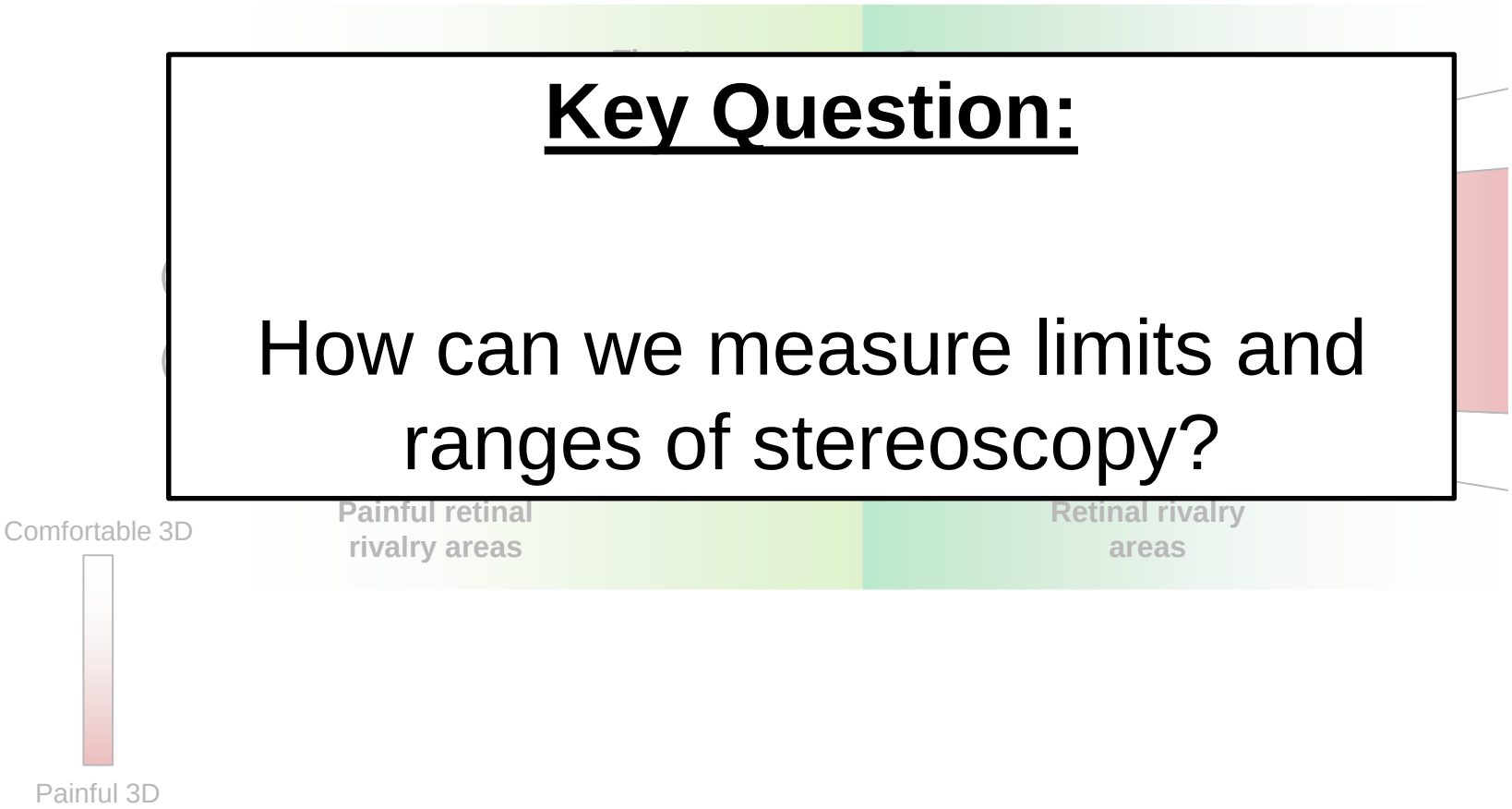
Stereoscopic Comfort Zone

Zone of comfort in which decoupling of accomodation and convergence can be achieved without discomfort



Stereoscopic Comfort Zone

Zone of comfort in which discoupling of accomodation and convergence can be achieved without discomfort



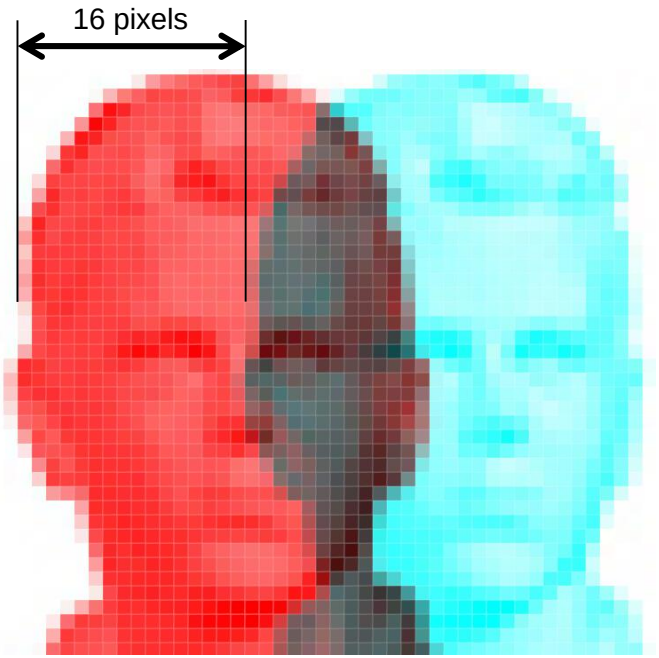
Key Question:

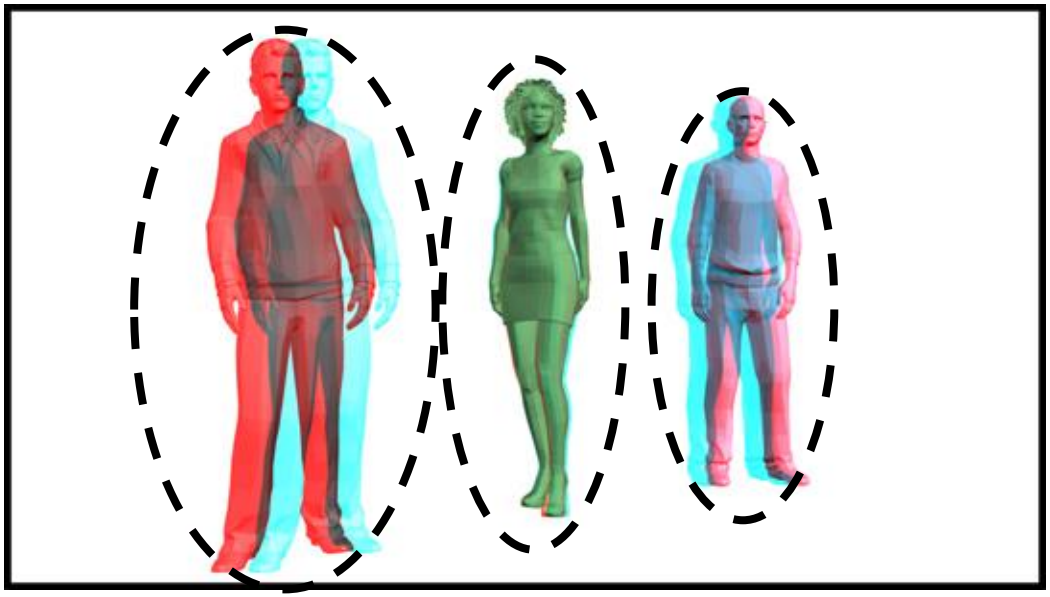
How can we measure limits and ranges of stereoscopy?

The Stereoscopic Parallax

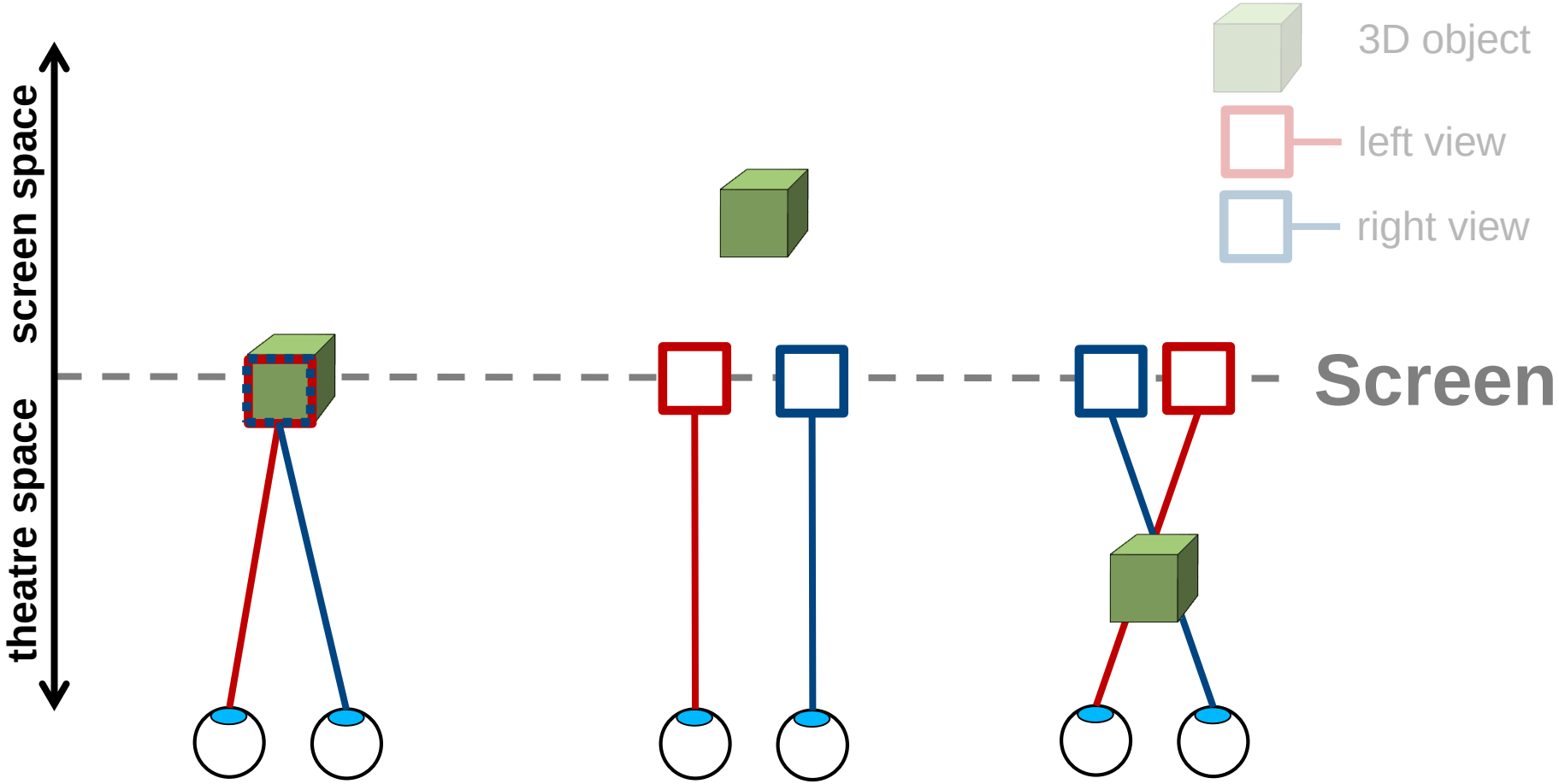
Parallax is the difference between the two cameras

Parallax can be measured in pixels





The Stereoscopic Parallax

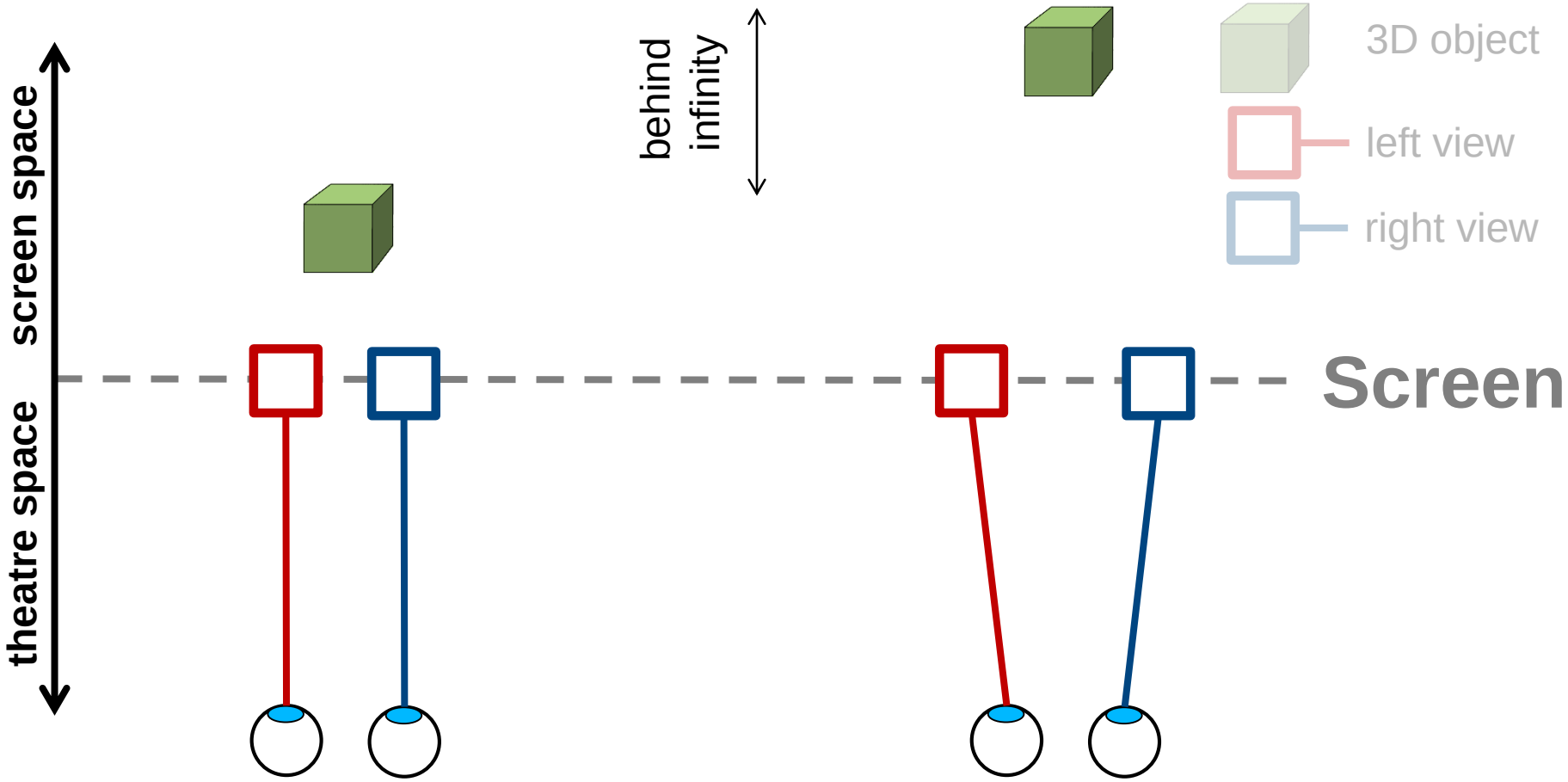


Zero parallax:
Object on the screen

Positive parallax:
Object behind the screen

Negative parallax:
Object in front of the screen

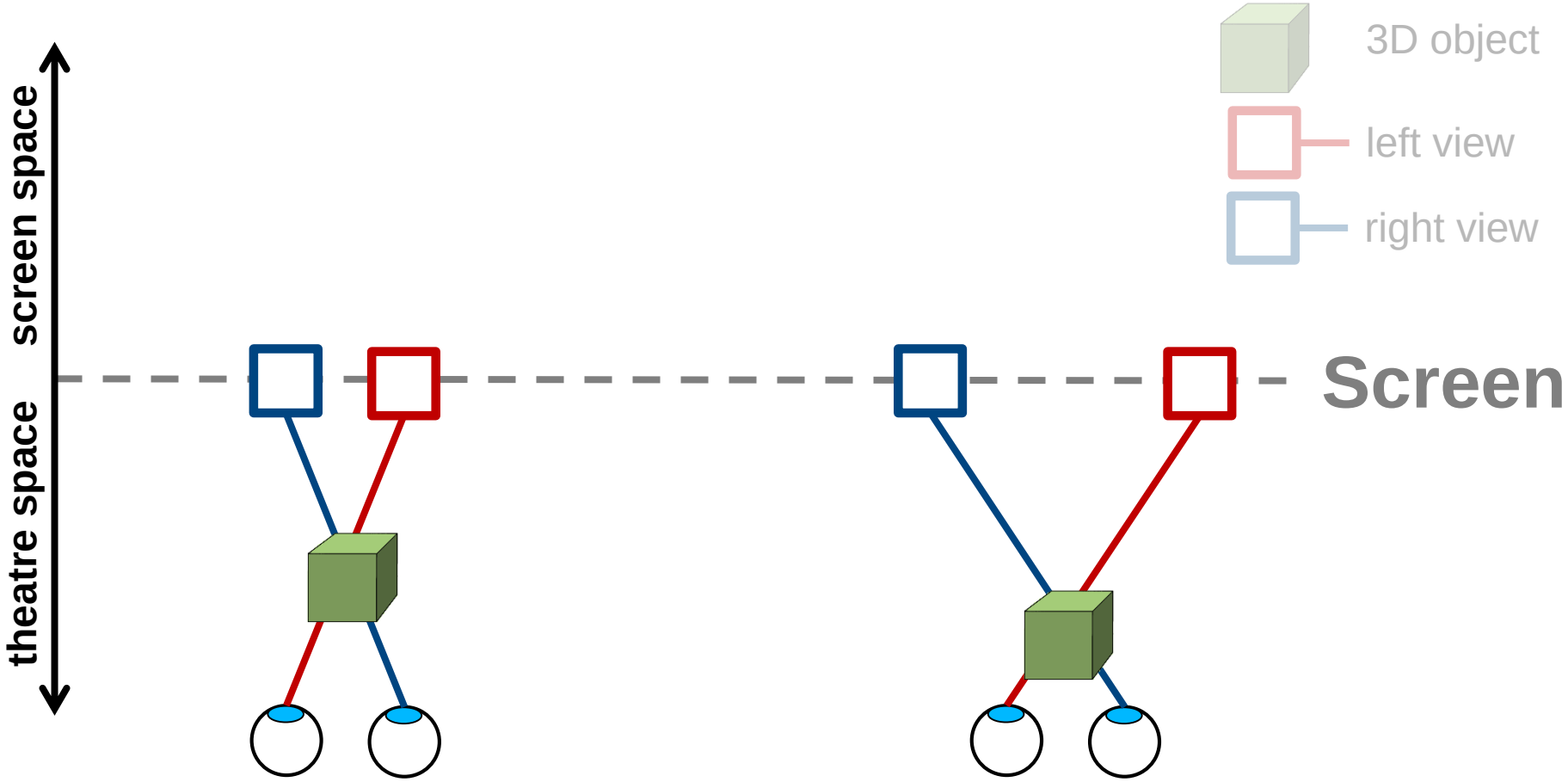
Positive Parallax



Maximum positive parallax (MPP):
Equal to eye width where eye sight is parallel and objects are perceived at stereoscopic infinity

What happens beyond MPP:
Eyes are diverging which can be painful and object appear even further away

Negative Parallax



Mid distance parallax (MDP):
Eyes sight is crossed and objects are perceived half way to the screen

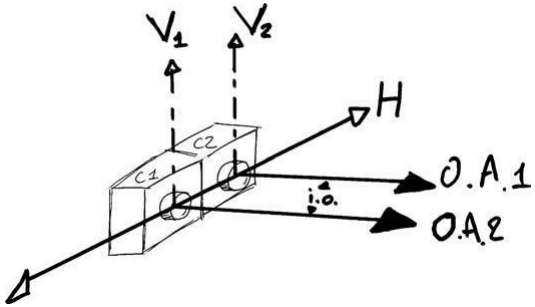
Maximum negative parallax:
Is time sensitive (e.g., objects can stay at 1x to 2x times MDP or can move up to 3x MDP)

4

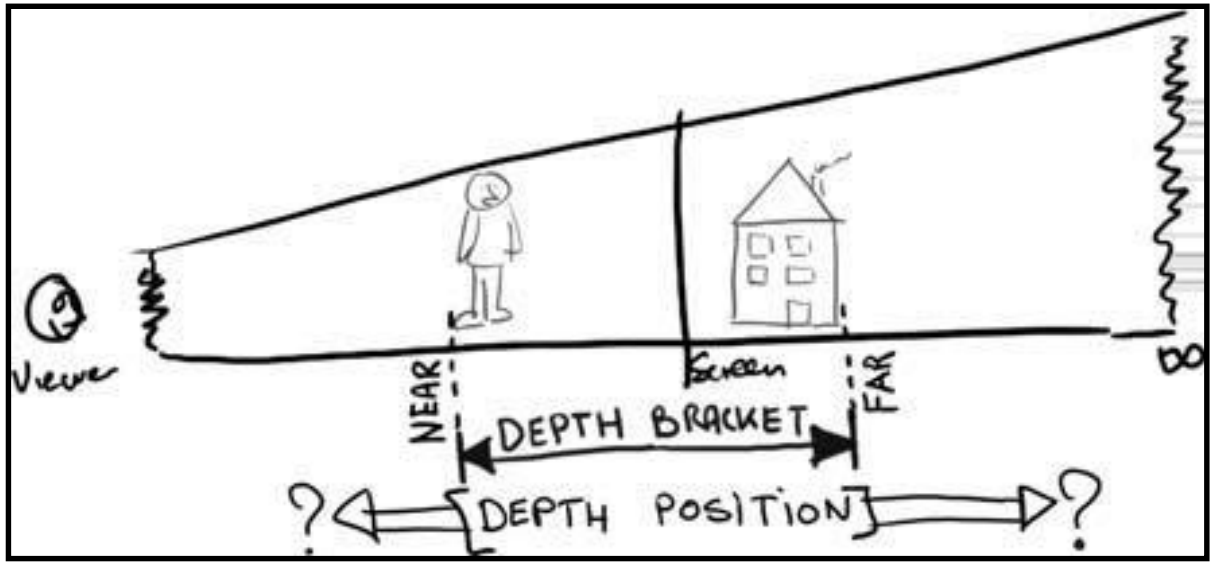
- Camera requirements
- Interoccular distance and depth bracket
- Convergence and depth position
- Depth perception inside the theater

Camera Requirements

- **Matching cameras**
  - 3D is made of pairs of matching cameras
- **Matching parameters**
  - White balance
  - Shutter speed
  - Exposure
- **Matching optics**
  - Focal length
  - Focus point
  - Zoom
- **Matching geometry**
  - Cameras in correct relative positions



Depth Bracket and Depth Position



Depth bracket:

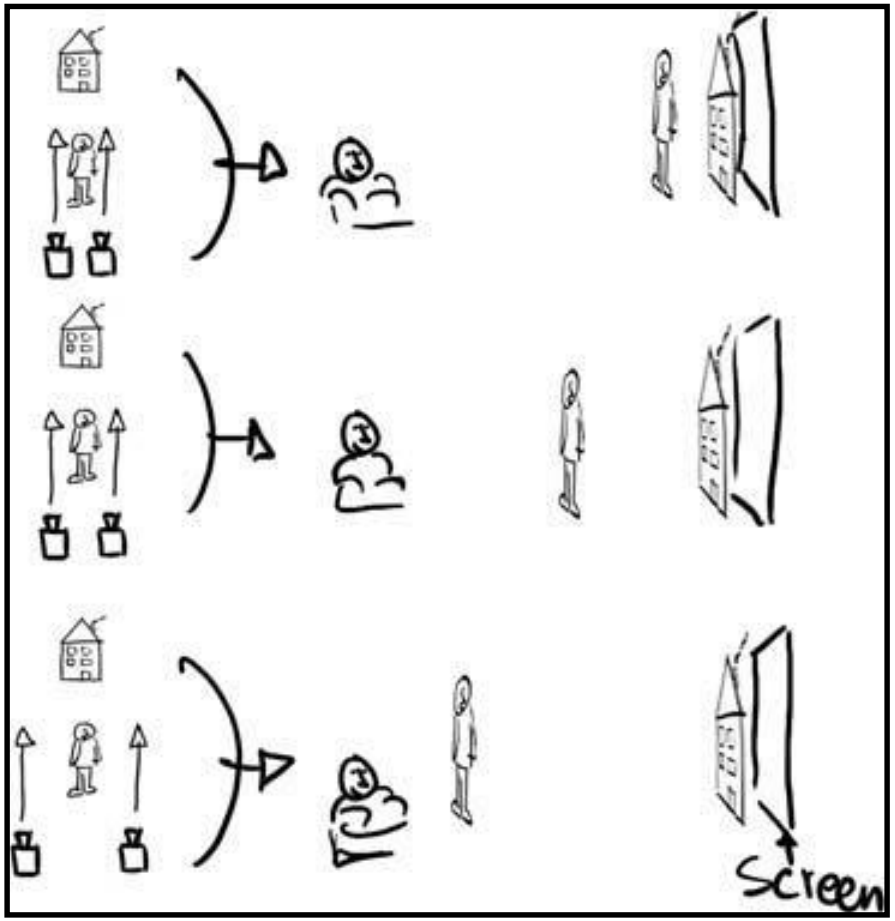
- Describes the total depth of a scene in terms of parallax.
- Controlled by interaxial distance

Depth position:

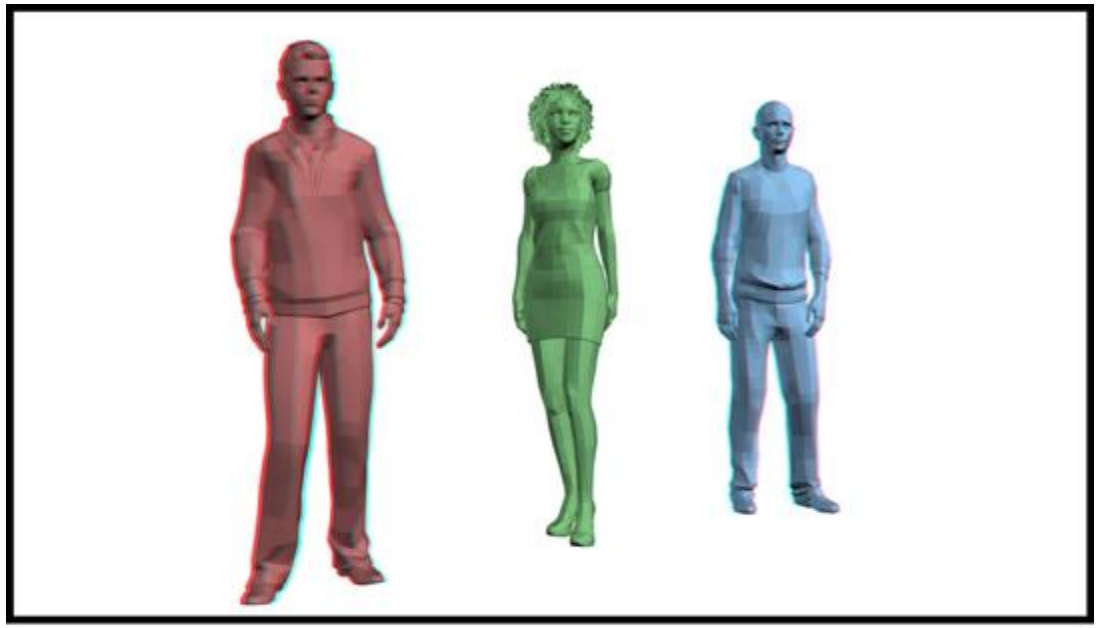
- Placement of the depth bracket inside the real estate.
- Controlled by (post-) convergence

Interaxial Distance

- **Distance between left and right camera**
- **Sets the depth bracket**
  - The overall depth of a scene
  - Foreground to background distance
- **Created on set**
  - Hard to change later on

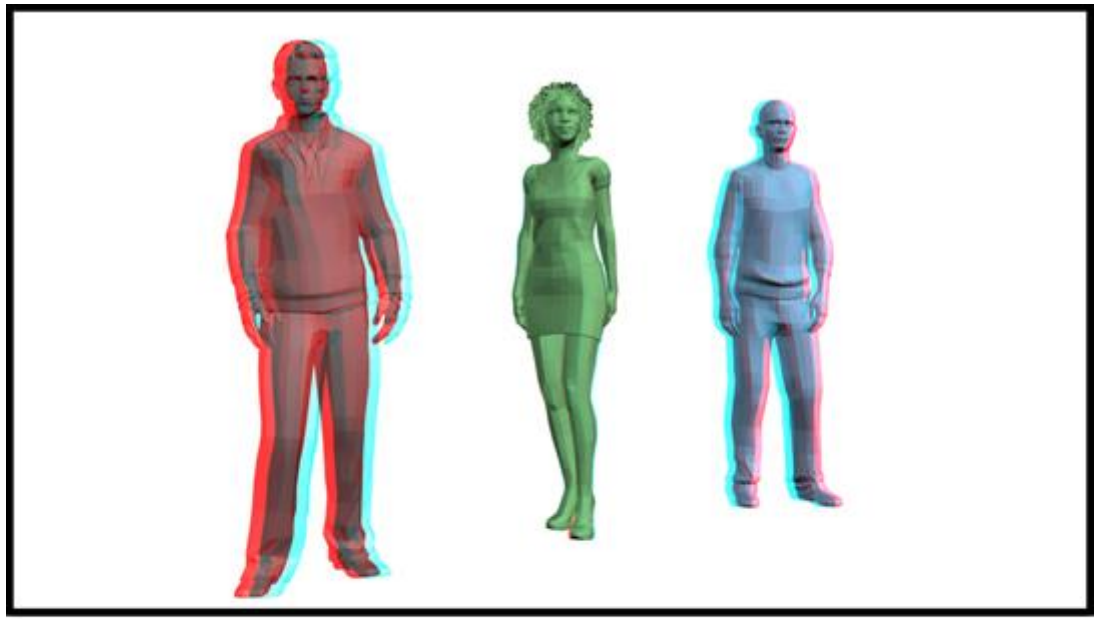


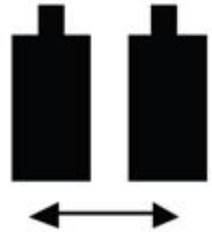
Interaxial Distance



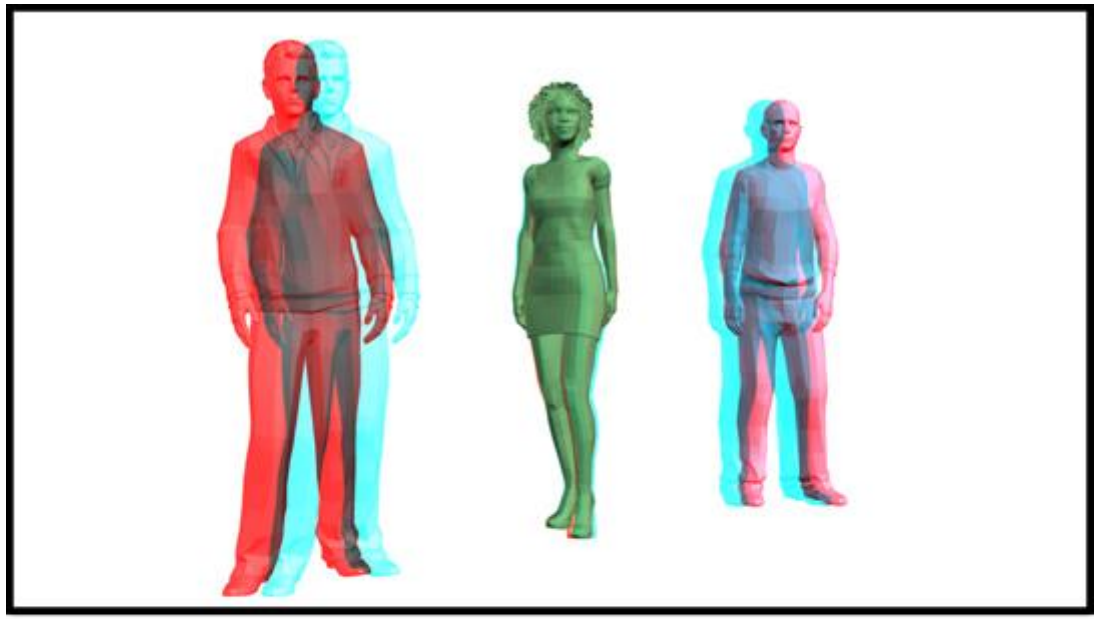
SMALL IA

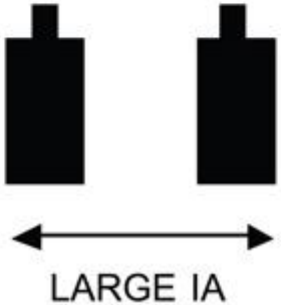
Interaxial Distance





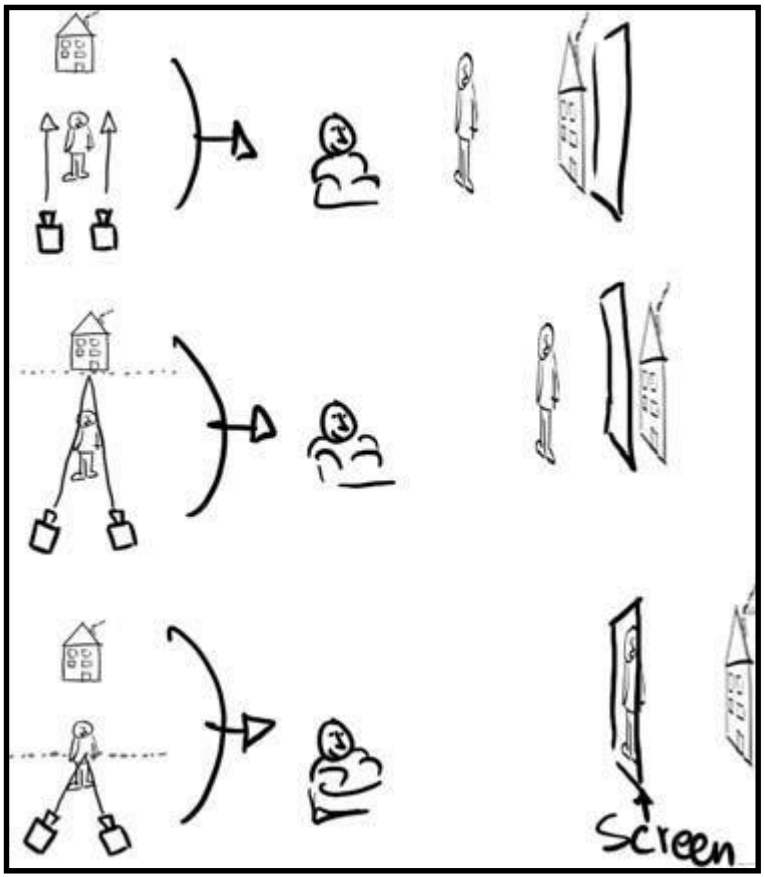
Interaxial Distance

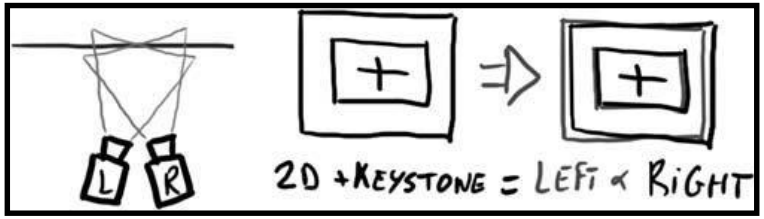




Convergence

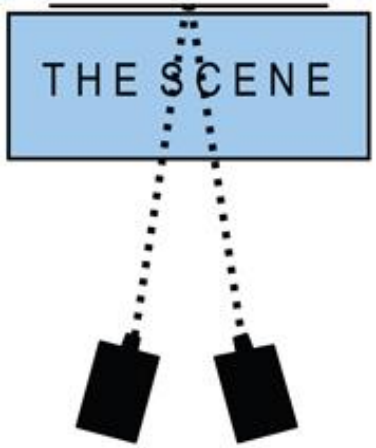
- **Angle formed by the cameras**
- **Sets the depth position**
  - Moves the scene along the z-axis
- **Created:**
  - On set: toe-in camera setup (can cause keystone effect)
  - On post: Horizontal image translation

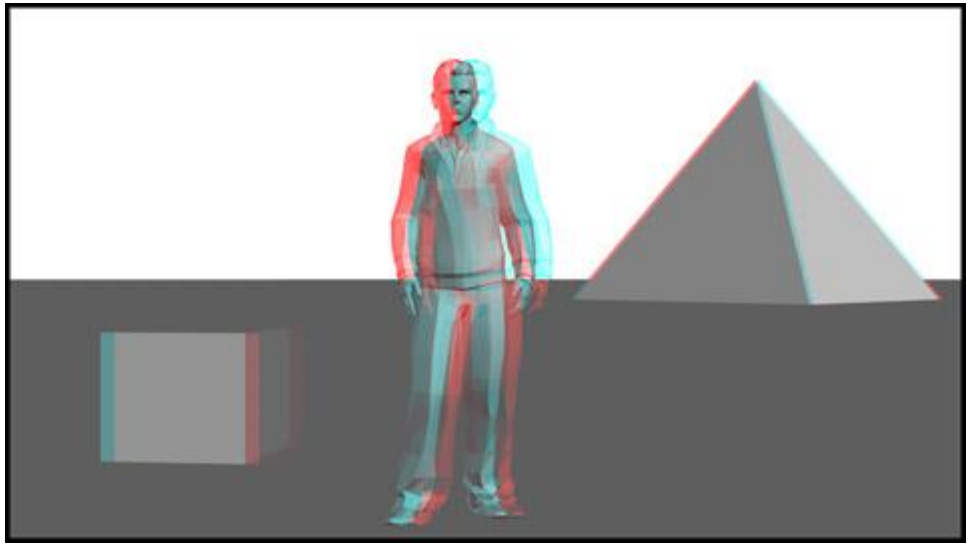




Convergence

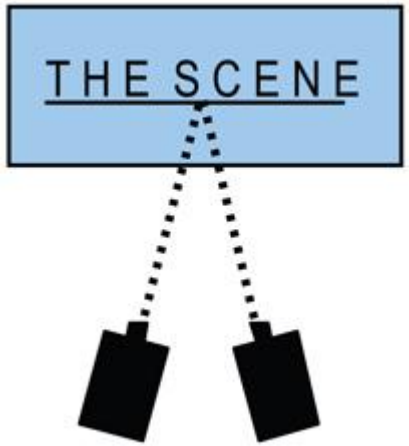
Converging behind the scene places the scene in front of the screen plane.

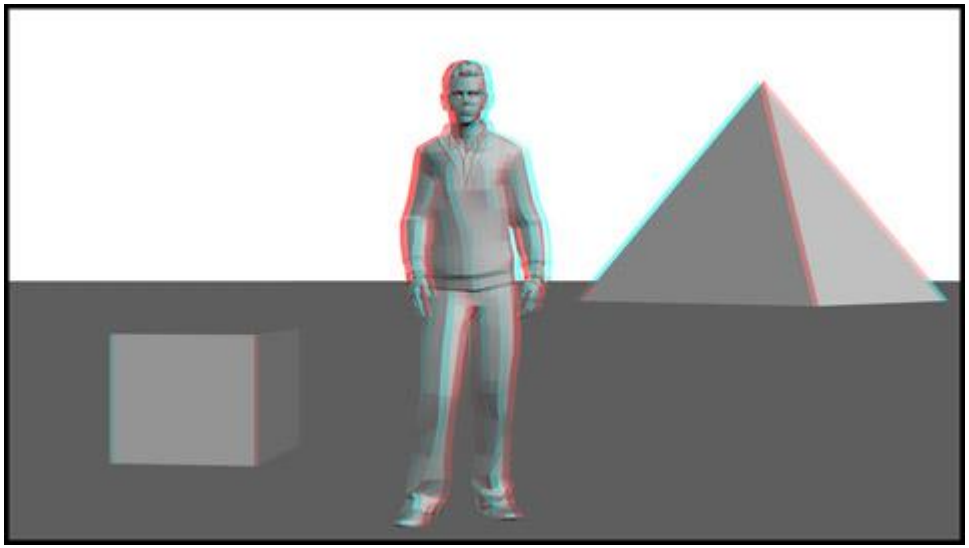




Convergence

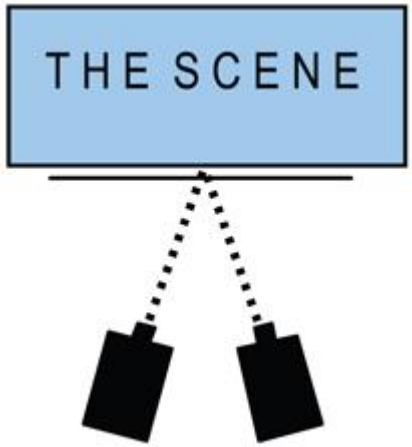
Converging in the middle of the scene places it half way in front of the screen plane.





Convergence

Converging in front of the scene will place it entirely behind the screen plane.



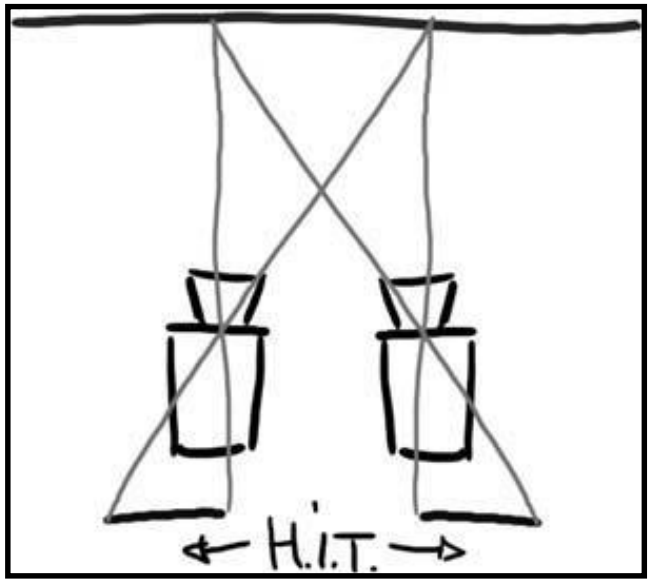
Post Convergence

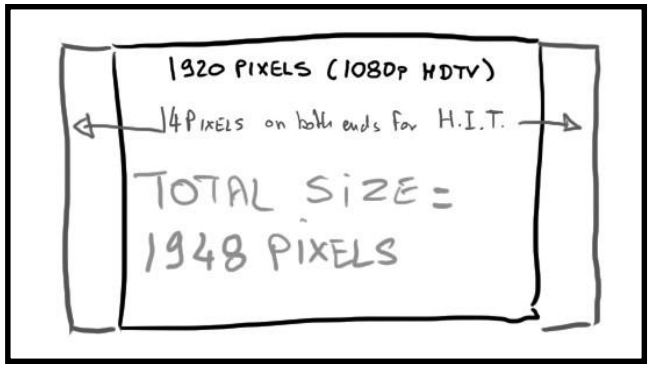
- **Reseting the depth position of a scene by shifting images**

- **Also called H.I.T.**
  - Horizontal image translation
  - Affects zero parallel setting (ZPS)

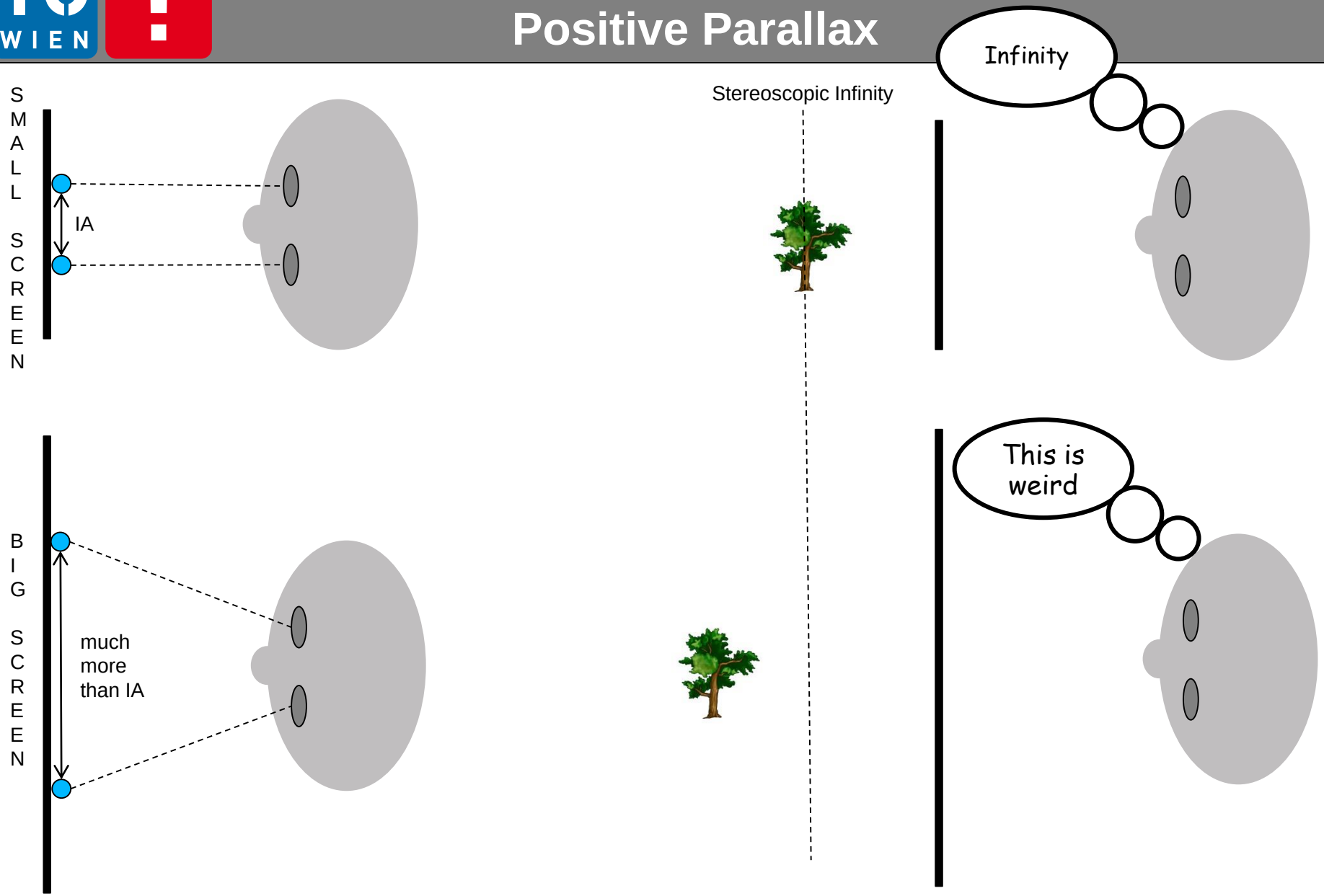
- **Generates no keystone**
  - Parallel camera configuration is adviced
  - Convergence in post-production

- **Requires overshooting**
  - Otherwise the image is zoomed and cropped

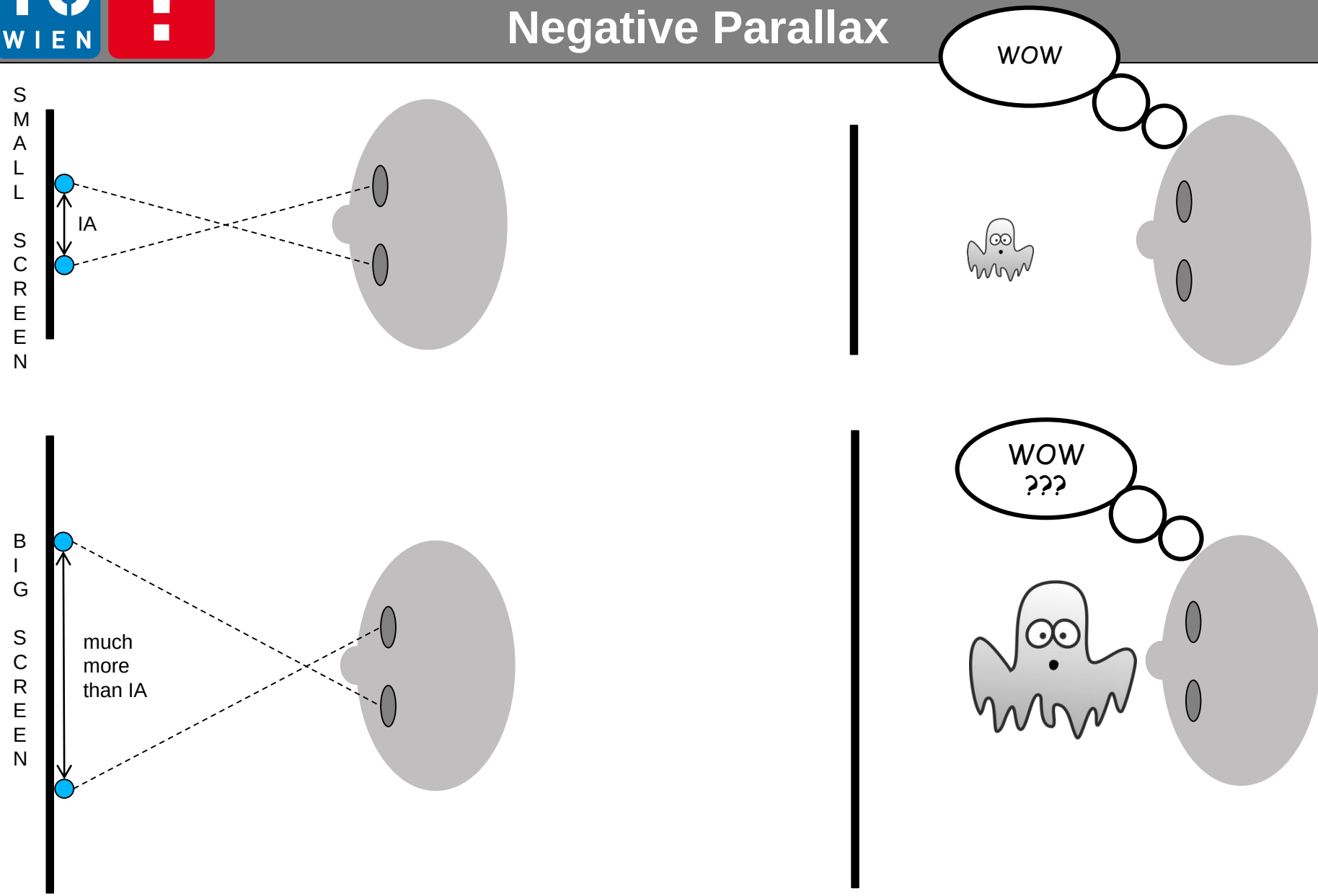




Screen Size Effect on 3D – Positive Parallax



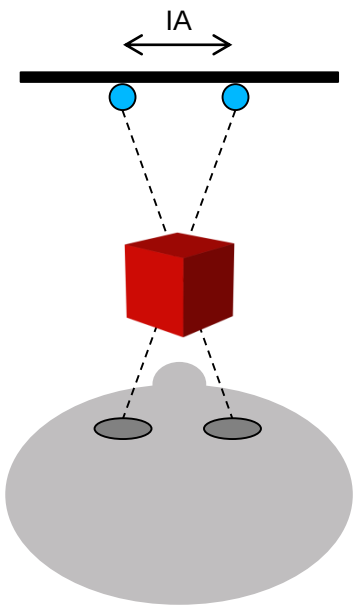
Screen Size Effect on 3D – Negative Parallax

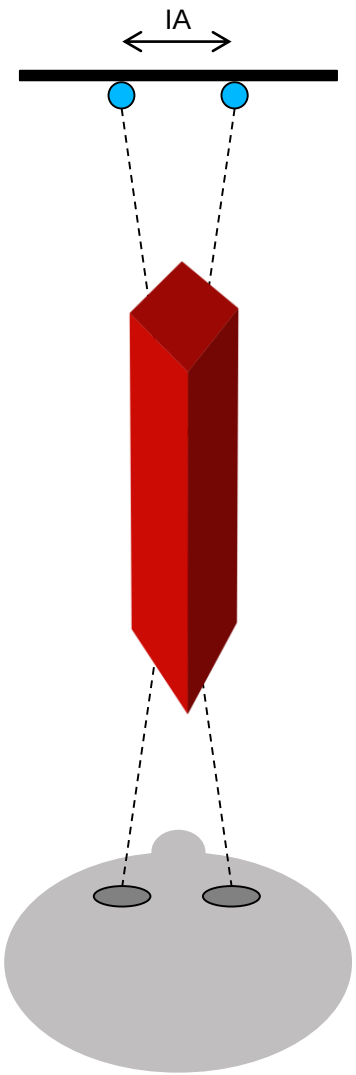


Screen Size Effect on 3D

- **The depth of a 3D picture increases with its 2D size**
- **Risk of diverging parallax on large screens**
- **Always visually check your 3D on a full-size screen**

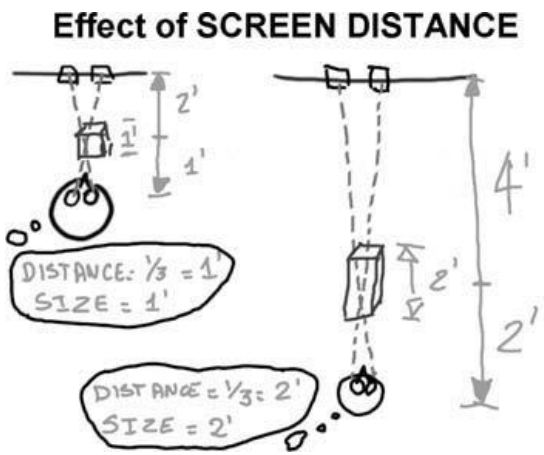
Seating Position Effects on 3D

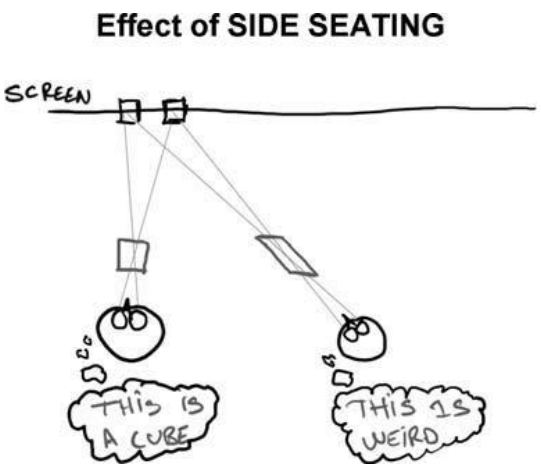




Seating Position Effects on 3D

- **Effects of seating position**
  - Sitting closer decreases the 3D effect of out-of-screen objects
  - Sitting farther away increases the 3D effect of out-of-screen objects
  - Sitting on the side leads to deformations of the shapes

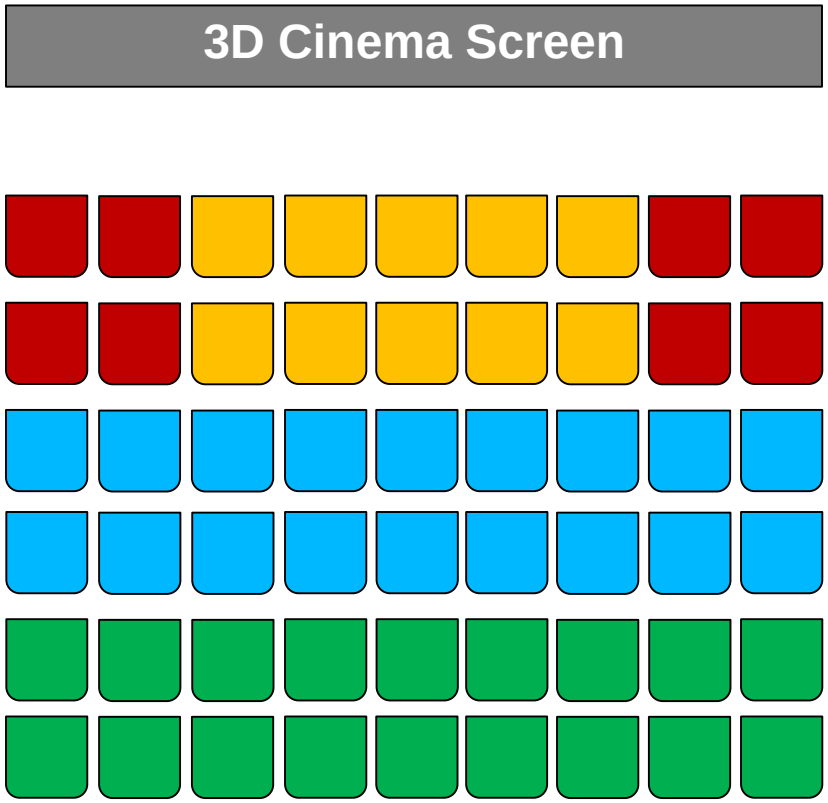




- **Depth of out-of-screen objects increases with the distance to the screen, but only along the Z axis**

Best Seats Inside The Theater

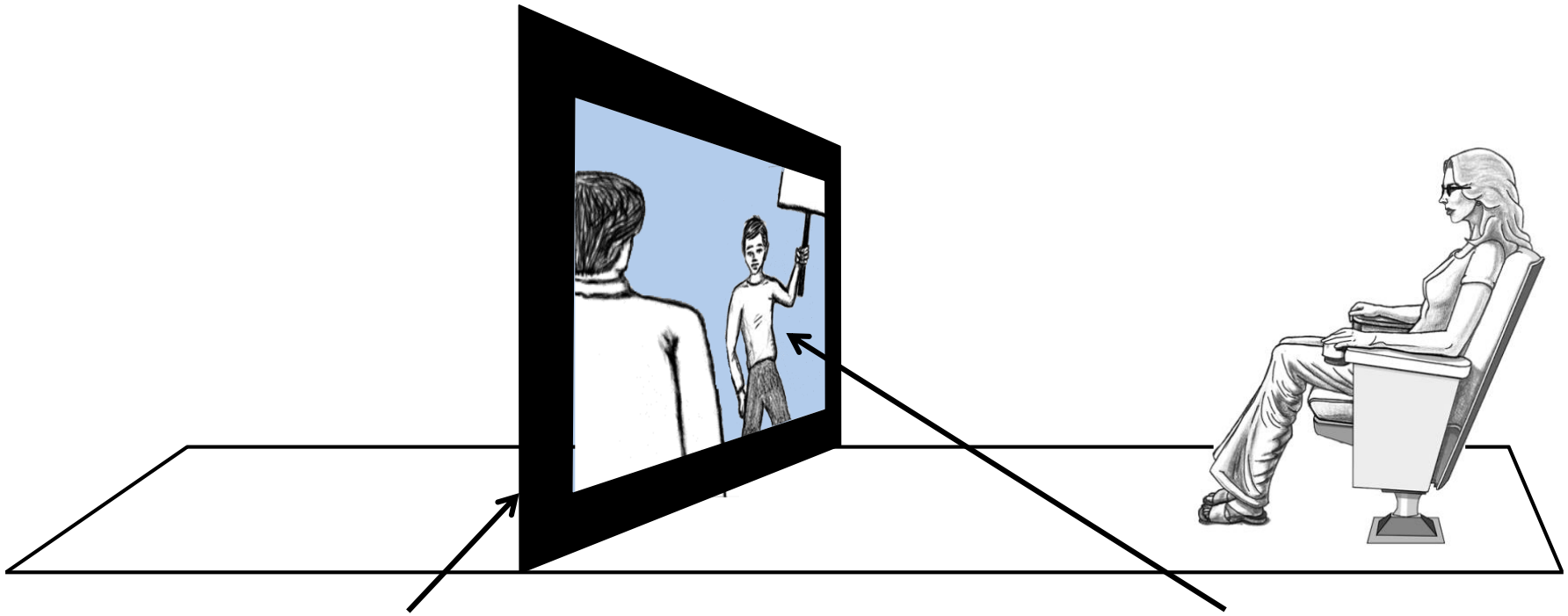
- **Green seats**
  - Most comfortable 3D experience
  - Last rows
- **Yellow seats**
  - Most intense 3D experience
  - Front rows
- **Red seats**
  - Weird 3D experience
  - Far-side seats in the first third
- **Blue seats**
  - “Normal“ 3D experience
  - Remaining seats



5

- **The 3D screen is a window**
- **A 3D object has a volume**
- **A 3D object has a size**

2D Screen



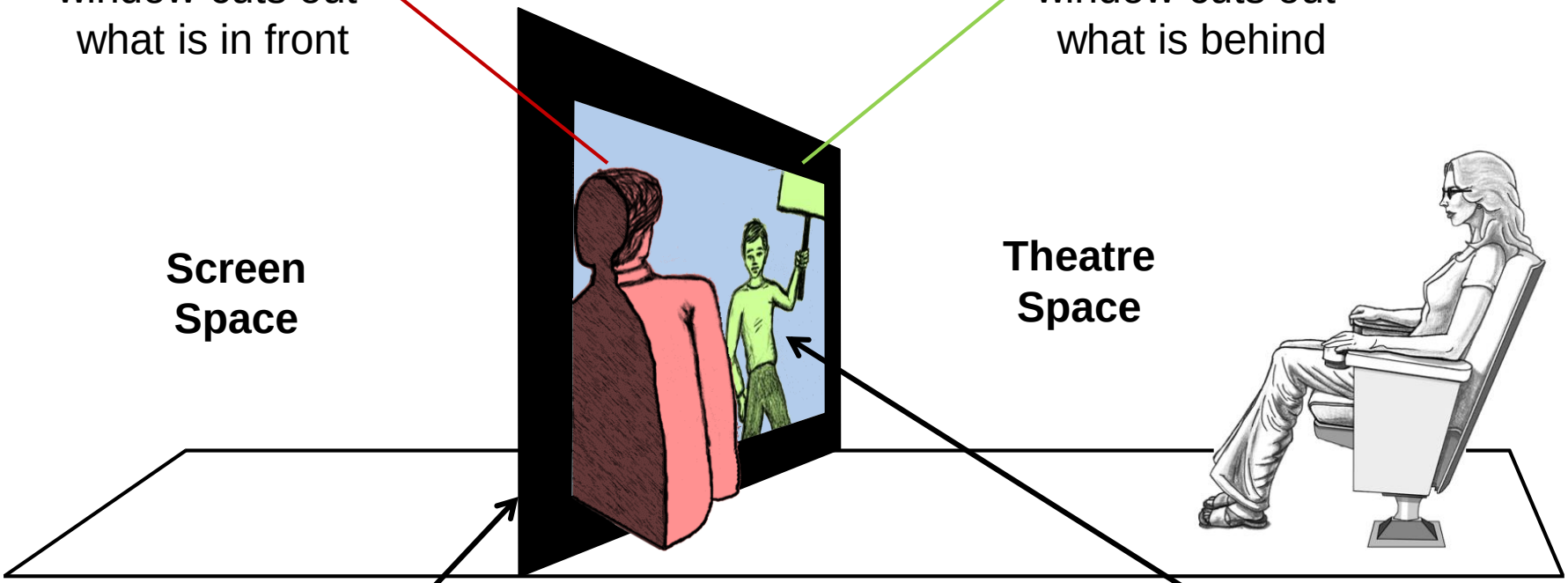
Proscenium:
Black border of screen
which appears to be a static flat plane in 2D

Screen image

3D Screen

not natural:
window cuts out
what is in front

natural:
window cuts out
what is behind



Screen Space

Theatre Space

Proscenium:
Black border of screen
which appears to be a rectangular hole in
3D (like a window)

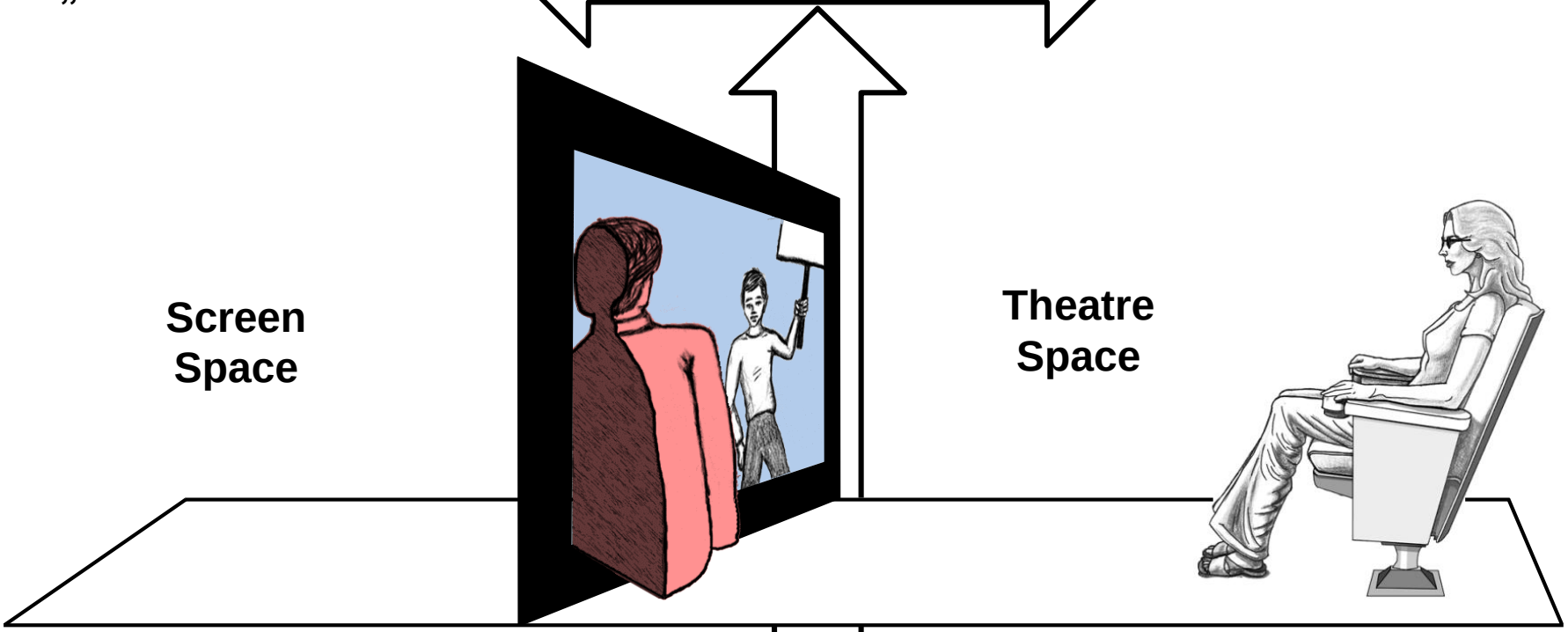
Screen image

Stereoscopic Window Violation

occlusion depth suggests „behind the screen“

visual dilemma

parallax suggests “in front of the screen“



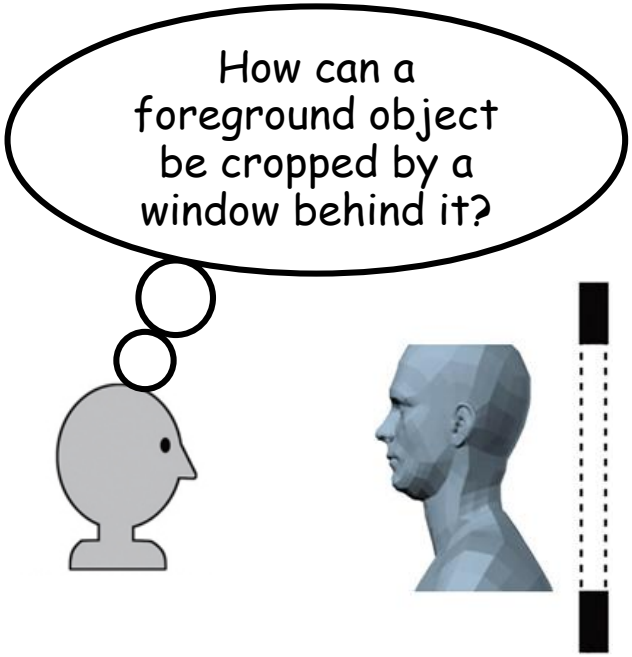
mild violation:
occlusion supersedes parallax

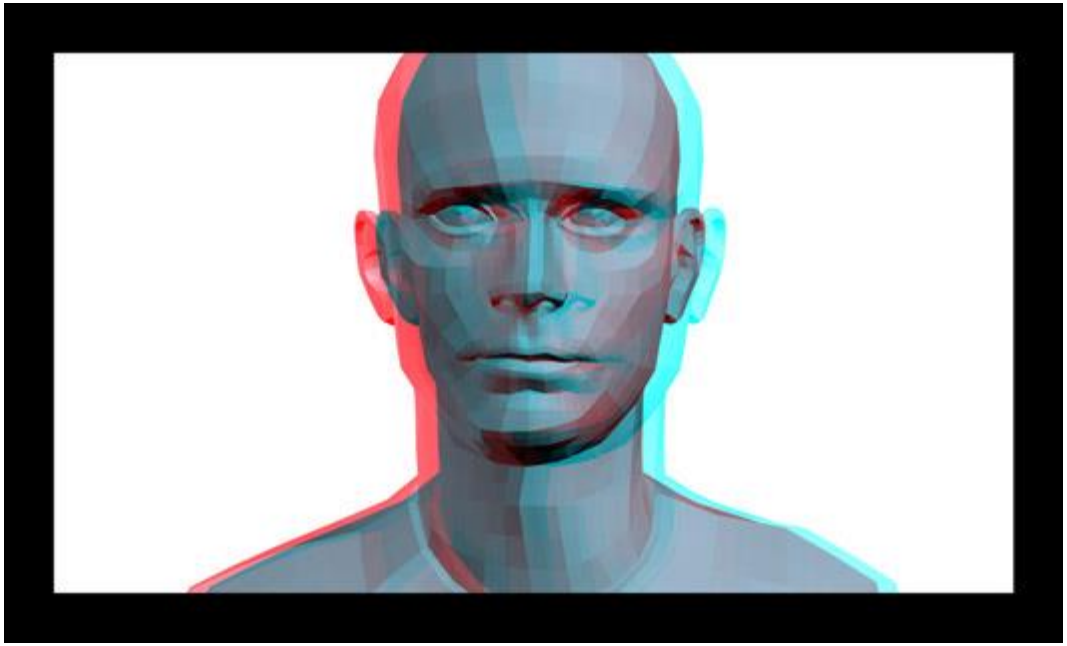
2 possible outcomes

strong violation:
stereopsis is impossible

Horizontal violation:

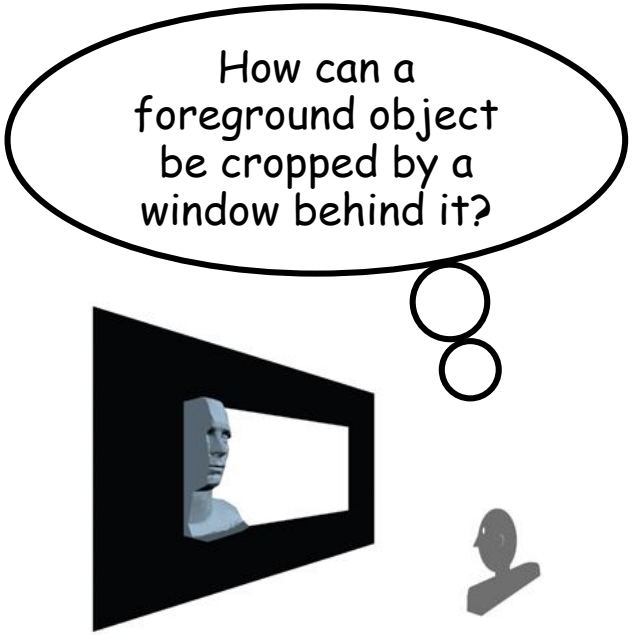
Occurs when an object in front of the window is cut-off or cropped by the horizontal upper or lower frame of the window





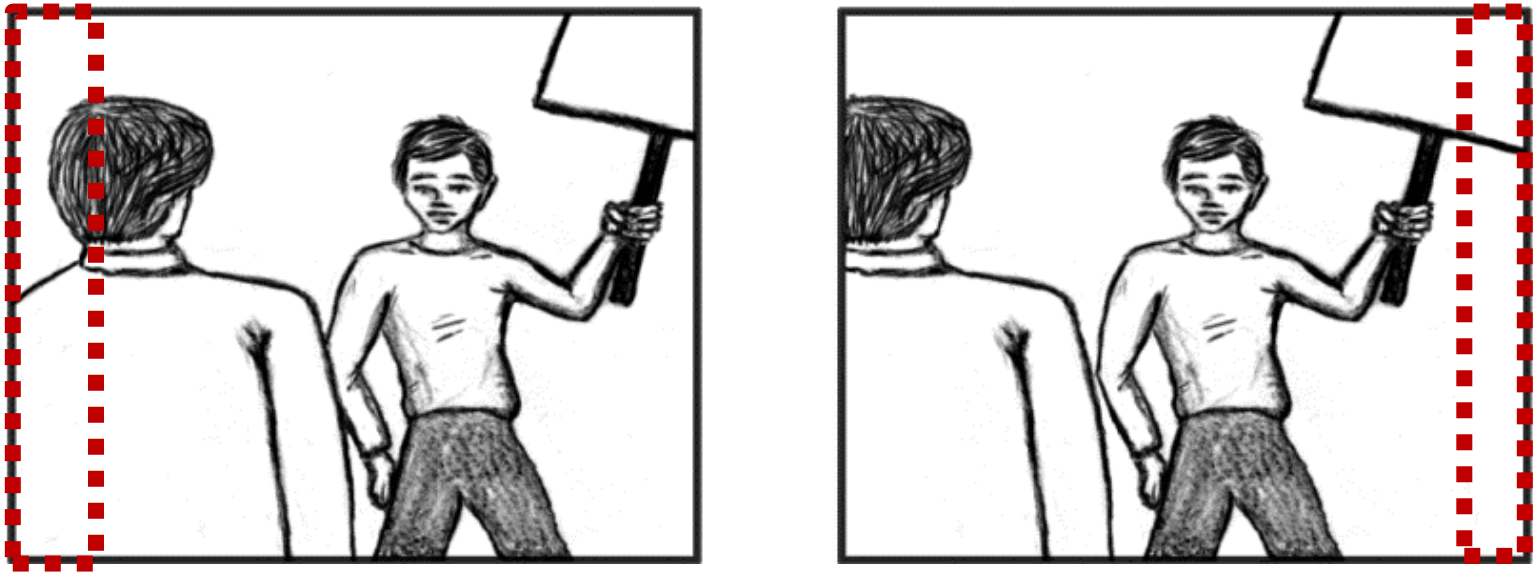
Vertical violation:

Occurs when the vertical sides of a background window crop a foreground object



Retinal rivalry: One eye sees what the other eye cannot see

Stereoscopic pair with retinal rivalry



Left view

Right view

Stereoscopic Window Violation

Retinal rivalry: One eye sees what the other eye cannot see

Stereoscopic Window Violation

Problem of stereoscopic window violations:
Major impact on 3D movie making as these violations limit 3D cinematography

Example 1:
In close ups there is a tendency to cut out top parts of heads => plague in 3D

Example 2:
In over the shoulder shots listener's silhouette is almost always breaking the window

Problem of stereoscopic window violations:

Major im atography

In close listener's
cut out breaking
plague

Challenge:

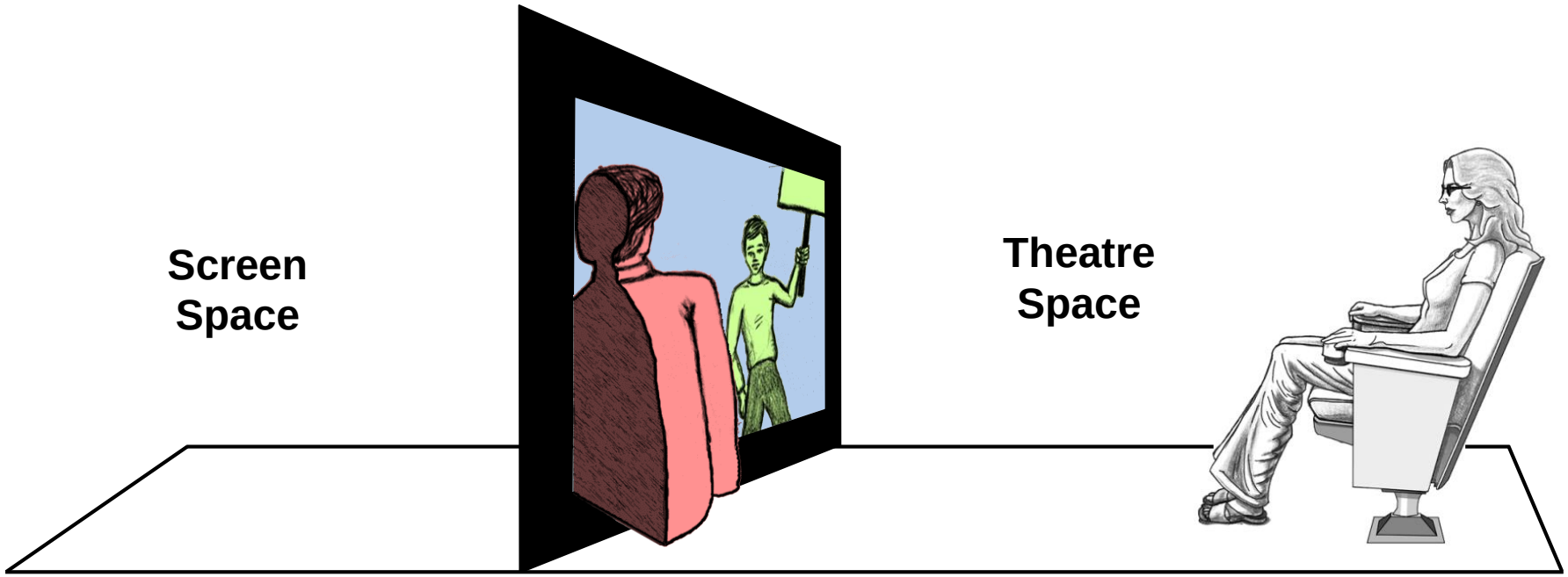
Scenes, actors, and actions want to fly and occupy the space

Tools needed to handle stereoscopic window violations

Handling Stereoscopic Window Violations

Solution 1:

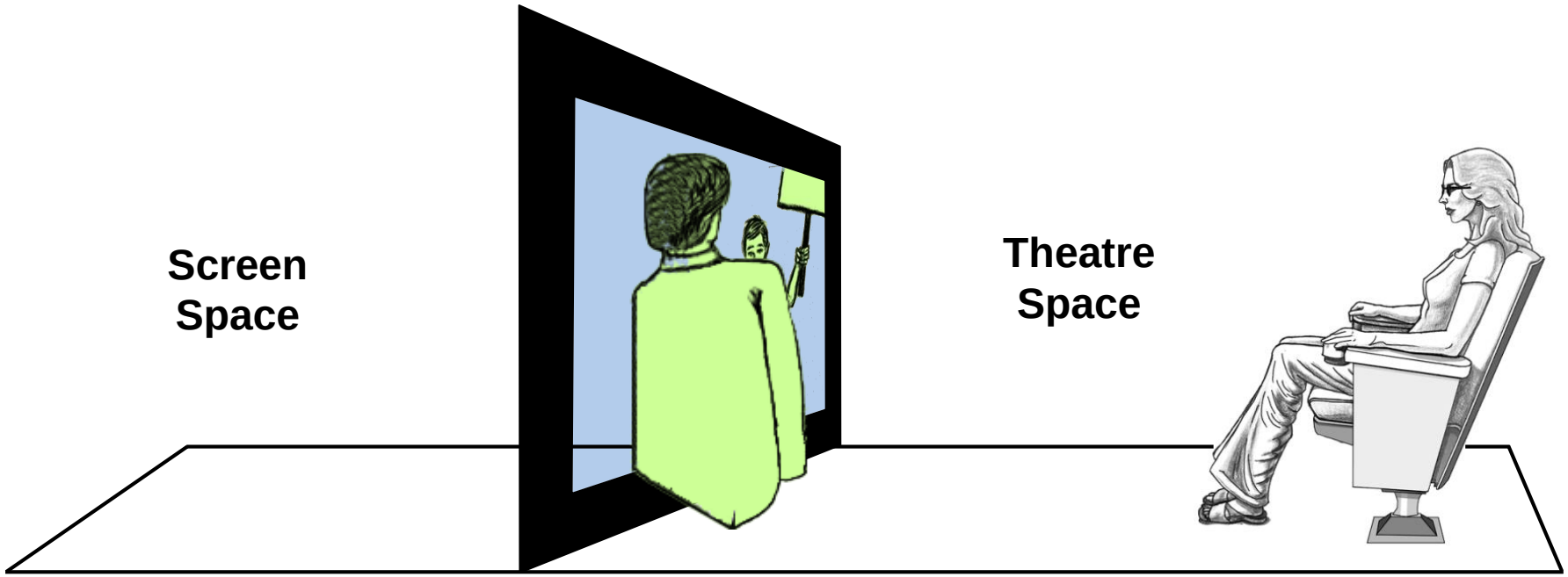
Recompose the shot by removing the problem object at frame boundary



Handling Stereoscopic Window Violations

Solution 1:

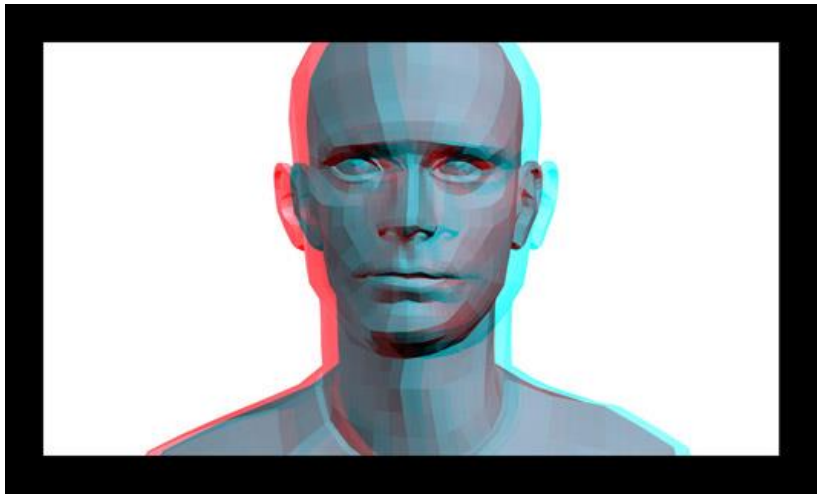
Recompose the shot by removing the problem object at frame boundary



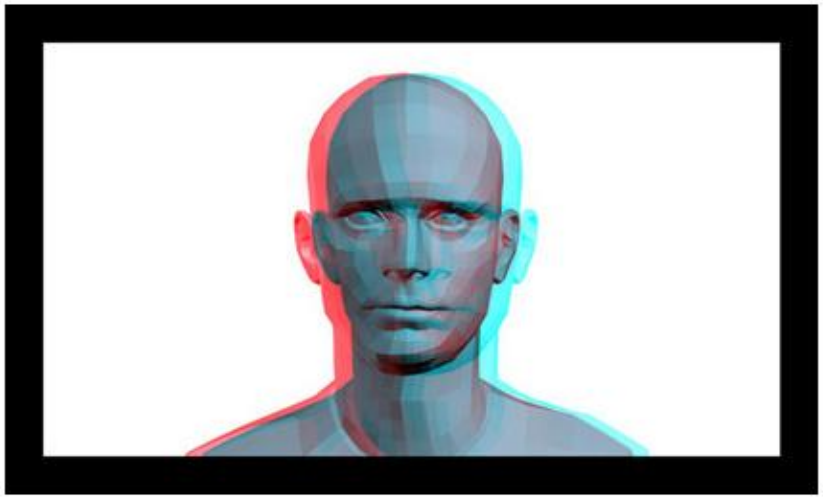
Handling Stereoscopic Window Violations

Solution 1:
Recompose the shot by removing the problem object at frame boundary

Original shot:
strong violation (top & bottom)



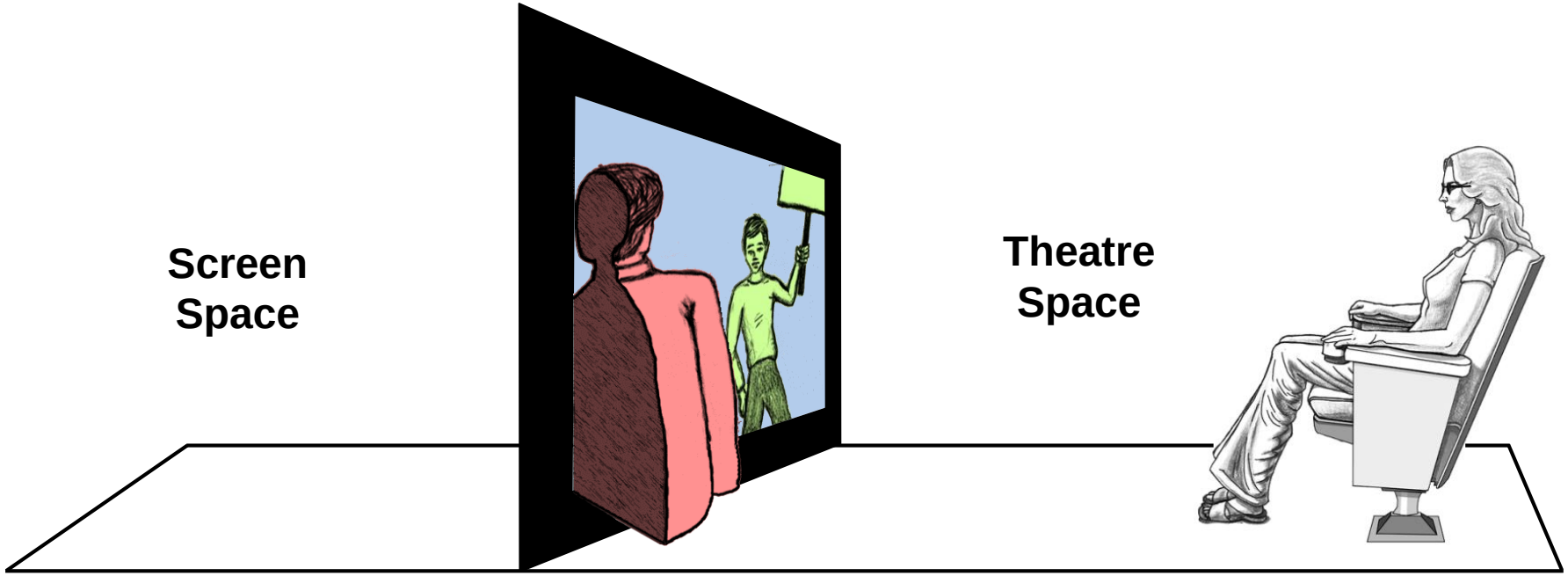
Recomposed shot:
minimal violation (bottom only)



Handling Stereoscopic Window Violations

Solution 2:

Change convergence point (e.g., apply HIT) such that all objects have positive parallax



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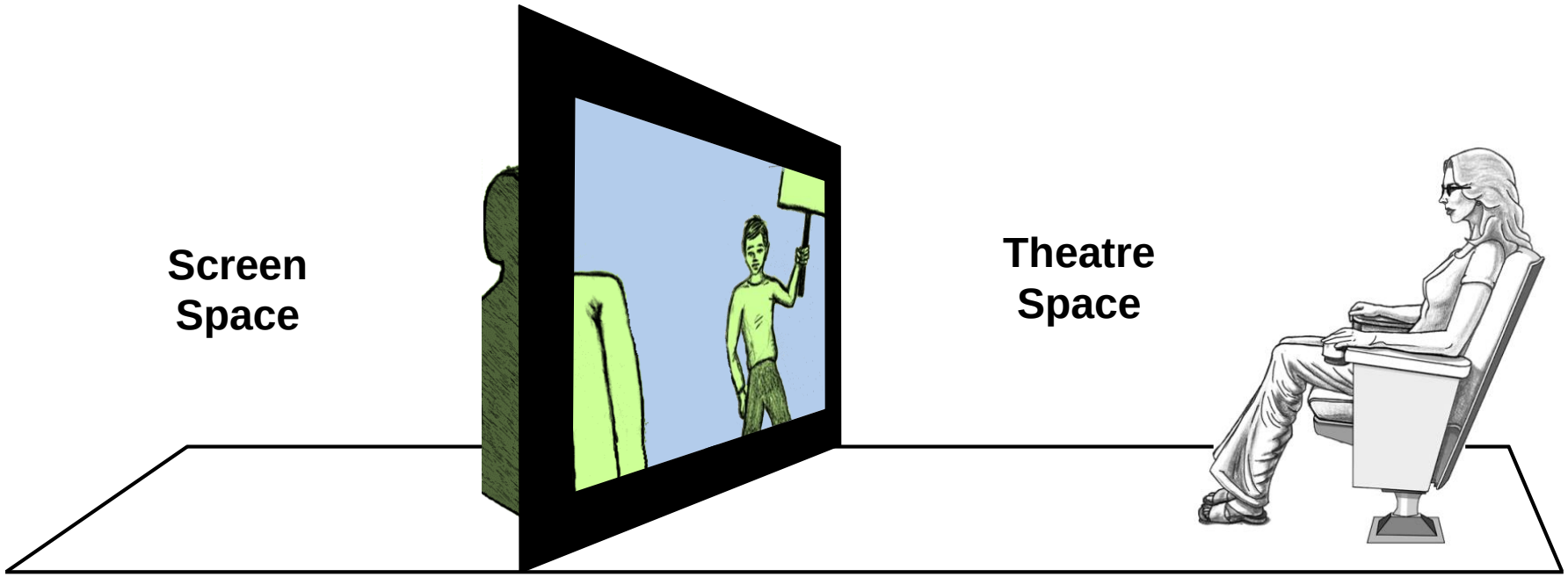
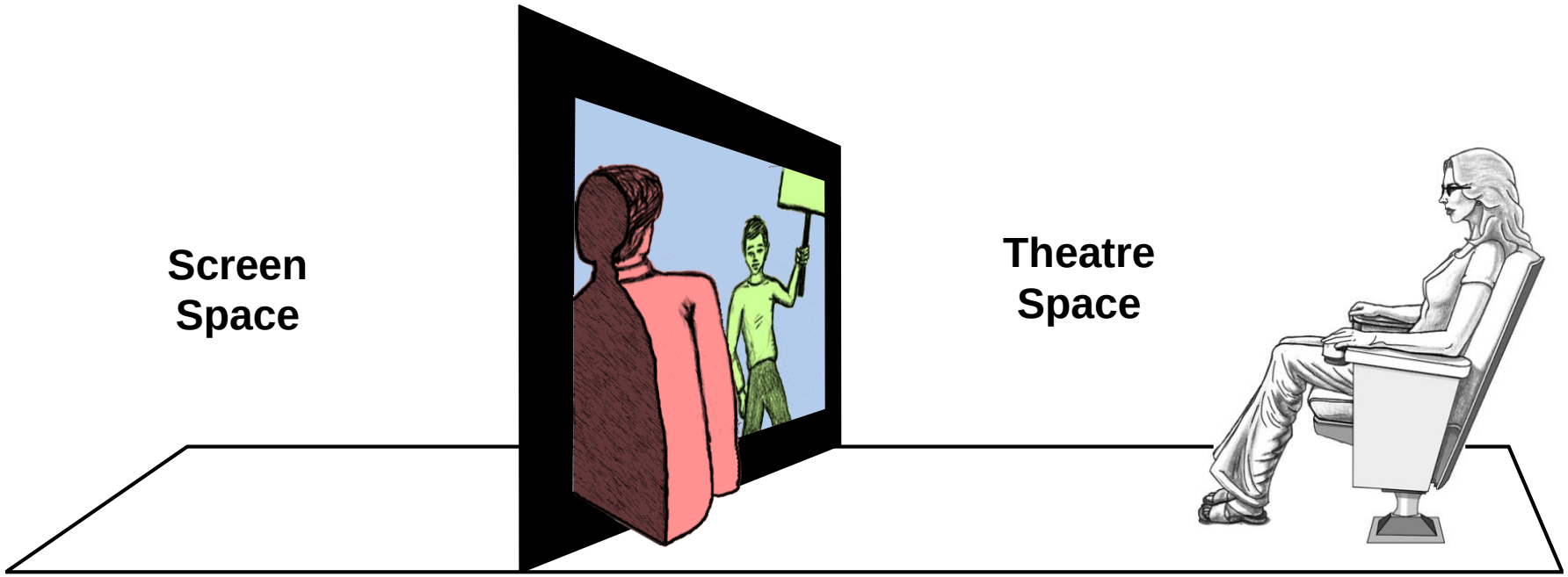


Handling Stereoscopic Window Violations

Solution 3:
Apply selective focus/vignette



Handling Stereoscopic Window Violations

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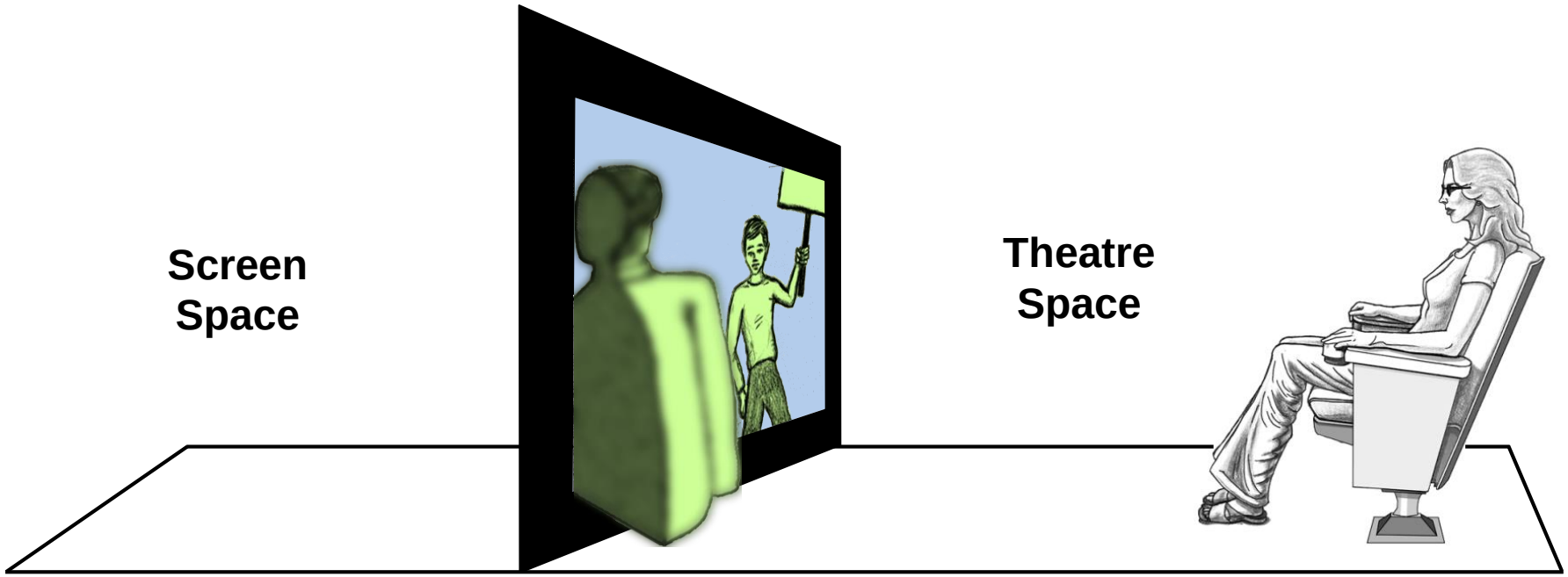
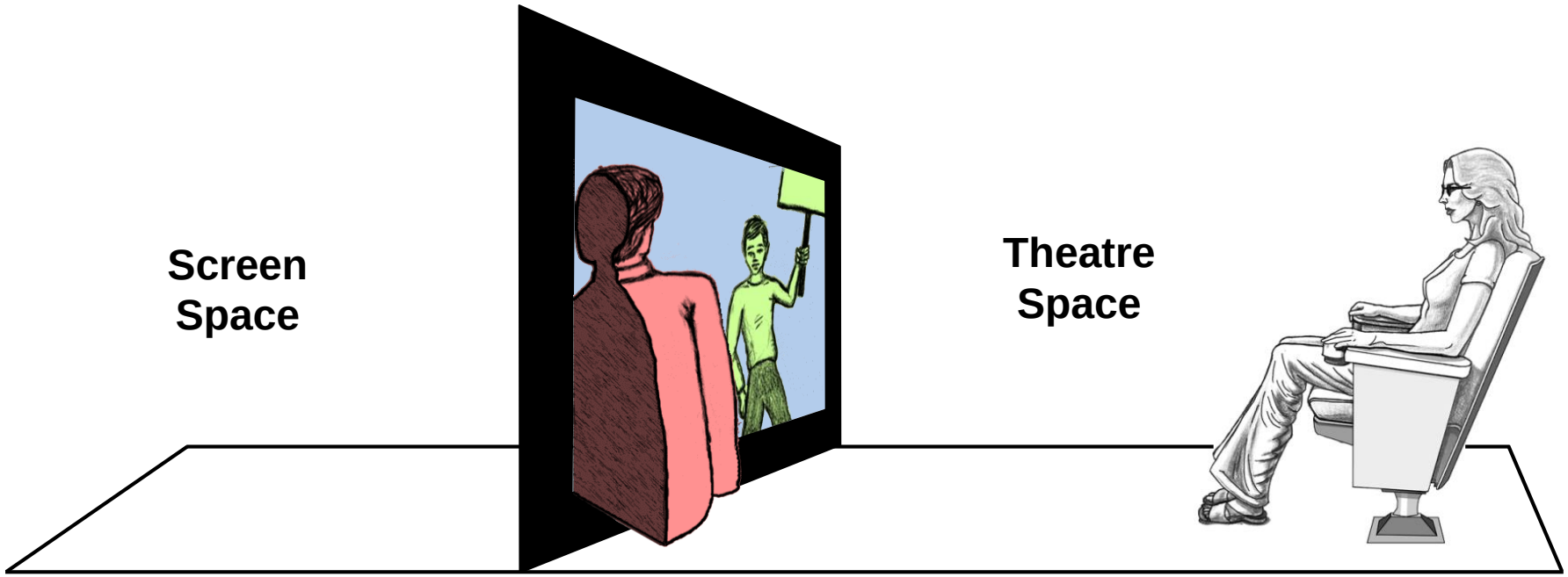


Handling Stereoscopic Window Violations

Solution 4:
Float the (stereoscopic) window



Handling Stereoscopic Window Violations

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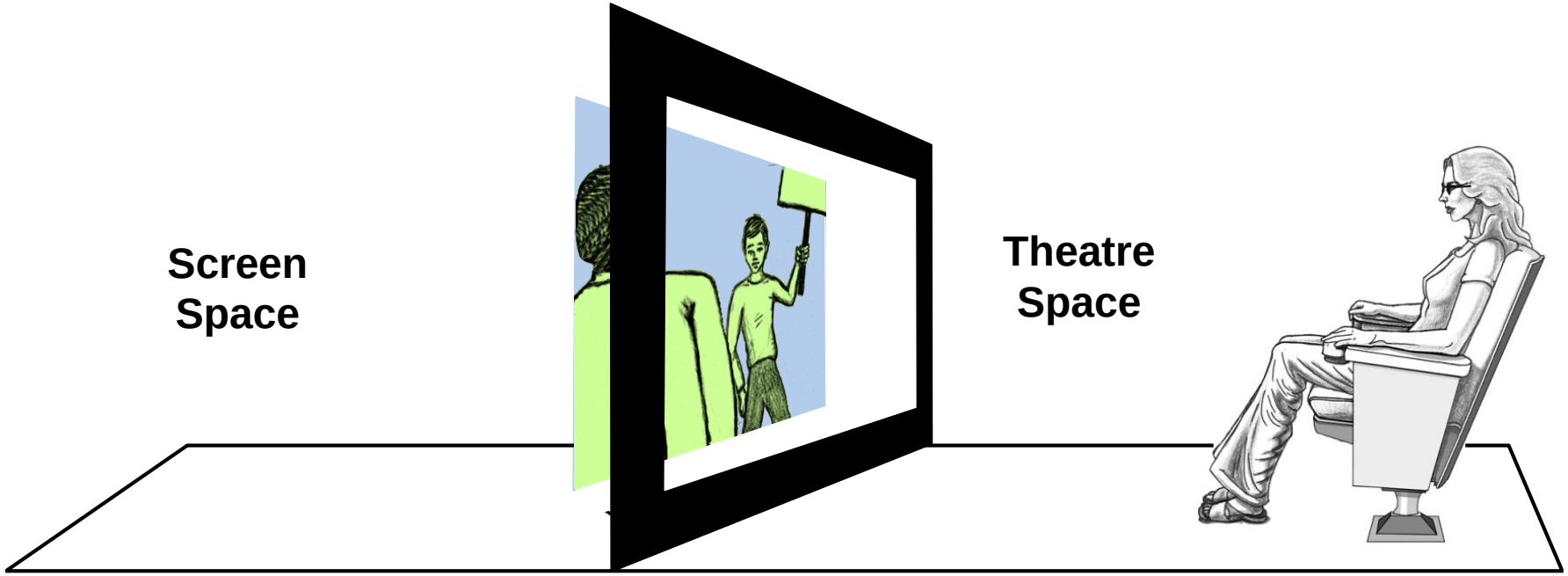
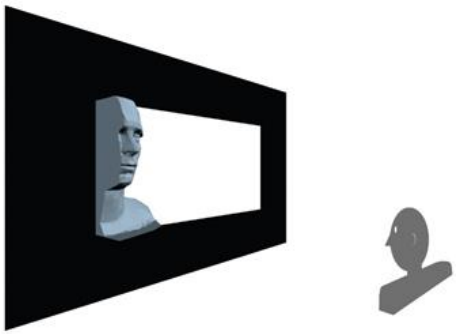
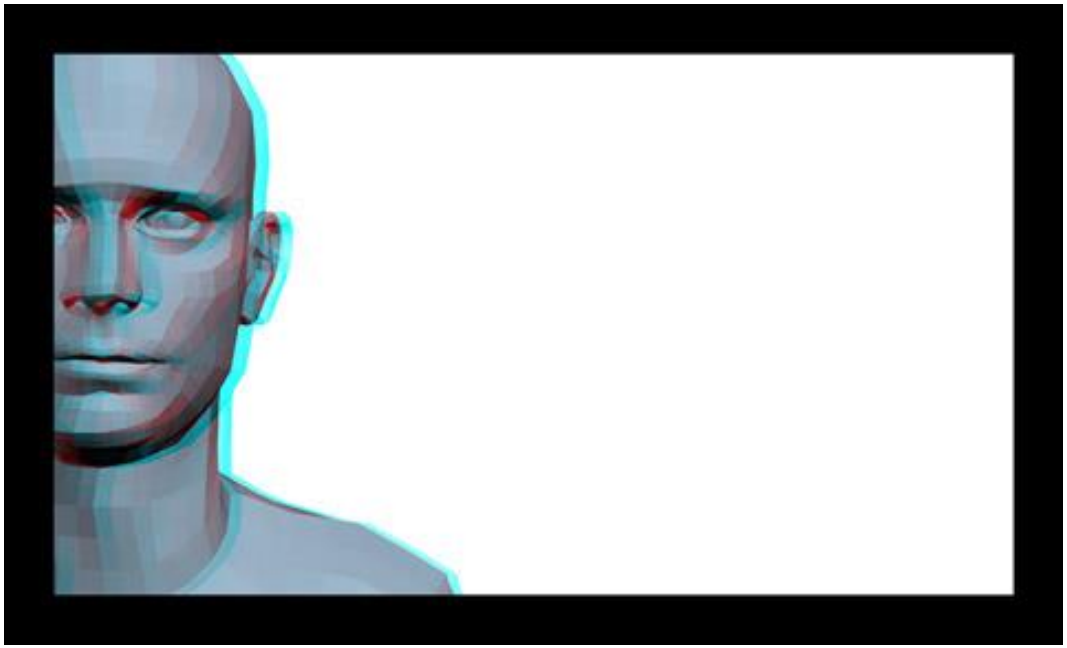


Floating Window

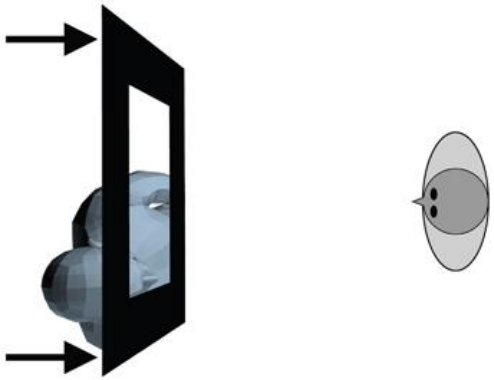
Question:
How can we float the window to correct window violations?

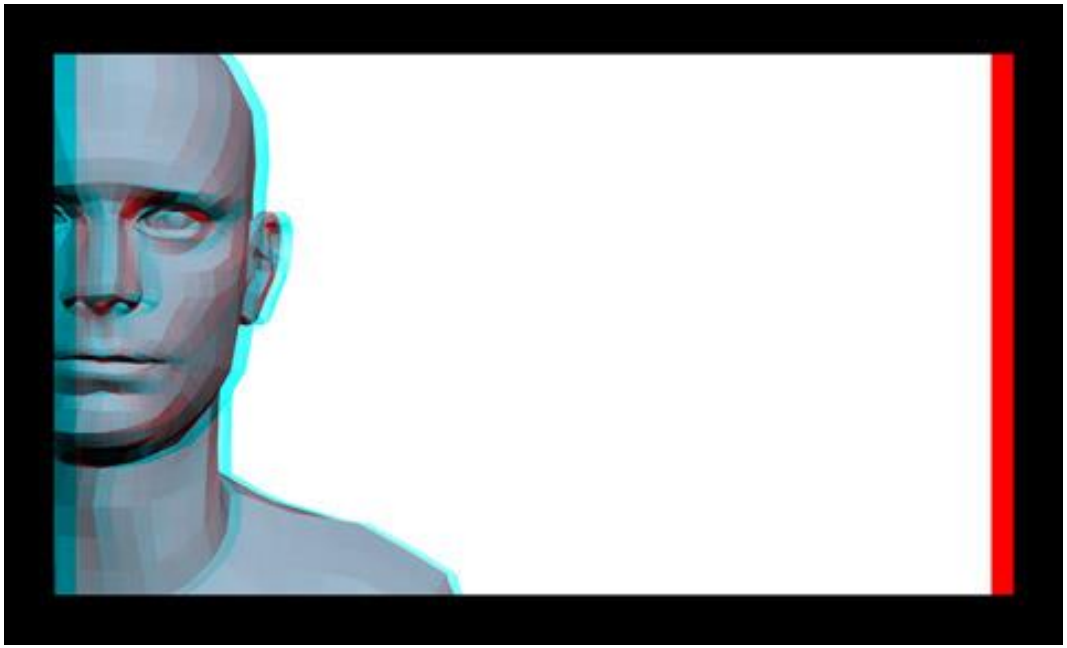




Solution 1:

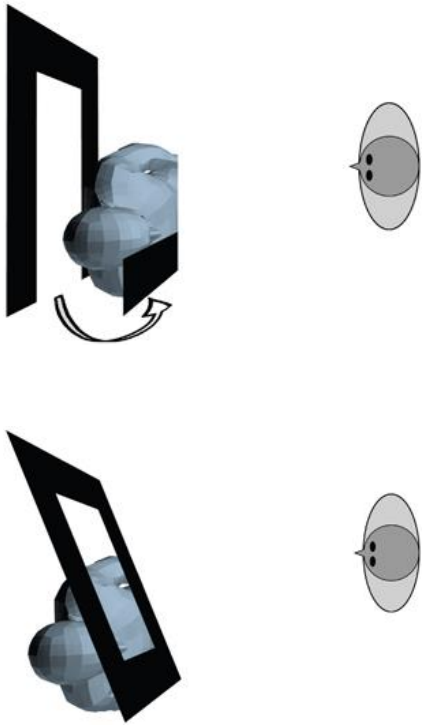
Move the entire window by masking the side of the left and right eyes' view

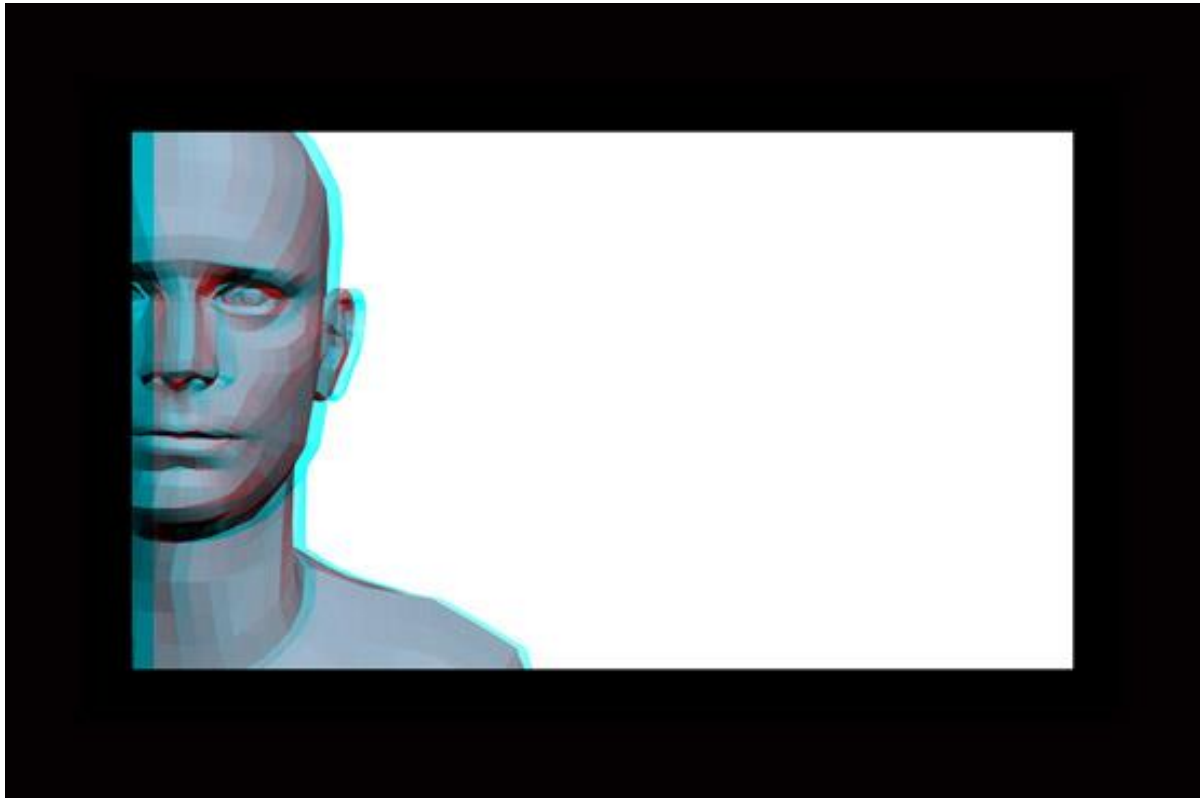




Solution 2:

Move part of the window by masking either the left or the right eye view



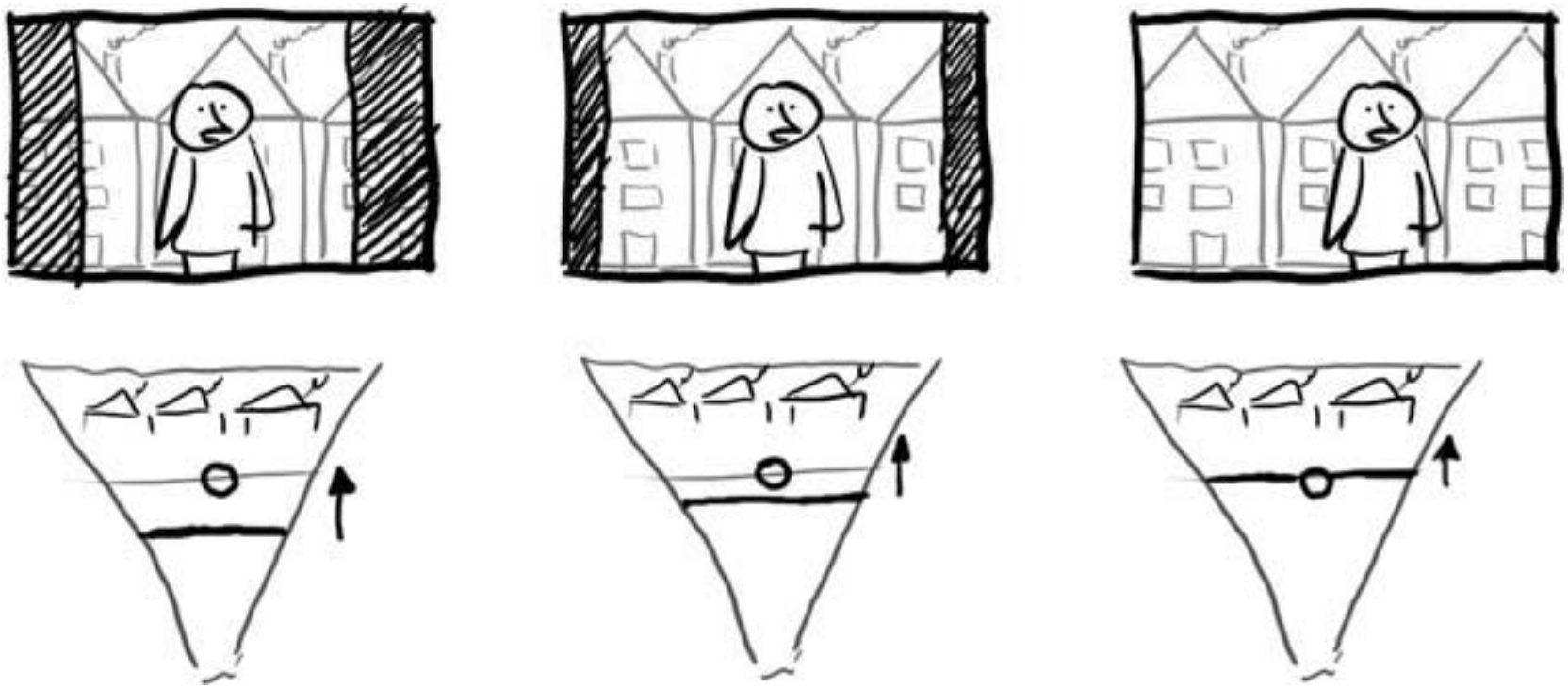


Example 1:

Move the screen to follow the action (remains unnoticed even across cuts)

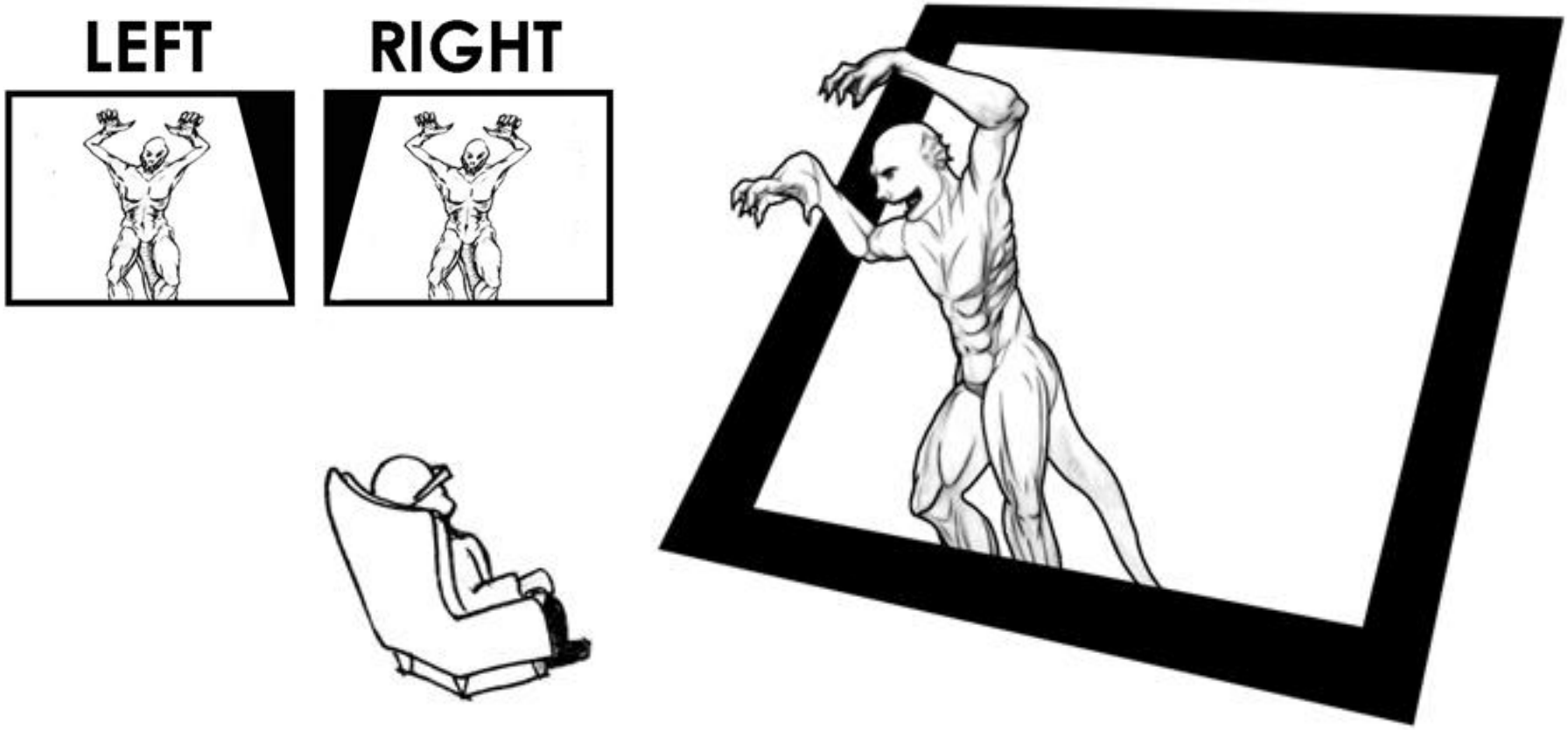
Example 2:

Move the audience against the action (can be used to generate camera motion)

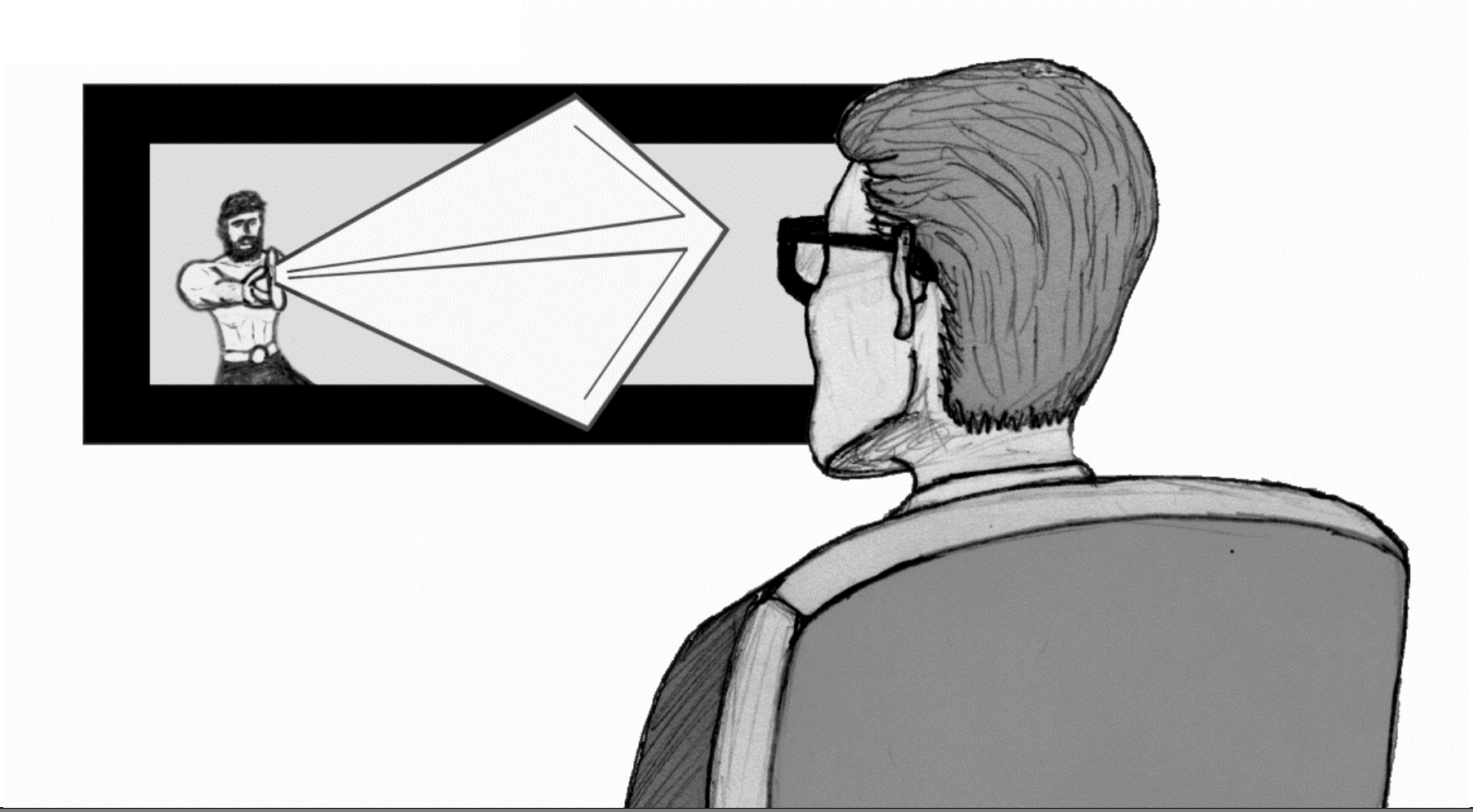


Example 3:

Add “impending danger“ feeling by angling the boarder masks of the dynamic floating window



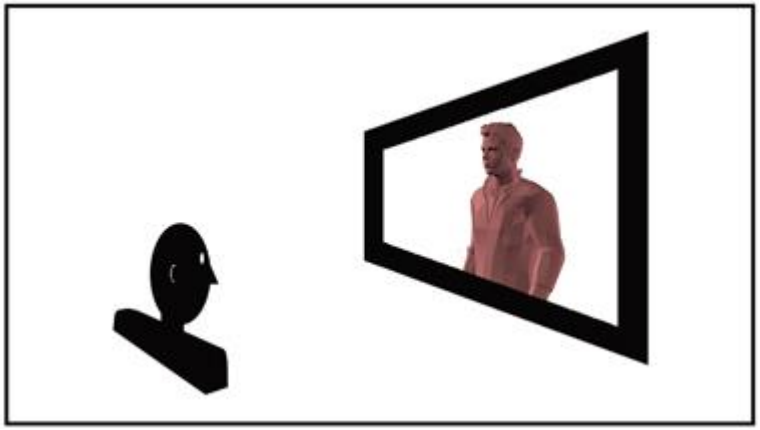
Example 4:
Object is composited over dynamic floating window



2D Screen vs 3D Window

2D

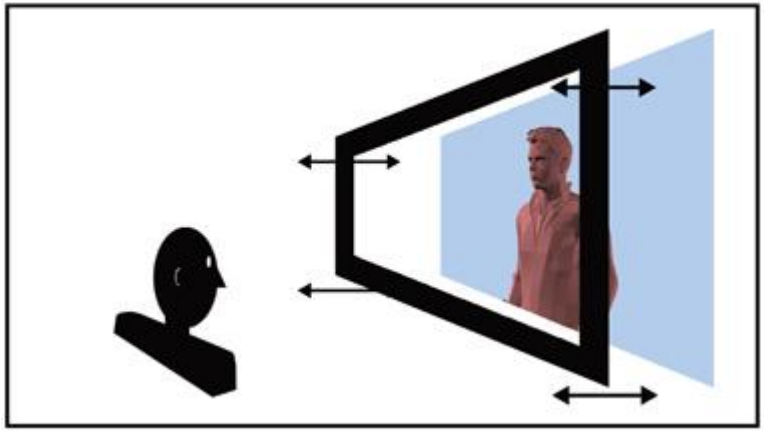
- The screen is a plane
- A frame (e.g., black curtains in cinema, plastic case on TV) surrounds every screen
- The screen and the frame share the same flat surface



vs

3D

- The screen is a window
- The window is an optical mask and defines a “screen space” and a “theatre space”
- The window does not have to share the screen surface but can move forwards, backwards or tilt)



Window Violations and Floating Windows

Two distinct types of perceptual conflicts caused by window violations:

Occlusion vs. Stereopsis

Retinal Rivalry

Need for solution that meets four criteria:

1. Remove occlusion vs. stereopsis conflicts
2. Minimize retinal rivalry artifacts
3. Must be invisible to the audience
4. Must be controllable by the filmmakers

Static floating window:

Tackles only the first need by moving the proscenium to the maximum negative parallax (furthest position into the theater) that would account for all possible window violations.

Dynamic floating window:

Tackles all four needs by controlling the position, shape, and orientation of the proscenium through manipulation of the image border mask.

DEMO

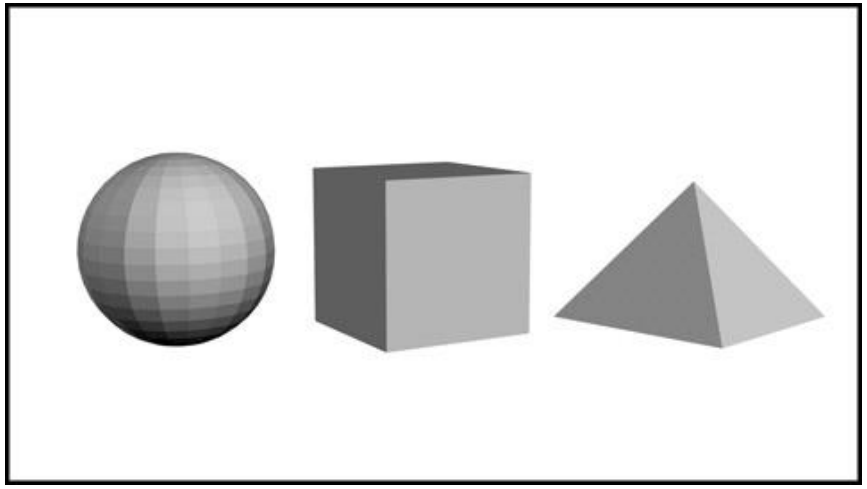
“Stereo 3D Tutorial: The Over The Shoulder Shot”

https://www.youtube.com/watch?feature=player_embedded&v=I71i8anneP8

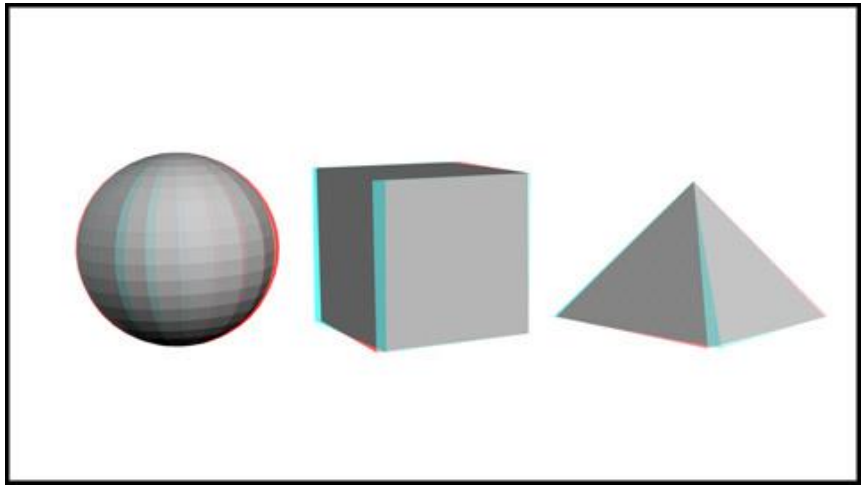
The 3D Volume Effect

A 3D object has a volume. Changing the IA will affect the volume of objects. A small IA reduces volume and a large IA increases volume.

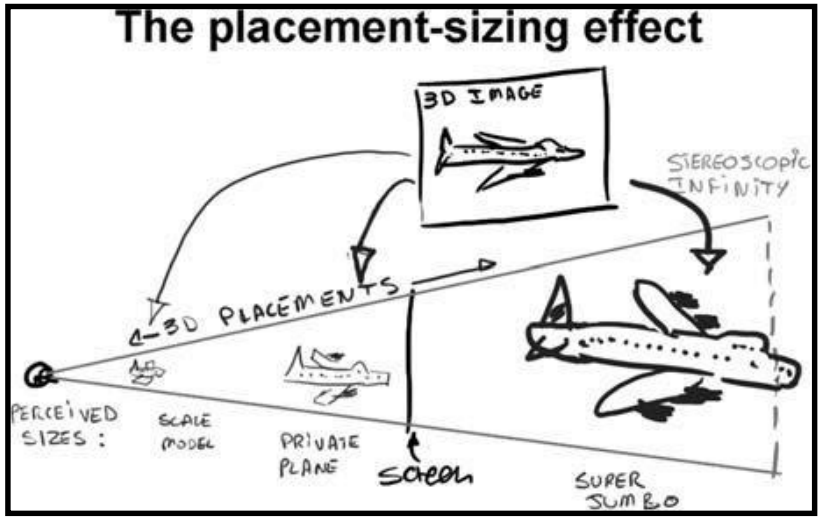
2D shot

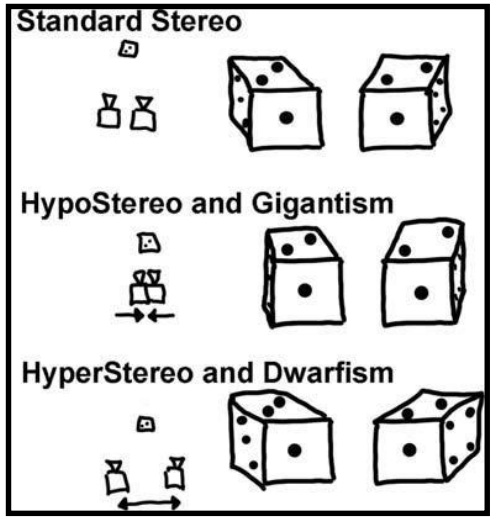


3D shot



New constraint:
2D image has a scale but 3D object has a size



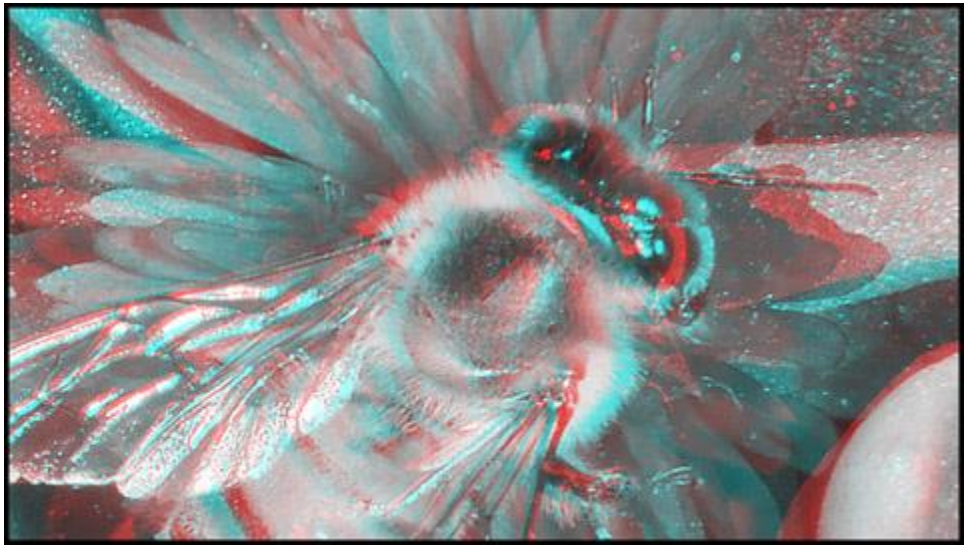


Reconverge 3D image with H.I.T.:
2D size does not change but 3D object size changes from jumbo jet (stereoscopic infinity) to scale model (theater space)

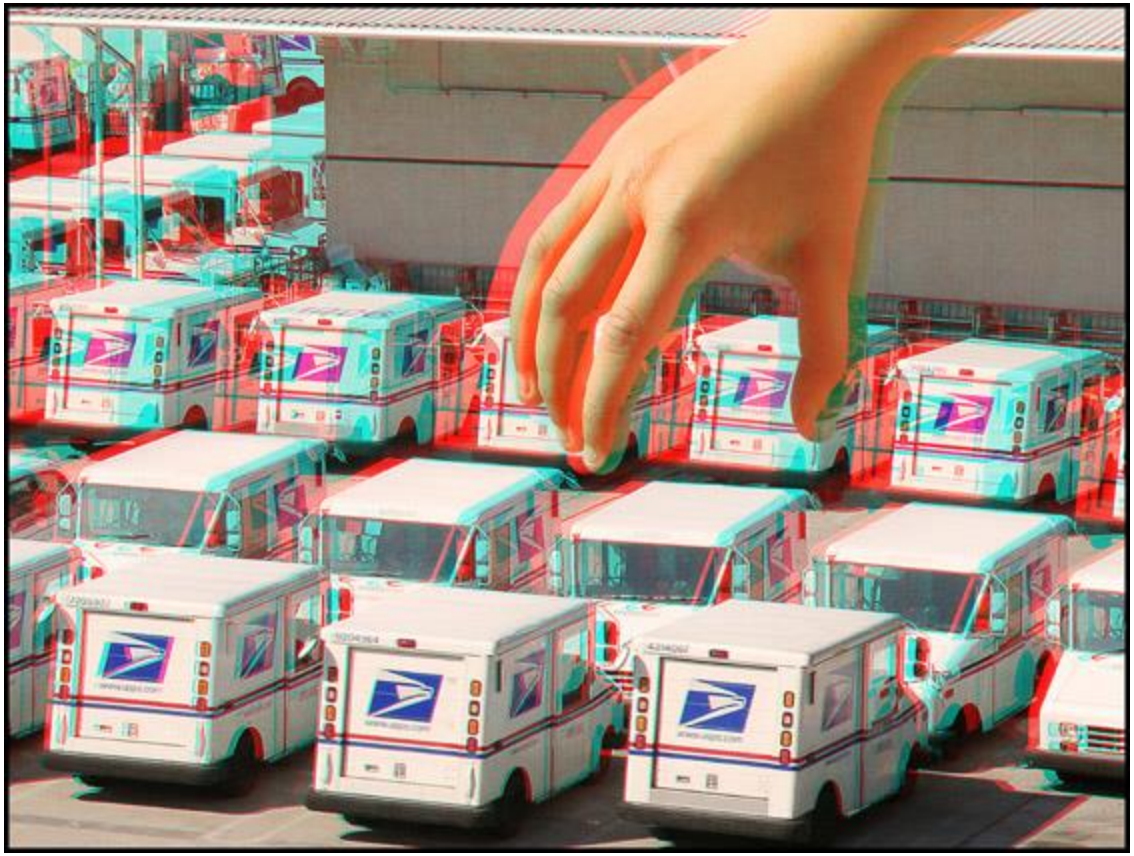
Hypostereo (audience shrinks):
IA less than IO

Hyperstereo (audience gigantism):
IA more than IO

The 3D Size Effect – Hypostereo Example



The 3D Size Effect – Hyperstereo Example

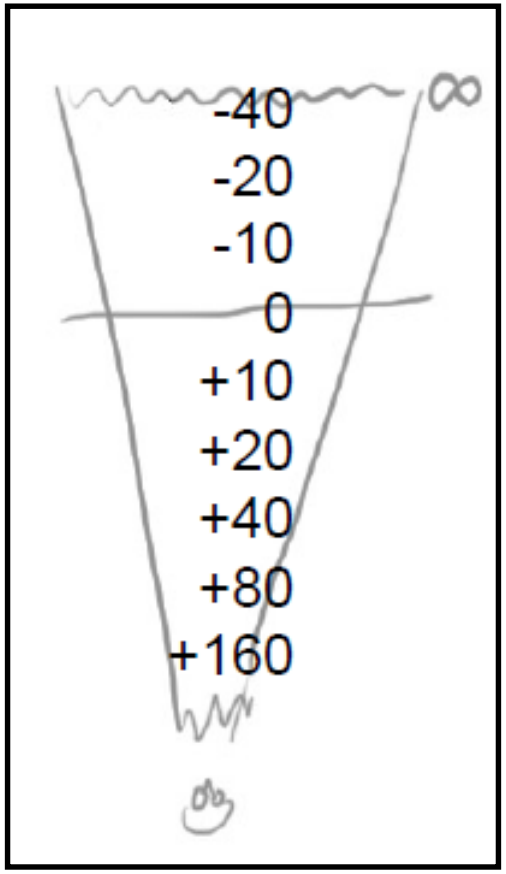


6

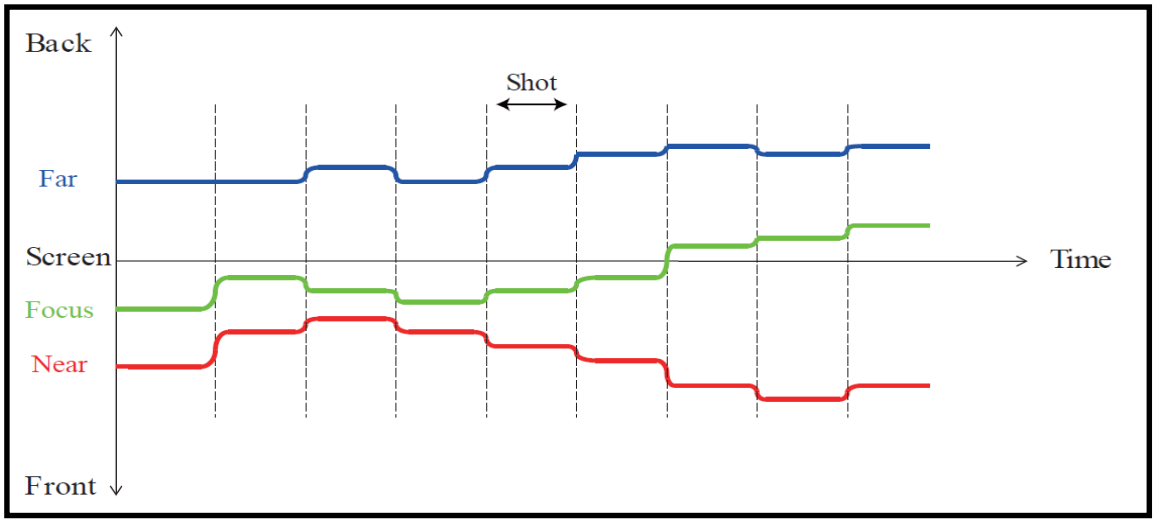
- **Deph budget, depth script, depth continuity**
- **3D story board**
- **Why go 3D**

Depth Budget

- **The amount of depth available to tell your story**
- **Counted in pixels**
- **Based on native pixel parallax (NPP)**
  - Maximum positive parallax
  - NPP = interocular distance/screen width * screen resolution
  - Can be extended
- **Depends on screen size**
- **Example:**
  - Interocular distance: 2.5 inch (65 mm)
  - Screen size: 30 foot (9144 mm)
  - Screen resolution: 2K (2048x1080 pixels)
  - NPP = (65 / 9144) * 2048 ≈ 14 pixels



Depth Script

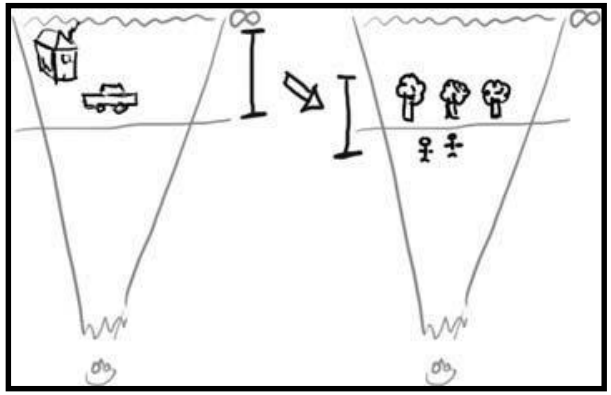


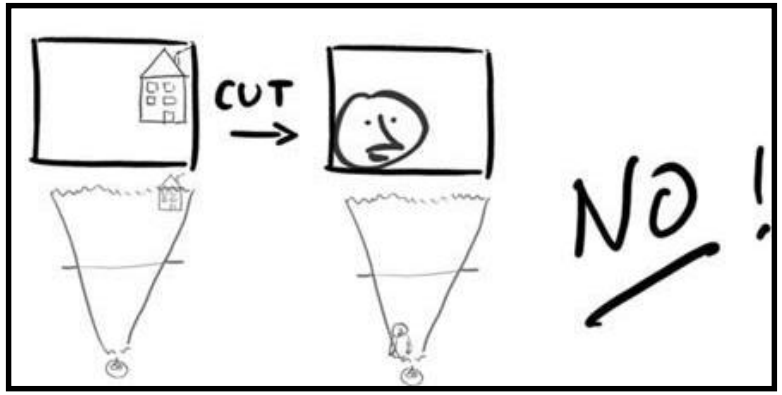
- **The modulation of the depth to tell your story**
- **Sets the sequences‘ depth budget (affects the ongoing story)**
- **Needed for visual comfort (alternate strong 3D, violent 3D and smooth 3D)**

Depth Continuity

Problem:

Depth brackes of in/out shots should overlap. If not, stereopsis is interrupted.





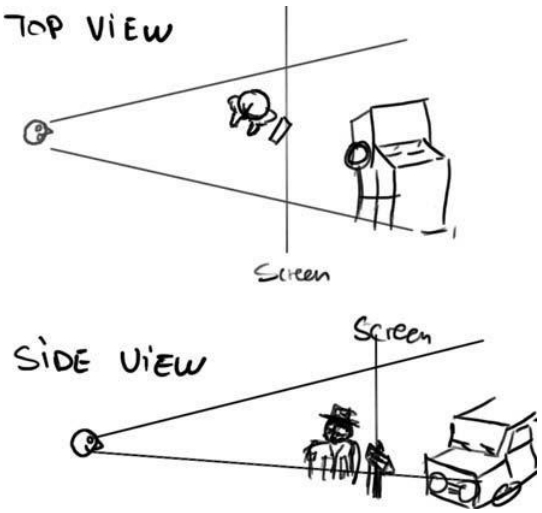
Solution:

Use active depth cuts, a technique to cut between two shots with different depth brackets. Basic steps:

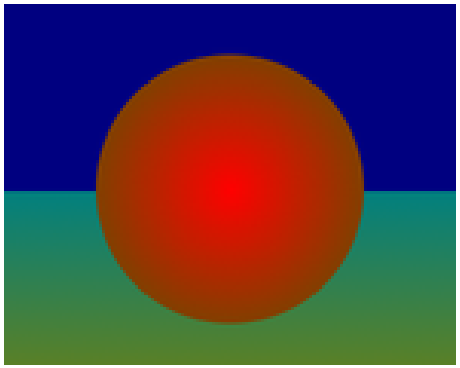
1. Re-converge out-shot to the screen
2. Cut to the in-shot, with focus point placed in same depth
3. Re-converge in-shot to its original depth

3D storyboard encodes visual and depth structure of the movie

Example 1:
Brush thickness code (thinner lines behind the screen, bolder lines in front of the screen)



Example 2:
Top/side view of the set (draw depth layouts of the scene)



Example 3:
Color encoding (cold-to-warm conventions)

Why go 3D?

- **Because it will serve your story**
  - Otherwise, you would better make a 2D movie
- **Because it will boost the box office**
  - Average 3x on per-screen revenue
- **REMEMBER:**
  - A 3D movie is NOT two 2D movies
  - Different shots, different type of storytelling
  - 3D develops new cinematography language

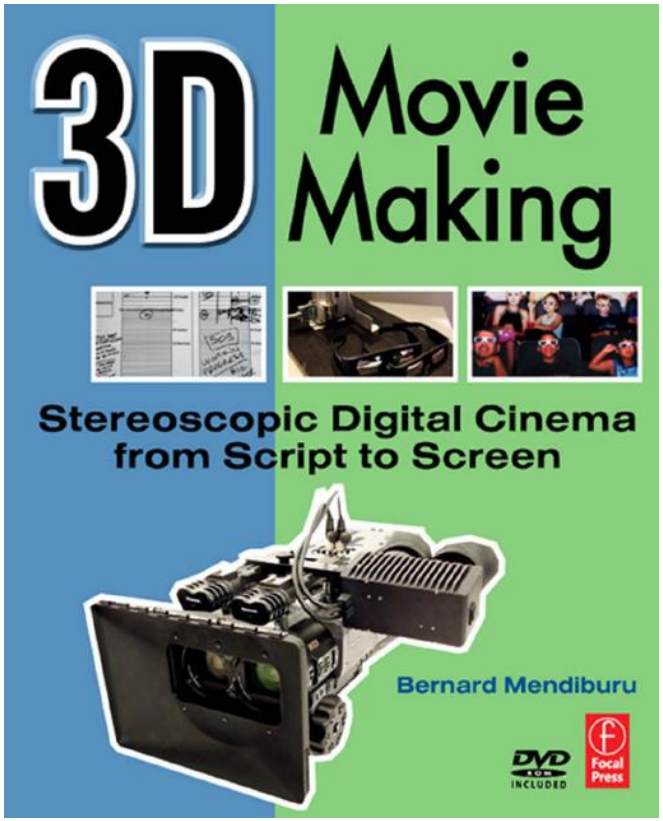
The End

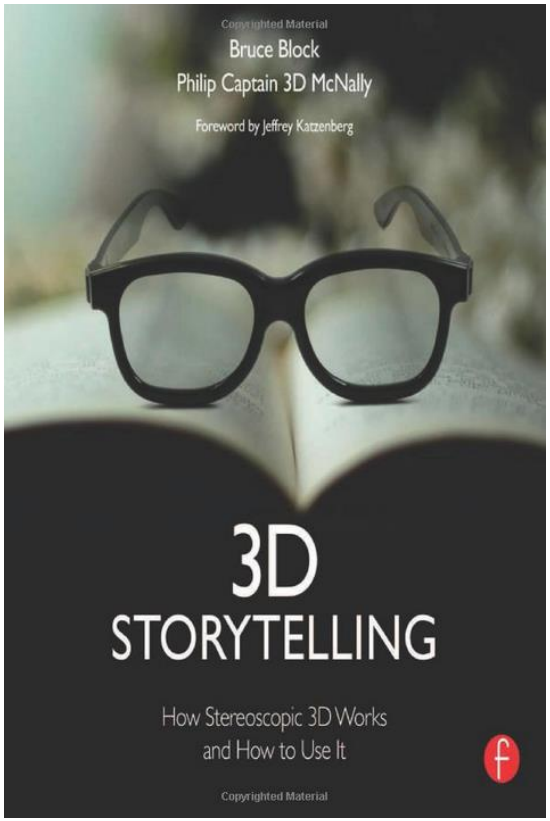
“The first rule of 3D is ‘do not harm’. Do not harm the audience. Do not harm the story“

Philip “Captain 3D“ McNally

References

- **Bernard Mendiburu – 3D Movie Making**
- **Bruce Block, Phil Captain 3D McNally – 3D Storytelling: How Stereoscopic 3D Works and How to Use It**





Additional Links

- **Dashwood Cinema Solutions**
  - http://www.dashwood3d.com/blog/beginners-guide-to-shooting-stereoscopic-3d/
- **The Basics of Shooting Stereoscopic 3D**
  - http://3droundabout.com/?cat=4&tag=the-basics-of-shooting-stereoscopic-3d
- **Stereoscopy News**
  - http://www.stereoscopynews.com/