Influence of views asymmetries and depth rendering on visual comfort: towards 3D video technical recommendations

Orange Labs, Networks and Carriers
Research & Development

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Context and objective

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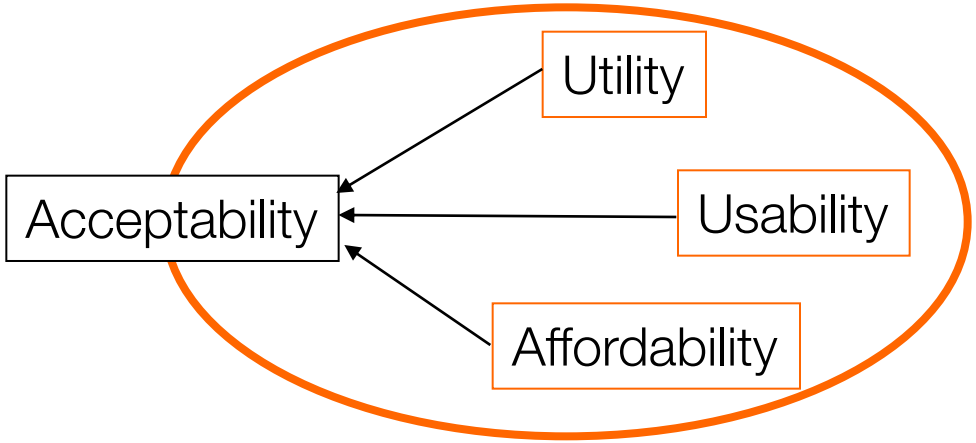
Context

Quality of Experience (QoE) of 3D services

- QoE of 3D services: 3 main components



Adequacy / feeling needs

Media quality (speech, sound, image)

Ergonomics, …

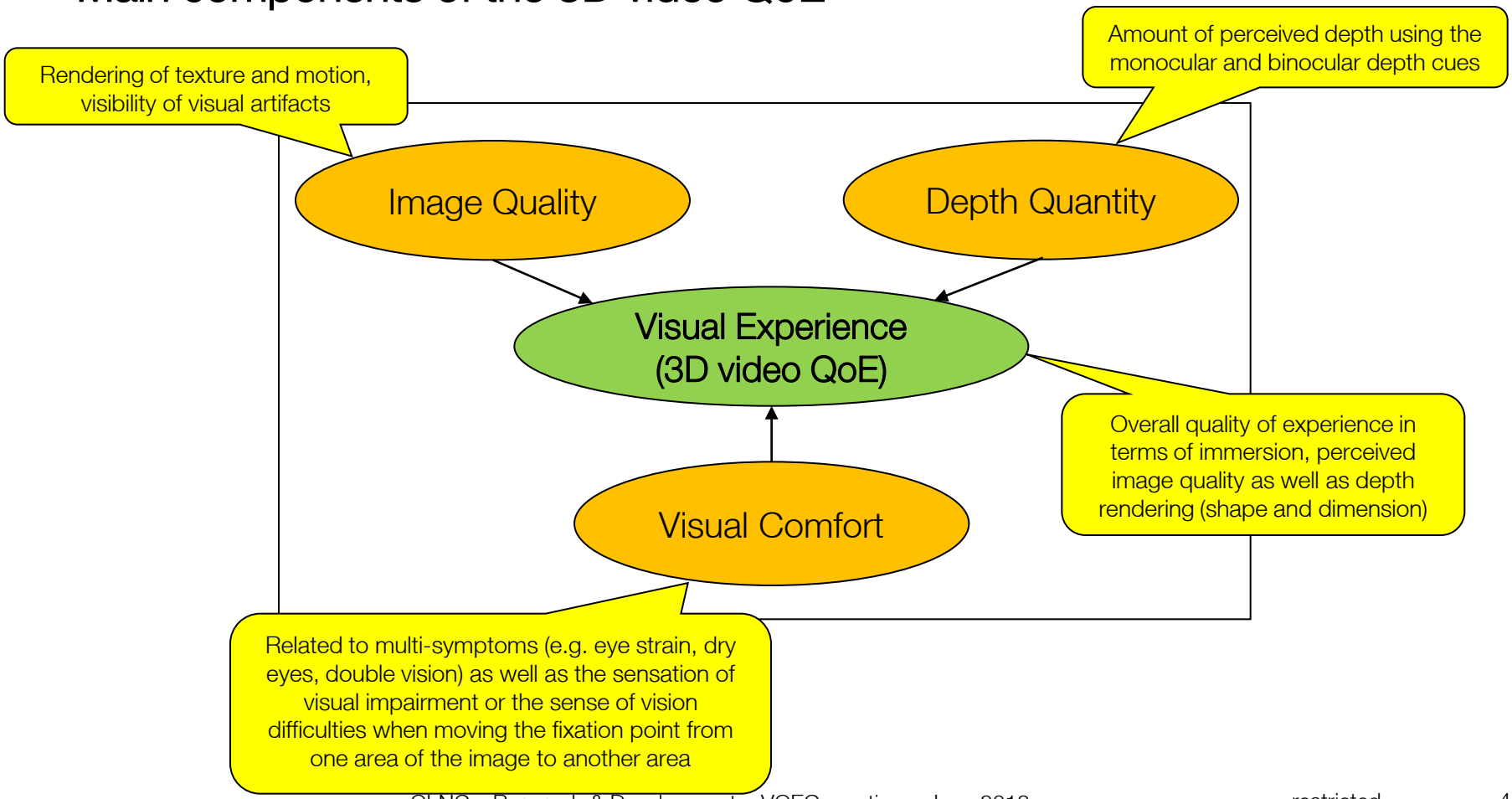
Price, accessibility, …

- Acceptability has to be defined in each service case
  - **3D professional services** : *utility* is a key issue
    - 3D systems are used even if the visual comfort is limited
  - **3D consumer services** : *visual comfort (usability)* can not be ignored
    - Visual eyestrain and annoyance are often mentioned by observers

The 3D video QoE assessment

Multidimensional approach is required

- Main components of the 3D video QoE



Main objective

To ensure Visual Comfort of end-users

- **Main objective:** considering the end-user's opinion and the HVS properties, to propose technical requirements in order to ensure an optimized visual comfort
- **User perception:** end-to-end architectures must be considered (mobile, PC, TV, ...)

Production & Postproduction

AV acquisition

Stereoscopic

2D+z

Others

Multi-views

Post-production

2D/3D conversion

Multiview interpolation

View synthesis from 3D representations

Mixed reality (augmented reality)

3D/3D conversion …

Codec

Proprietary & Standardized

Windows Media

TANDBERG

envivio.

New generations

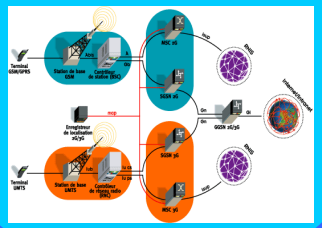
MPEG-C, MVC

Coming generations

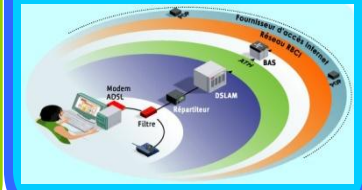
Depth-based representation

Network

Mobile (WiMax, 3GLTE)



xDSL, FTTx, …



Terminal

Anaglyph system

Active Shutters system

Passive (Polarised Glasses)

Autostereoscopic systems

End-user

Visual quality

Excellent

Good

Fair

Bad

Poor

Acceptability

Acceptable

Unacceptable

3D video QoE

Eyestrain

Naturalness

Image Quality

Visual Comfort

Amount of Depth

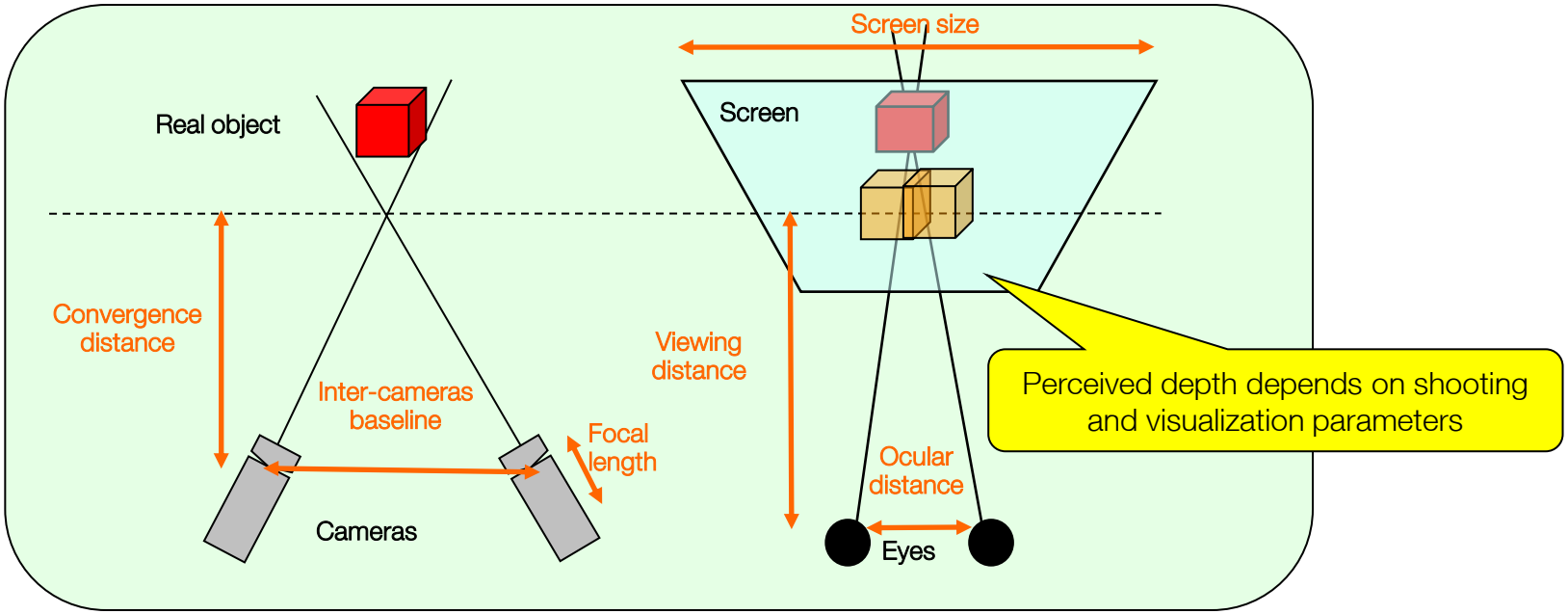
Viewing Experience

Main sources of Visual Discomfort

Depth Perception

Importance of shooting and visualization conditions

- Strong relation between shooting parameters and viewing configuration



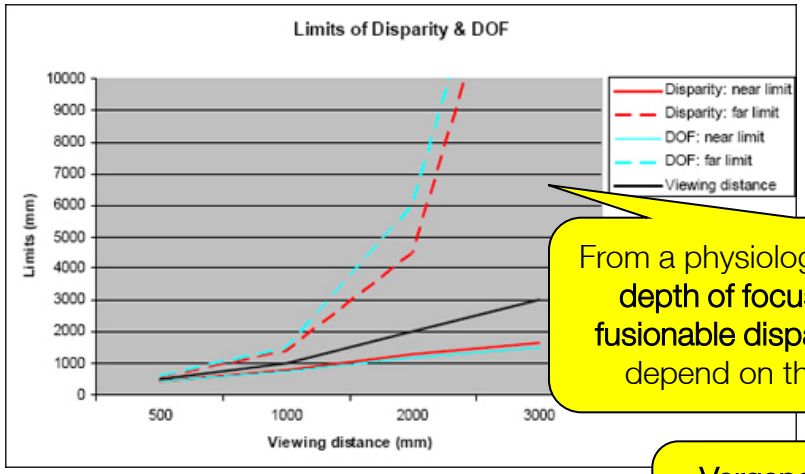
- **It is essential to model and control the perceived depth** to better understand end-users' opinion about the overall visual experience and related perceptual components

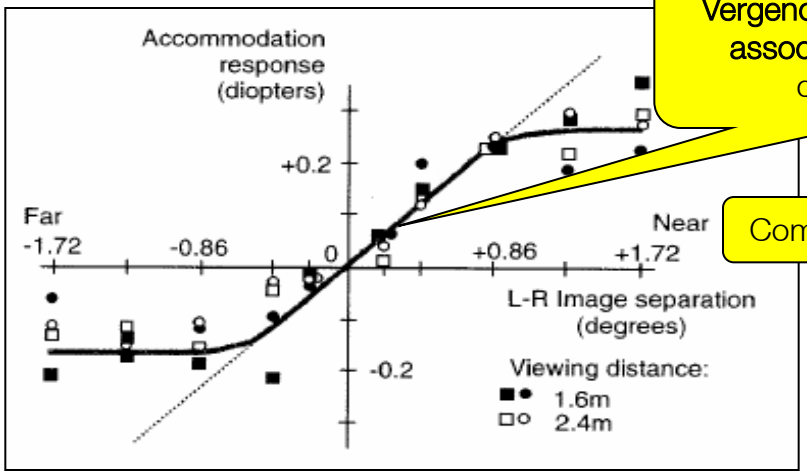
Binocular vision principle

Physiological feature of binocular depth perception!

- It is essential to consider the behavior of the human visual system

(Lambooij et al. 2007)



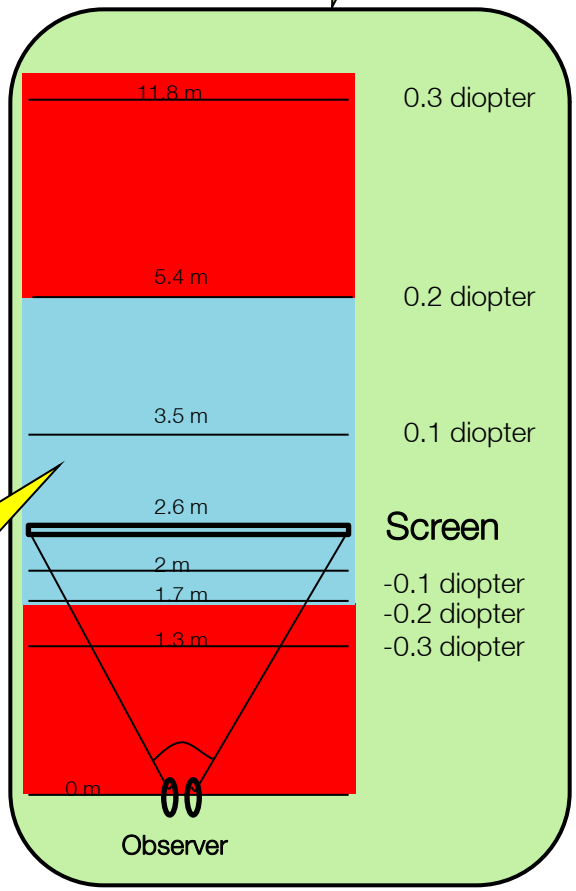


From a physiological point of view, **eye depth of focus (DOF) and largest fusionable disparities are limited** and depend on the viewing distance

Vergence/Accommodation association around the display plane

Comfortable viewing area ?

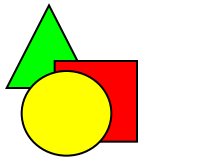
Impact on the **scene composition** and/or the **shooting parameters**

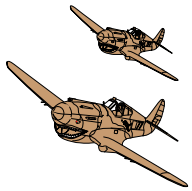


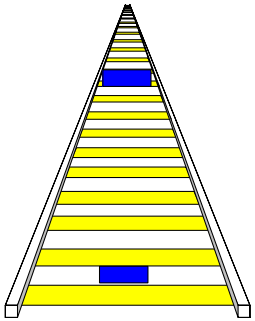
Monocular and binocular depth cues

To avoid depth cues contradiction in 3D video!

- **Monocular and binocular depth cues**
  - Monocular
    - Occlusion
    - Linear and aerial perspective
    - Relative size and density
    - Motion parallax
    - Accommodation
  - Binocular
    - Vergence
    - Disparity



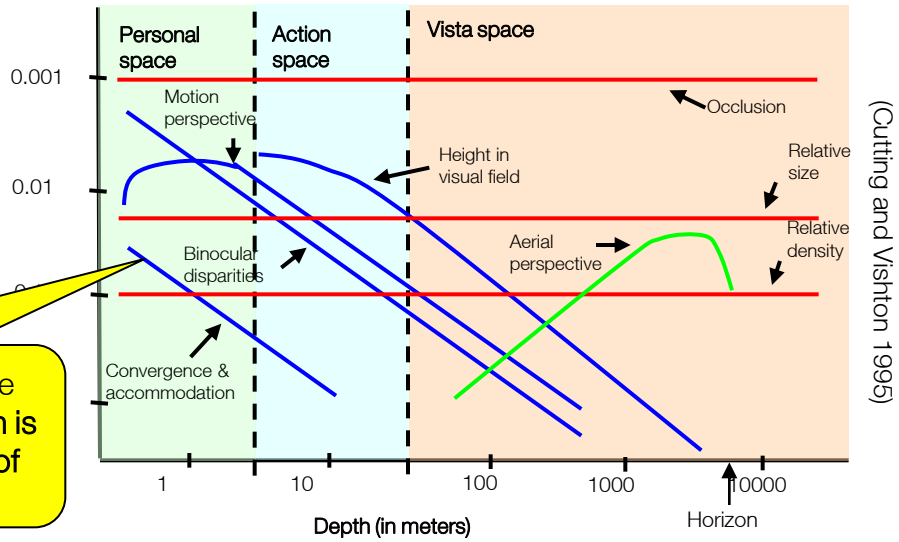




GUI key issue

- **Depth cues combination**
  - Addition
  - Dominance
  - Dissociation
  - etc.

Considering current S3D displays, the **vergence-accommodation dissociation is often mentioned as the main source of visual fatigue**

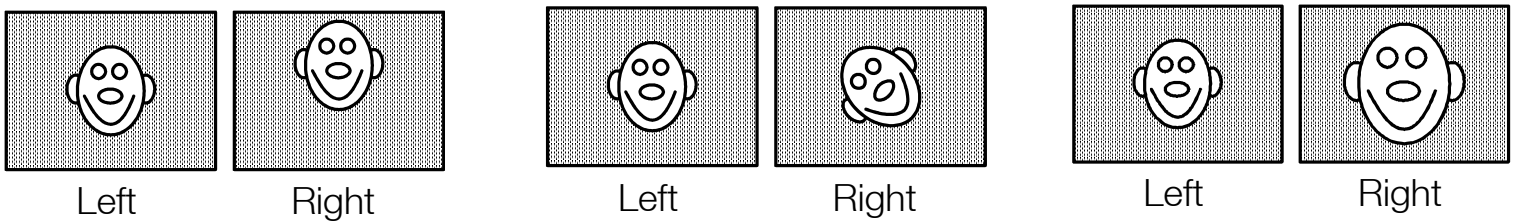


Main factors of visual discomfort

To consider HVS properties to reduce visual annoyance

- **Views asymetries**
  - Geometry, optics, photometry, colorimetry, temporal and spatial asymetries, crosstalk, etc.

  ⇨ Visibility and visual annoyance thresholds



- **Depth cues contradiction: impact on the HVS behavior**
  - 2D and 3D depth cues coherency
    - Occlusion, relative size, linear and aerial perspective, etc.
  - Accommodation and vergence conflict, largest fusionnable disparities, Depth of Focus
  - Well known objects: size and perceived distance, depth distortions

Assessment methodologies

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Main assessment methodologies

From psychophysics to focus groups

- **Psychophysics measurements focused on the human visual system performances**
  - Mainly visibility thresholds
- **Subjective assessment of the 3D video quality**
  - Several approaches
    - Video recommendations: ITU-R BT. 500 (2D), ITU-R BT. 1438 (3D)

Quality scale	Impairment scale	Comparison scale
Excellent	Imperceptible	-3 Much worse
Good	Perceptible but not annoying	-2 Worse
Fair	Slightly annoying	-1 Slightly worse
Poor	Annoying	0 The same
Bad	Very annoying	1 Slightly better
		2 Better
		3 Much better

Used to assess the **3D video QoE**

Used to determine **visibility and visual annoyance thresholds**

- **Focus groups**
  - End-users' feeling and opinion about 3D video services and products

The 3D Visual Comfort issue

Proposed relationship with technological factors

Strong impact on the **Visual Comfort** (red color)

Technological factors	
Views asymmetries	Vertical disparity
	Rotation
	Focale length (zoom)
	Definition (focus)
	Photometry (black level)
	Photometry (white level)
	Colorimetry (RGB)
	Temporal
Horizontal Disparities	Crossed and Uncrossed
Depth cues combinaison	Monocular and binocular depth cues
Crosstalk	Percentage of left view in right one
Dimensions	Shooting and visualisation parameters
Shape	
Image definition	Nombre of columns and rows
Framerate	Number of images per second
Compression	Bitrate in bits per second

Depends on the **target service** (mobile, PC, TV)

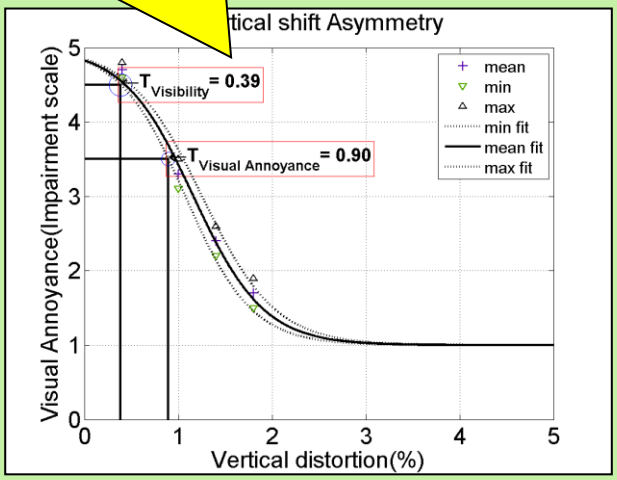
The Visual Comfort assessment

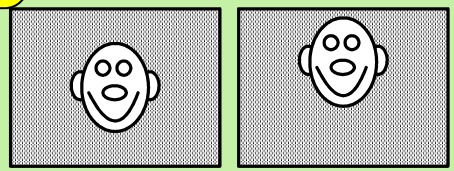
Impairment scale and/or Quality Scale

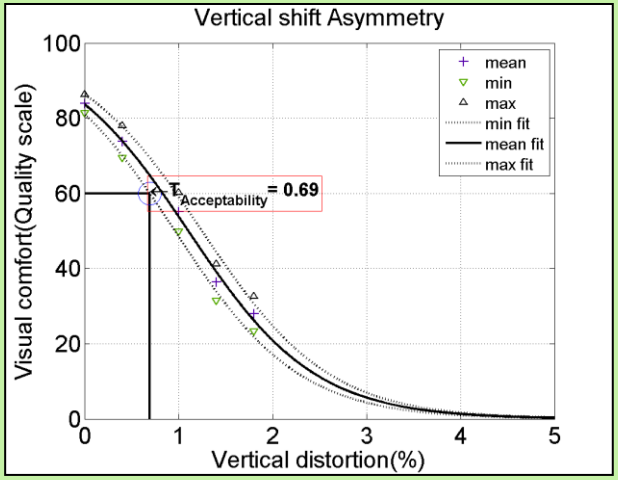
- **Definition of 3 different perceptual thresholds**
  - Visibility and Visual Annoyance thresholds (Impairment scale)
  - Acceptability threshold (80% of acceptability from Quality Scale scores?)

Visibility threshold used by Orange Labs to define technical recommendations

Vertical shift case







3D Visual Comfort assessment: towards 3D video technical recommendations

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3DTV technical recommendations

Some perceptual thresholds to ensure end-users' visual comfort

From subjective assessment with non-expert viewers

Artistic effects not taken into account

Item	Description	Perceptual threshold
Vertical disparity	Vertical shift difference (local or global)	<0,5%
Rotation	Rotation difference between the 2 views	<0,5°
Focal length	Magnification difference	<1%
Focus	Bandwidth difference in terms of spatial frequencies	<20%
Black level	Black level difference between the 2 views	<1%
White level	White level difference between the 2 views	<15%
Colorimetry	Colorimetry	<7,5%
Temporal	Temporal asymmetry (captation or visualisation)	<20ms
Disparity	Maximum crossed and uncrossed disparities	2,5%
Depth cue	2D and 3D depth cues coherency	-
Crosstalk	Percentage of one view in the other view	?
Dimension	Magnification or miniaturization of object dimensions	?
Shape	Stretching or compression of depth	?

To be investigated

Conclusion

Technical recommendations to ensure end-users' Visual Comfort

- **3D video recommendations based on technological factors**
  - Perceptual thresholds definition considering the impact on the Visual Comfort
  - Objective measurement of 3D technological parameters and thresholds comparison
    - Use or development of objective automatic industrial solutions
  - Target application: 3D video production and postproduction
  - Open issues
    - temporal integration of impairments?
    - combination of several parameters around thresholds?

- **Additional factors like artistic effects can influence visual comfort**
  - Production rules: camera movement, scene cut frequency, etc.

Thank you! Question?

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