An investigation of visual selection priority of objects with texture and crossed and uncrossed disparities

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Motivation of the study

Goal – compare visual attention (VA) between 2D and 3D **fully controlled contents** having objects with crossed disparity in comfortable and uncomfortable conditions.

Conducted experiments:

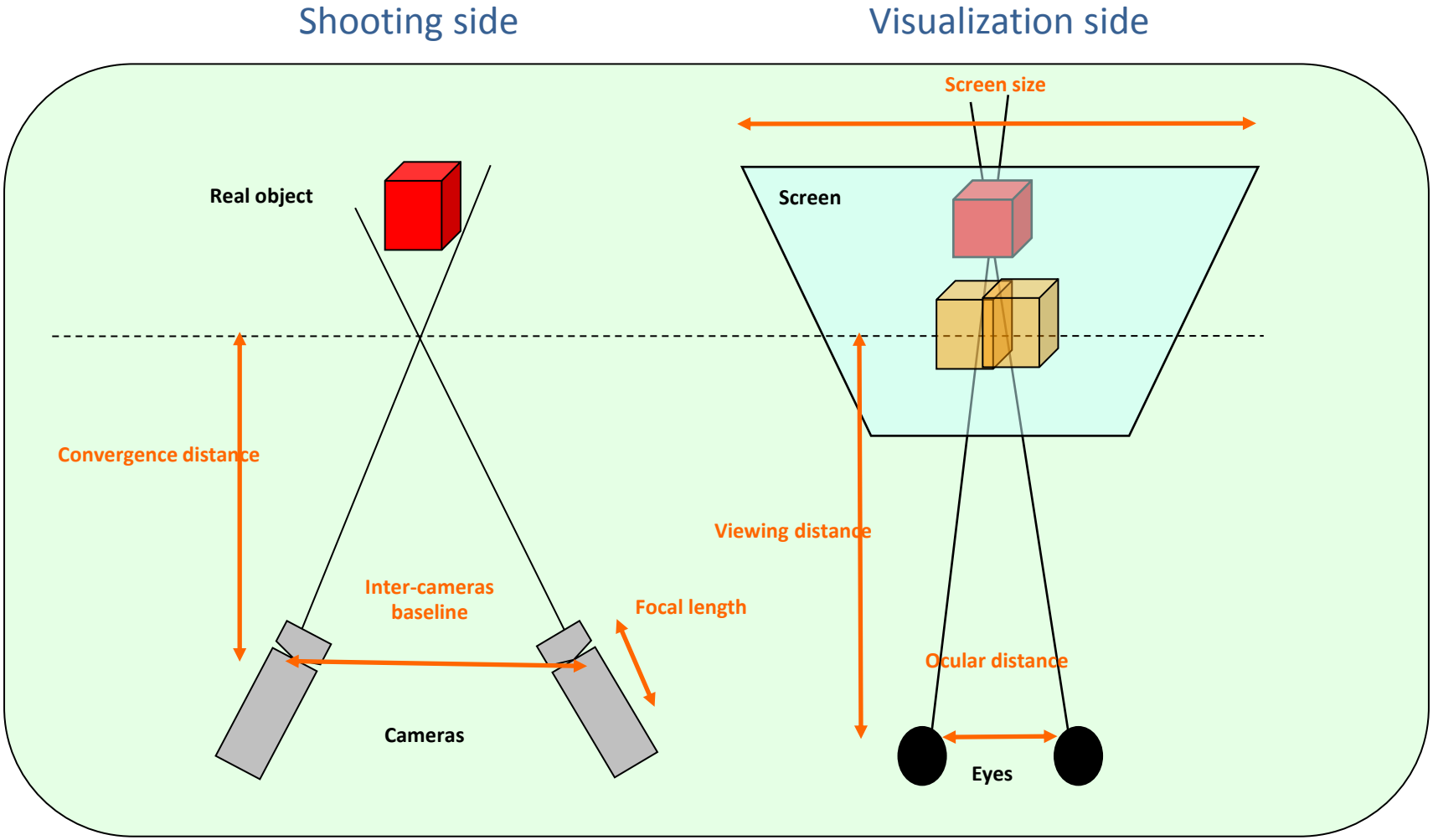
Exp.1 – Uncrossed disparity (UD);

Exp.2 – Crossed disparity (CD);

Exp.3 – Experiment with spheres.

Crossed disparity experiment (Exp. 2)

3D stereoscopic systems: shooting and visualization



Exp2. Scenes parameters

Scene	DoF, dpt	Baseline, mm	Convergence distance, m	Disparity on the screen, mm	
				foreground	background
cartoon	0.1	220	8	-15	15
	0.3	660	8	-46	46
hall	0.1	342	8	-15	15
	0.3	1020	8	-46	46
pigs	0.1	53	2.2	-15	15
	0.3	162	2.2	-47	45
table	0.1	325	5.45	-16	15
	0.3	1000	5.45	-45	44

Maximum disparity on the screen:

- Comfortable DoF=0.1 dpt 1.5 cm (1.6% of display width)
- Uncomfortable DoF=0.3 dpt 4.5 cm (4.8% of display width)

Amount of perceived depth is the equal for all the scenes with same DoF.

Exp2. Stimuli generation

Cartoon

Table

Hall

Pigs

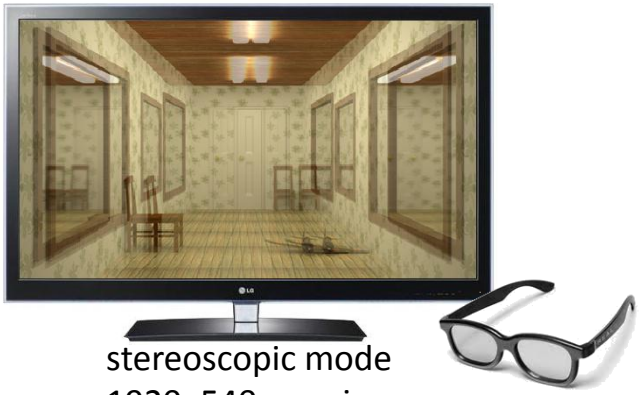
4 scenes × 3 depth levels = 12 stimuli

Exp2. Experimental design

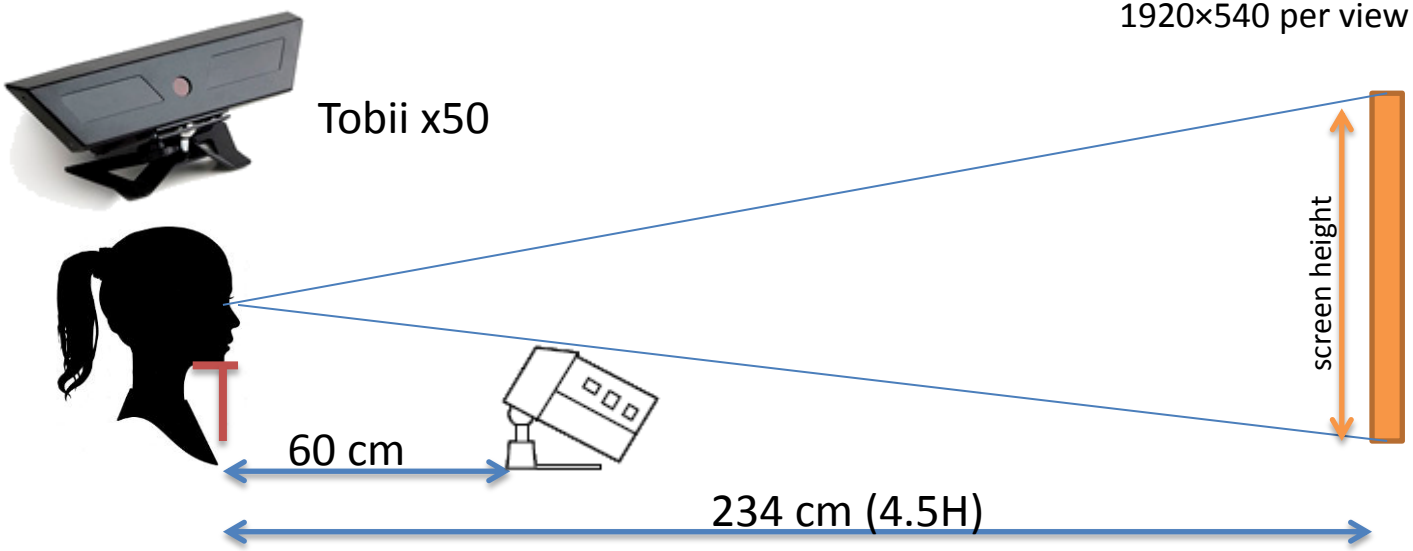
Methodology:

- 12 images divided into 3 sets;
- Each scene was seen only once by every observer;
- 51 observers (17 observers per image).

LG 42LW (93×52 cm)



stereoscopic mode
1920×540 per view

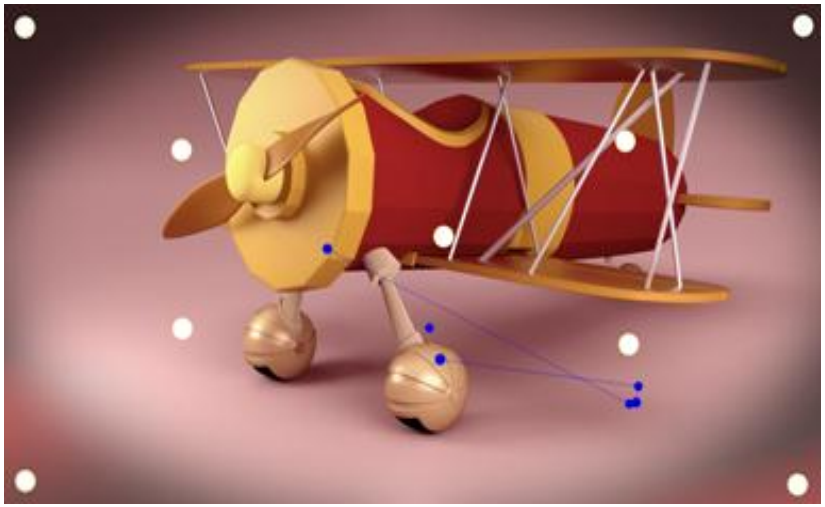


Exp2. Experimental methodology

Test stages:

1. Instruction sheet
   - free-viewing task;
2. Calibration (5 point calibration + calibration chart)
3. Training 1 min 20 s
4. Test
   - duration 1 min 40 s
   - 1 set (4 images: cartoon, hall, table and pigs)
   - 20 s per image + 5 s of gray screen

51 people were tested
17 people per image

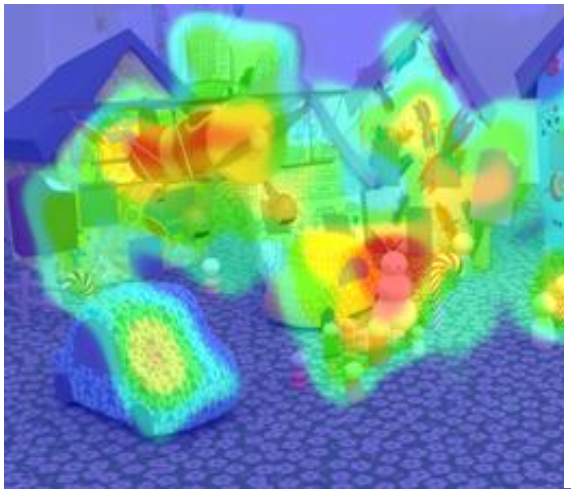


Unsuccessful calibration chart

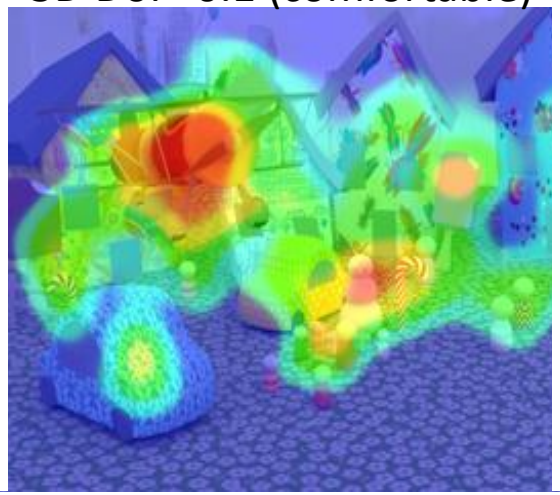
Successful calibration chart

Exp2. Qualitative results of the heat maps

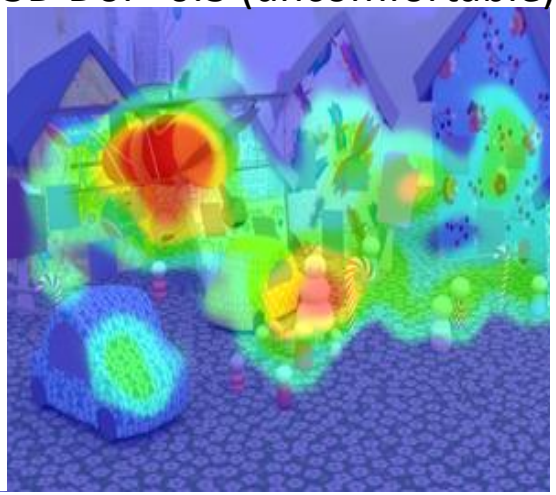
2D

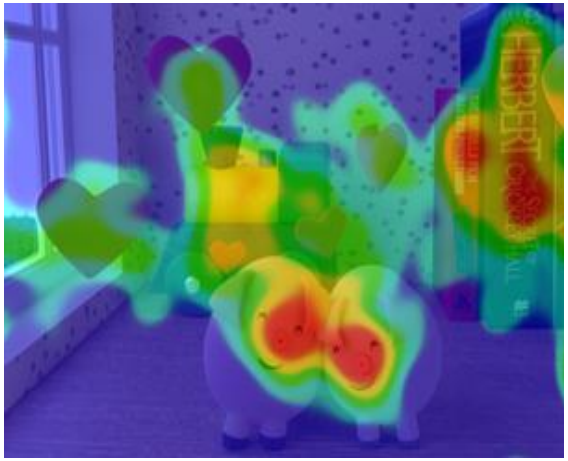


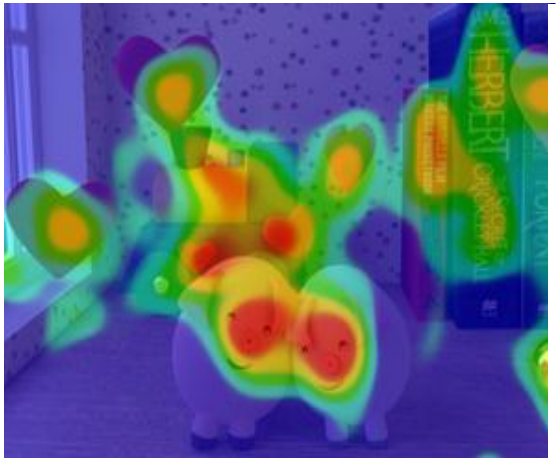
3D DoF=0.1 (comfortable)

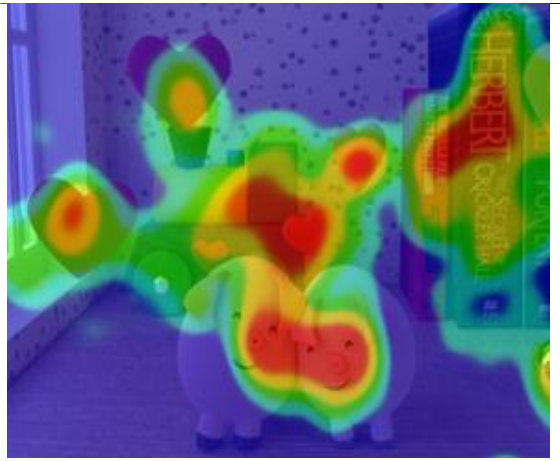


3D DoF=0.3 (uncomfortable)









Conclusions for Exp.1(UD) and Exp.2(CD)

We performed eye-tracking experiments using fully controlled 3D content with crossed disparity and compared visual attention between 2D, 3D comfortable and 3D uncomfortable conditions:

Is there an influence on VA in comparison with 2D? Of:	Exp.1 UD	Exp.2 CD
Disparity	NO	YES
Texture	YES	?
Discomfort	NO	NO
Saccade length (4 s)	YES ↓	?
Saccade length (20 s)	NO	NO
Fixation durations (20 s)	NO	NO
CC and AUC (20 s) add 4s	NO	NO

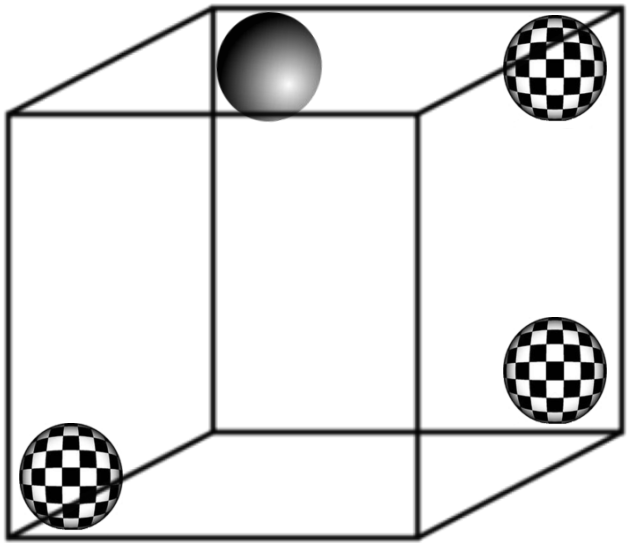
Observers reported that it was interesting to look at objects with excessive disparity

So what is more influential in guiding our gaze: texture or depth ?

Experiment with spheres (Exp. 3)

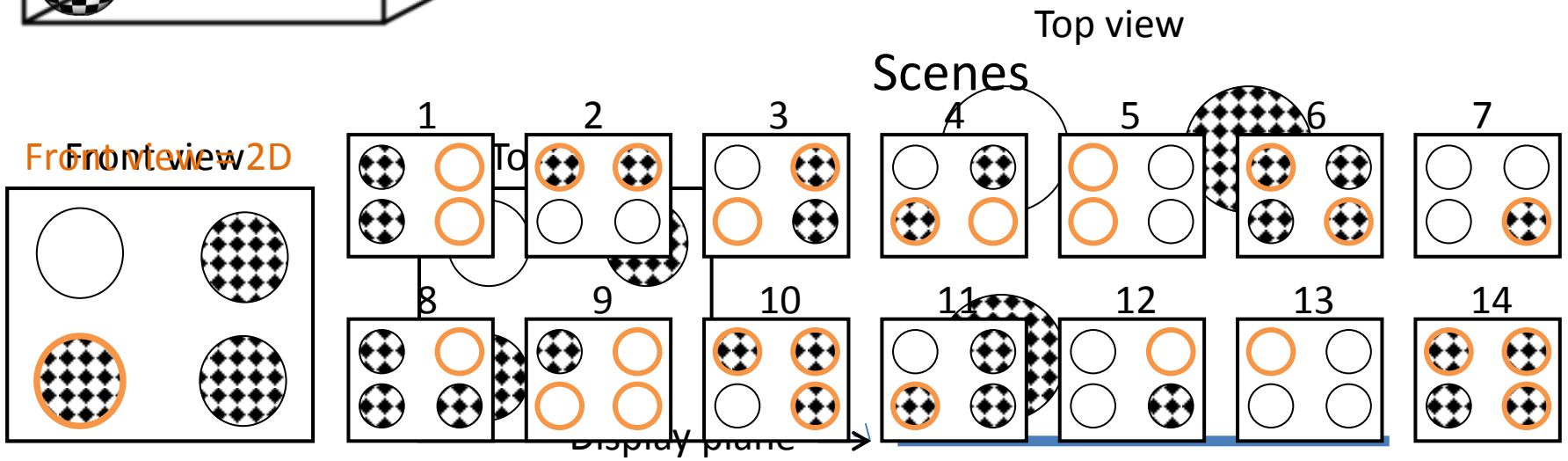
Exp3. Stimuli generation

Arrangement of spheres in depth

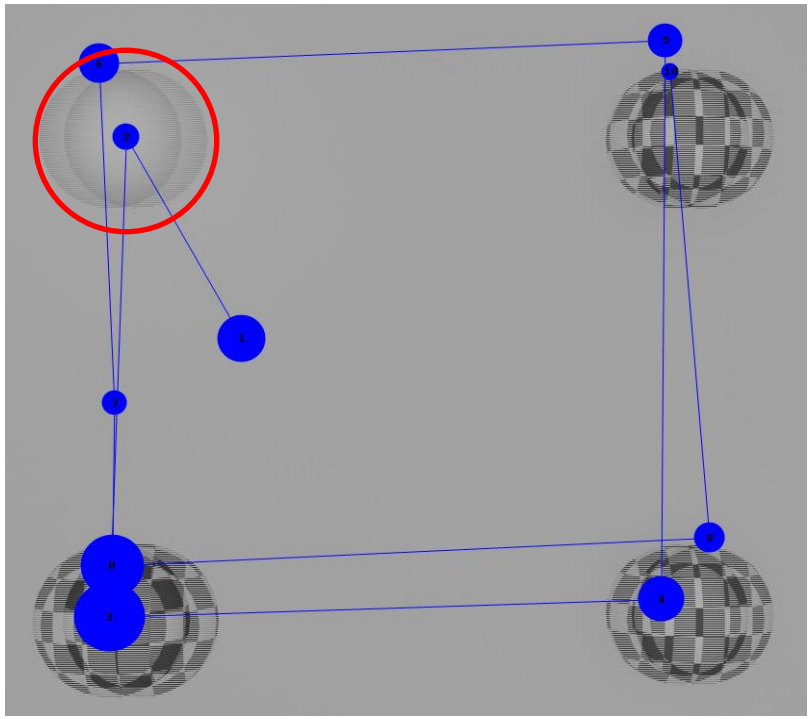


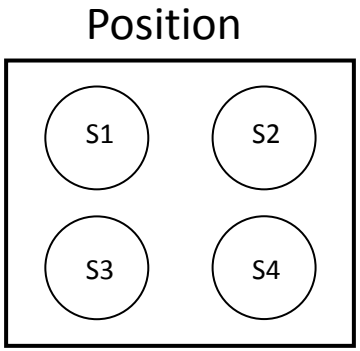
Parameters to study:

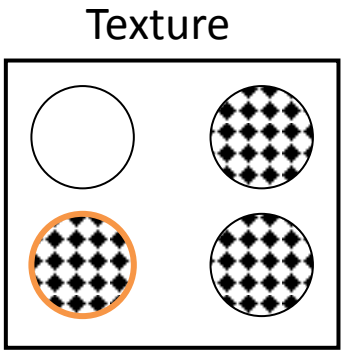
1. Texture
   - check board
   - gray
2. Depth
   - 2D
   - Uncrossed disparities (UD)
   - Mixed disparities (MD)
   - Crossed disparities (CD)



Exp3. Eye tracking data analysis





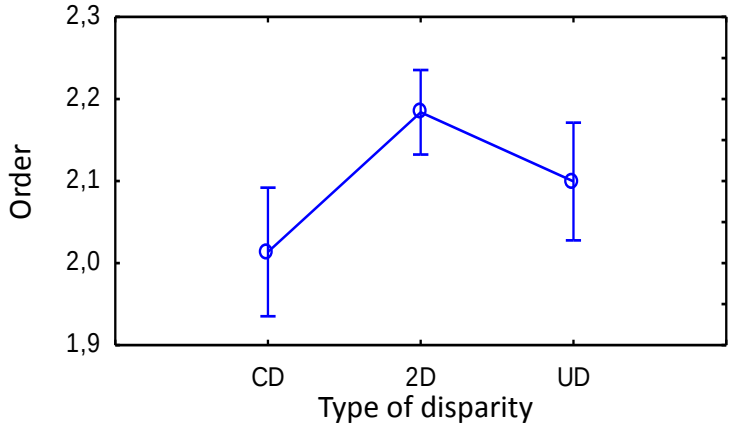


Position	s1	s2	s3	s4
11_MD	1	4	2	3
11_2D	1	2	3	4
11_CD	2	4	1	3
11_UD	1	3	2	4

Image	Observer	Position	Depth	Order	Texture
11_MD	5	1	1	1	0
11_MD	5	2	1	4	1
11_MD	5	3	-1	2	1
11_MD	5	4	1	3	1

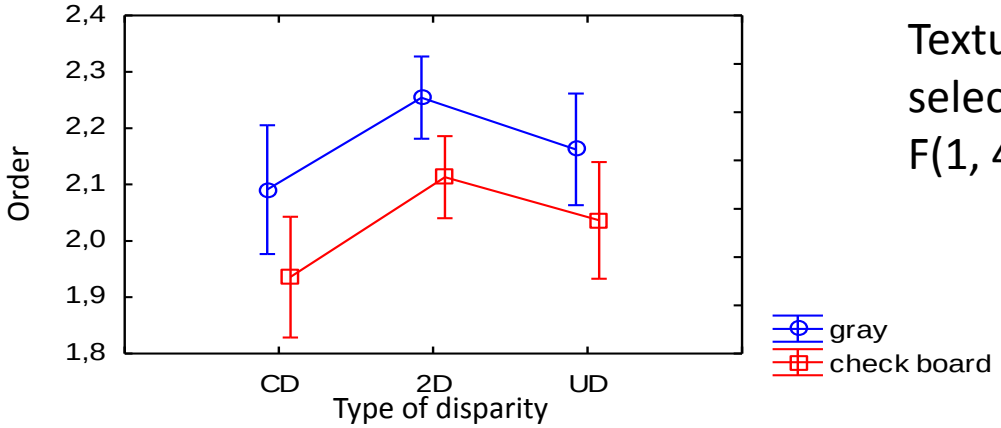
Exp3. Influence of depth on visual attention

Average order of selection per disparity



CD significantly influences on visual attention in comparison with 2D – $F(1, 3264)=13.14$, $p<0.05$, $p=0.0003$.

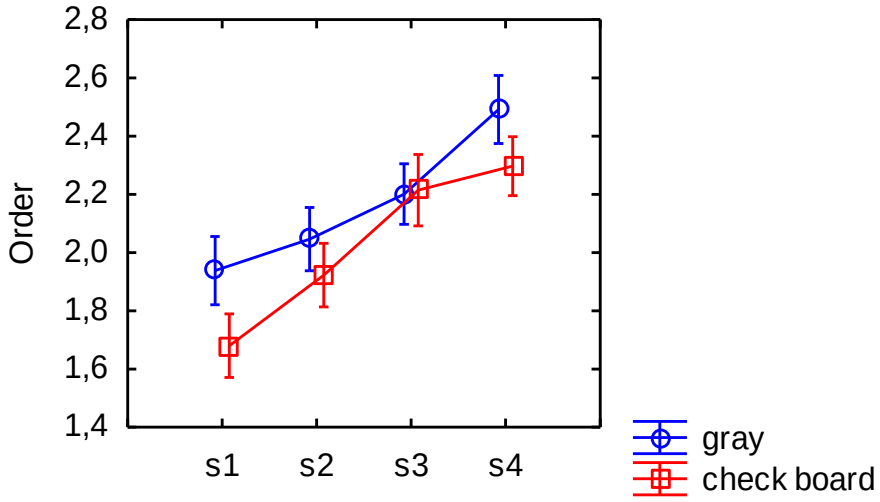
Average order of selection per texture



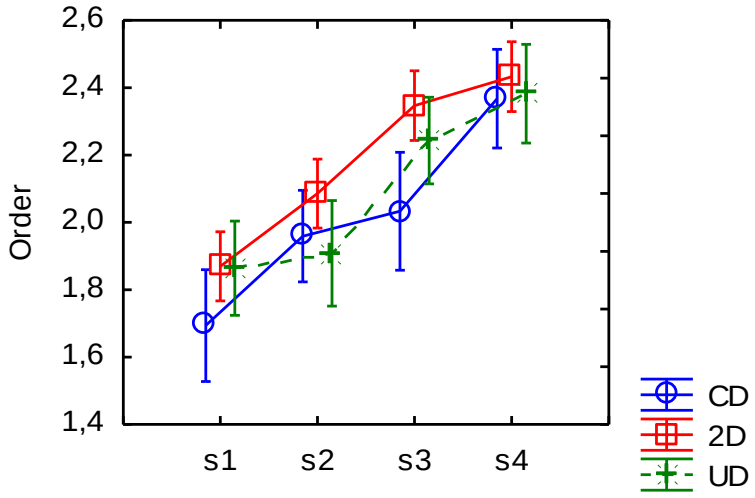
Texture significantly influences sphere selection order:
$F(1, 4456)=12.31$, $p<0.05$, $p=0.0005$

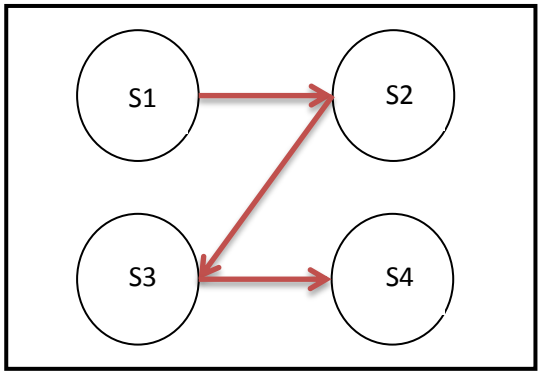
Exp3. Influence of the position of the spheres on test results

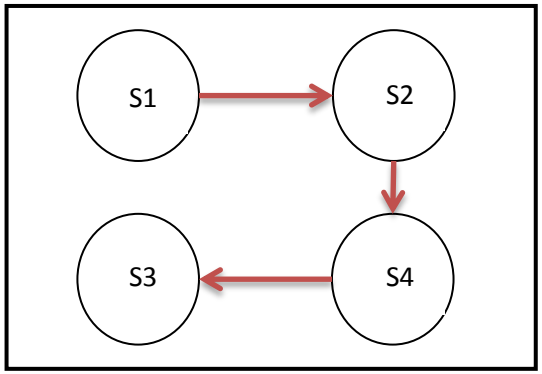
Influence of position and texture on the order



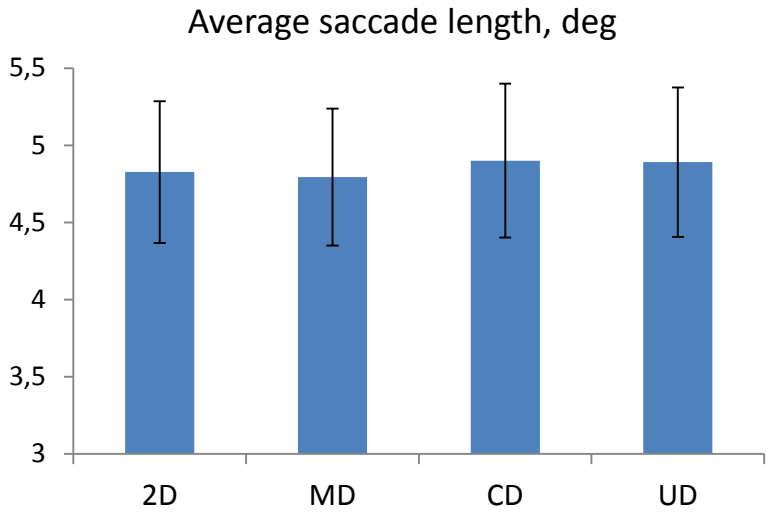
Influence of position and depth on the order



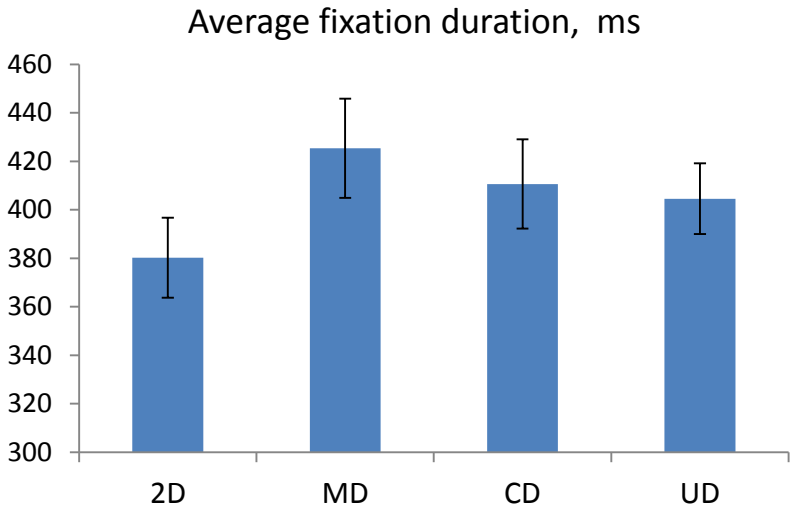




Exp3. Saccade length and fixation duration (5 s)



No significance



Paired comparison with 2D (t-test):

MD: $t(13)= -4,06$, $p<0.05$, $p=0.0013$
CD: $t(13)= -2,68$, $p<0.05$, $p=0.019$
UD: $t(13)= -3,98$, $p<0.05$, $p=0.0016$

Conclusions Exp.3

We performed eye-tracking experiment using low-level visual stimuli and studied which factor was more influential in guiding our gaze: texture or depth (2D vs. CD or 2D vs. UD).

Is there significant influence on visual attention? Of:	UD	CD
Disparity (in comparison with 2D)	NO	YES
Texture (Gray vs. Check Board)	YES	YES
Position (S1 vs. S2 vs. S3 vs. S4)	YES	YES
Saccade length (5 s) (in comparison with 2D)	NO	NO
Fixation durations (5 s) (in comparison with 2D)	YES↑	YES↑

If scene remains behind the display plane there is no difference in visual attention between 2D and 3D.

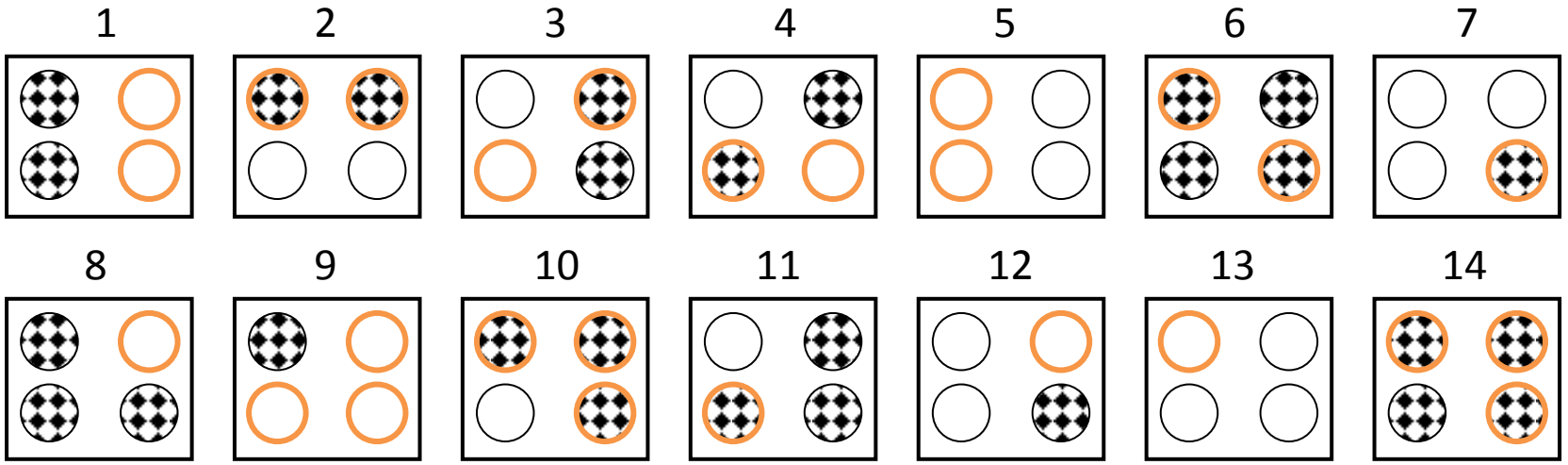
Perspective: design a test to avoid position bias.

THANK YOU

Exp3. Scenes parameters and configurations

Scene	DoF, dpt	Baseline, mm	Convergence distance, m	Disparity on the screen, mm	
				foreground	background
UD	+0.15	315	6	-	23
MD	±0.1	500	8	-15	15
CD	- 0.1	300	9.5	-15	-

Scenes



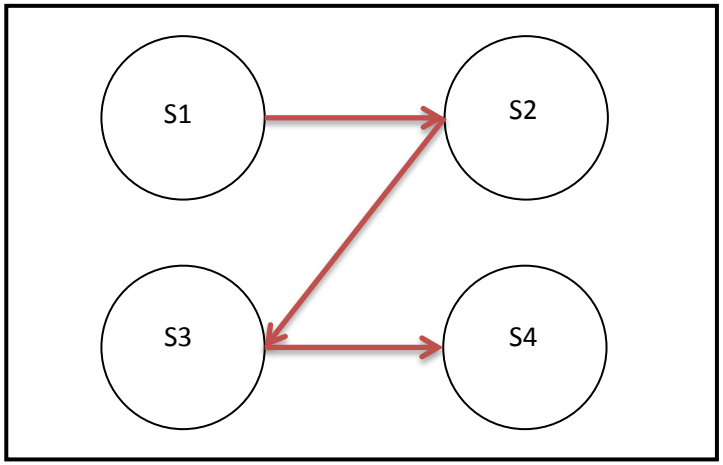
14 scenes × 4 depth configurations = 56 stimuli

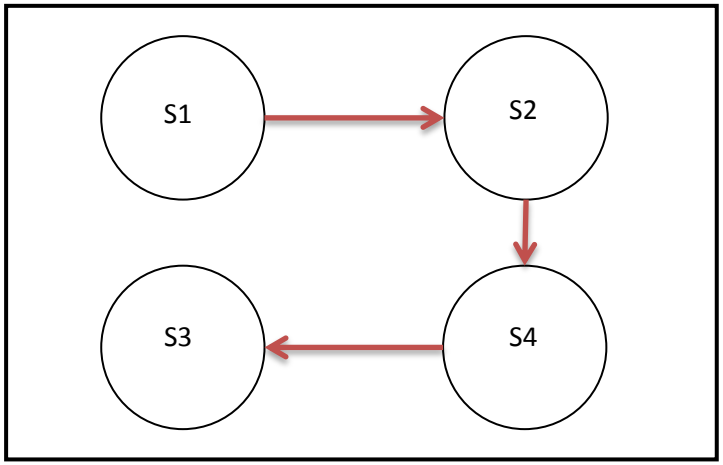
Exp3. Experimental methodology

Test stages:

1. Instruction sheet
   - free-viewing task;
2. Calibration (5 point calibration + calibration chart)
3. Training 1 min 40 s
4. Test
   - 56 stimuli
   - duration 9 min 30 s
   - 5 s per image + 5 s of gray screen

28 people took part in the experiment





Conclusions Exp3

We evaluated features influencing the saliency of the objects in stereoscopic conditions by using content with low-level visual stimuli:

- We detected that texture is the most important feature for selection of objects;
- Objects with crossed disparity are significantly important for selection process, but objects with uncrossed disparity are less important for visual attention;
- Any significant difference between 2D and 3D conditions were revealed for average saccade length. Though, average fixation duration was higher when viewing stimuli with spheres in 3D; there was no difference in average fixation duration for the content with crossed disparity.

Impact of image acquisition on QoE

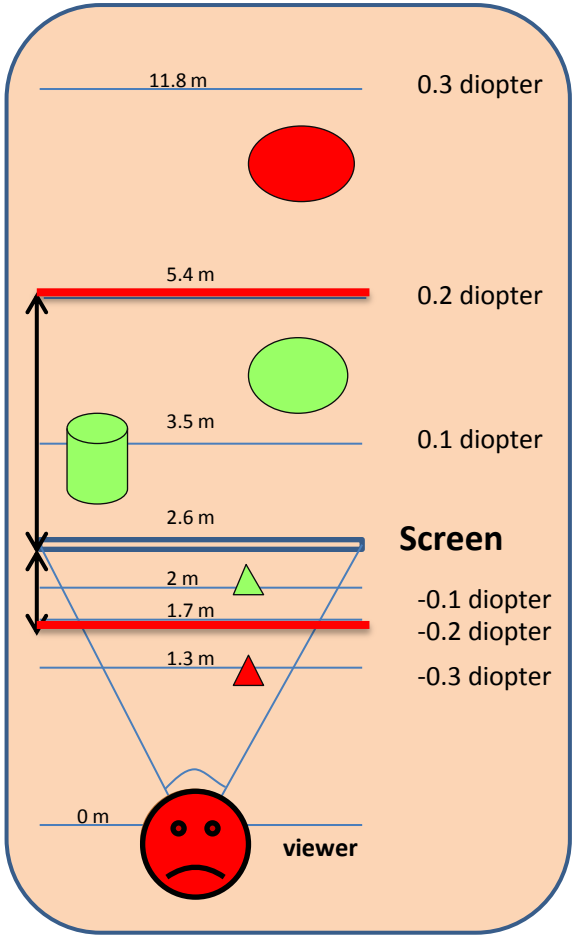
Optimization rules:

Rule 1 - Optimize the stereoscopic geometry on the Region of Interest depth plane

Rule 2 - Optimize the perceived scene to be located in the comfortable viewing zone

Priority rule - Rule 2 is prior to Rule 1

Depth of focus (DoF) describes the limits of the accommodative output under natural viewing conditions which concurs with the range of fusion.



Visual attention

Visual Attention: mechanism allowing to select and analyze some parts of our visual field

Visual attention is used:

- to select important areas of our visual field (alerting);
- to search a target in cluttered scenes (searching);
- allows to orient eye-movements.

There are two kinds of visual attention:

- Overt visual attention: involving eye movements;
- Covert visual attention: without eye movements. Attention can be voluntarily focused on a peripheral part of the visual field.

Types of the eye movements:

- Saccade: quick eye movements from one fixation location to another.
- Fixation: phase during which eyes is almost stationary.

Visual attention

A. Yarbus [Yarbus, 1967] demonstrated how eye movements changed depending on the question asked to the subject.

Bottom-up attention: some things draw attention reflexively, in a task-independent way:

- Involuntary;
- Very quick;
- Unconscious.

Top-down attention: some things draw attention intentionally, in a task-dependent way:

- Voluntary;
- Very slow;
- Conscious.

Motivation

Goals:

- Compare visual attention between 2D and 3D conditions using low-level visual stimuli;
- Find out which factor is more influential in guiding our gaze: texture or amount of depth.