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# Standard for metadata configuration to match scale and color difference among heterogeneous MR devices

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ISO-IEC JTC 1 SC 24 WG 9 Meetings, Jan., 2019  
Seoul, Korea

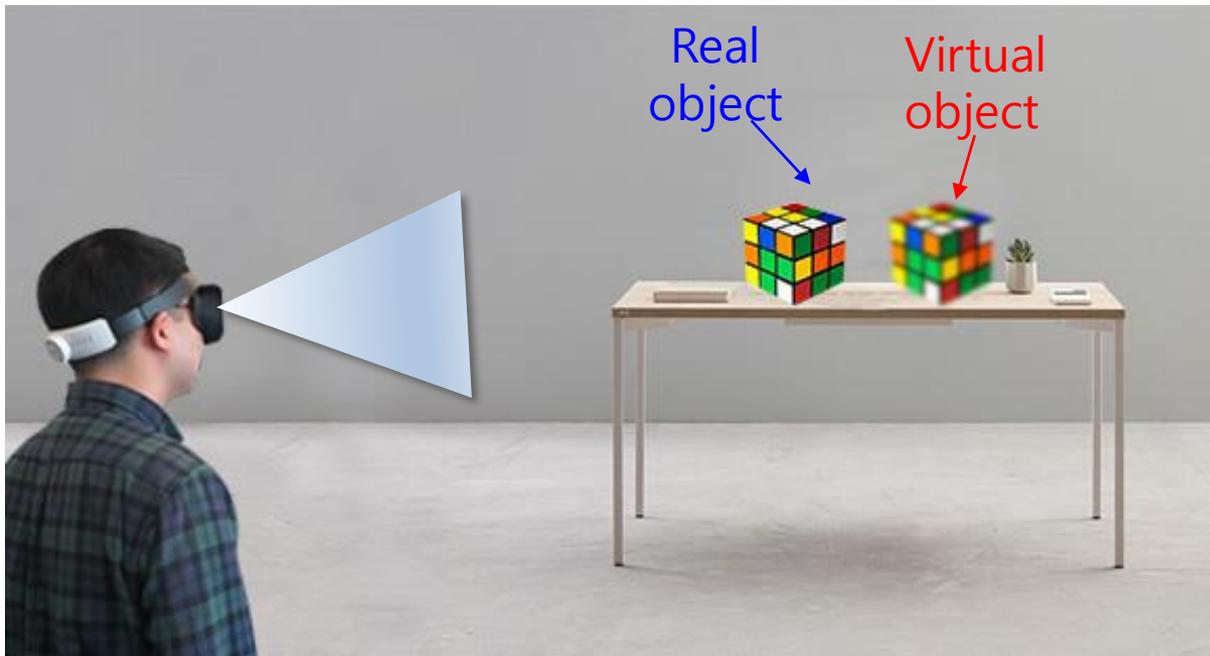
Gerard J. Kim, Korea Univ., Korea  
Dongsik Jo, Wonkwang Univ., Korea  
Howon Kim, ETRI, Korea

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# Motivation

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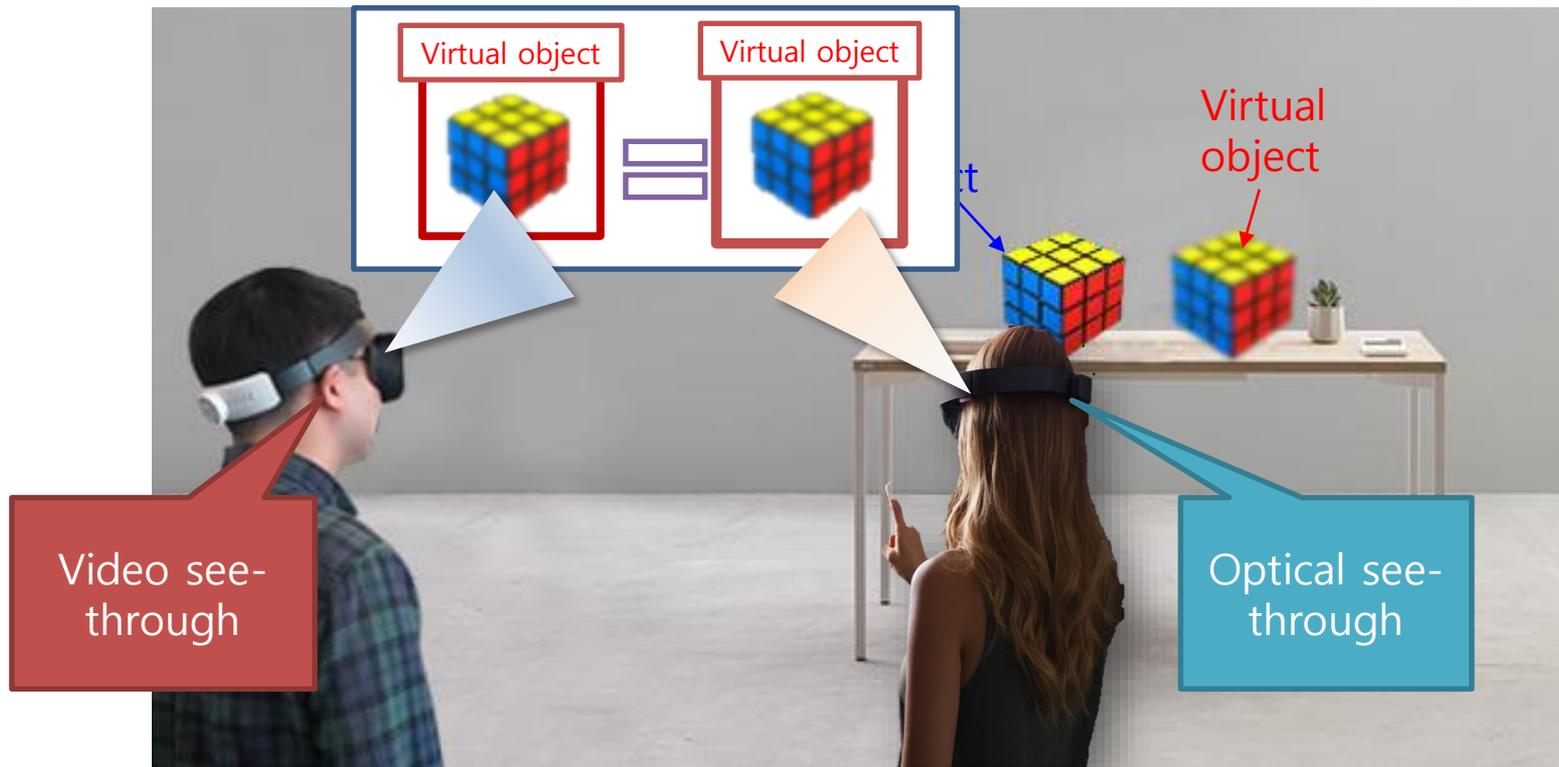
- ✓ Participant's perceptions of virtual object according to different mixed reality devices (e.g. color or scale)



- ✓ Participants must be able to consistently perceive color and scale among different MR devices (same color and size)

# CorrectAR (MatchAR)

- ✓ To perceive the same color and scale among different MR devices



- ✓ Validation experimental standards : setting, procedure, ...

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# Previous works (1/2)

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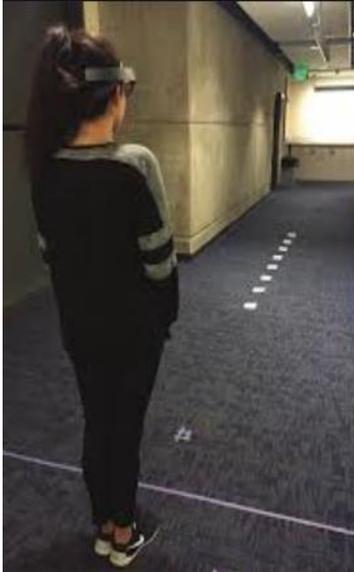


Users under-estimate egocentric distance in a VE

Throwing at a shorter distance

Third Person View and Guidance For More Natural Motor Behaviour In Immersive Basketball Playing (VRST 2014)

# Previous works (2/2)



## Various design decisions affect user depth perceptions

- Aerial perspective
- Billboarding, cast shadows
- Ray tracing
- Dimensionality (2D VS. 3D)
- Shading
- Texture

Designing for depth perceptions in augmented reality (ISMAR, 2017)  
<https://www.youtube.com/watch?v=kLQ-gN99QBw>

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# How to derive the standard guideline

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## With respect to AR/MR, What may be parameters to affect user perceptions

- Independent variables : Display type, distance, .....
- Dependent variables : Perceived size(scale), color difference between virtual and real

## Validation experimental standards for mixed and augmented reality

- Control variables
- Experimental setup
- Procedure

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# Parameters to affect user perceptions

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# Parameters to affect user perceptions

## Device characteristics

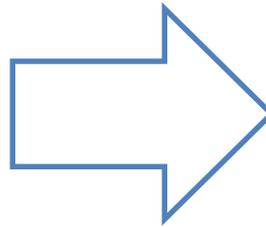
- ✓ Display type (video or optical)
- ✓ Resolution
- ✓ Aspect ratio
- ✓ Brightness
- ✓ Contrast
- ✓ FOV (viewing Angle)
- ✓ Refresh rate
- ✓ Response time (Tracking)

## Environment

- ✓ Light condition
- ✓ Occlusion

## Object characteristics

- ✓ Type (LOD)
  - Realistic representation
- ✓ Texture quality
- ✓ Distance between the user and the object
- ✓ Viewing direction



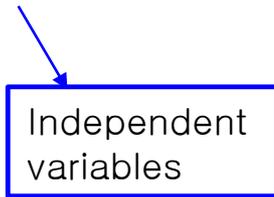
## Participants perceptions

- ✓ Color
- ✓ Scale
- ✓ Naturalness
- ✓ Visibility
- ✓ Readability
- ✓ .....

# Parameters to affect user perceptions

## Device characteristics

- ✓ Display type (video or optical)
- ✓ Resolution
- ✓ Aspect ratio
- ✓ Brightness
- ✓ Contrast
- ✓ FOV (viewing Angle)
- ✓ Refresh rate
- ✓ Response time (Tracking)



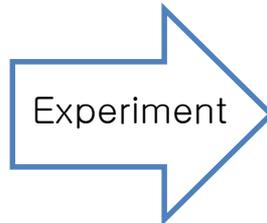
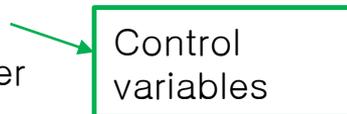
## Environment

- ✓ Light condition
- ✓ Occlusion



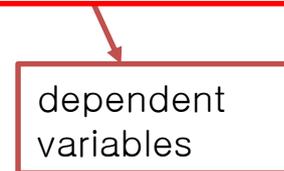
## Object characteristics

- ✓ Type (LOD)
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## Participants perceptions

- ✓ Color
- ✓ Scale
- ✓ Naturalness
- ✓ Visibility
- ✓ Readability
- ✓ .....

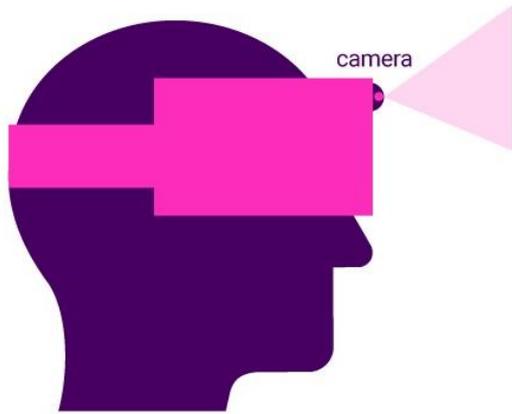


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# Validation experimental standards

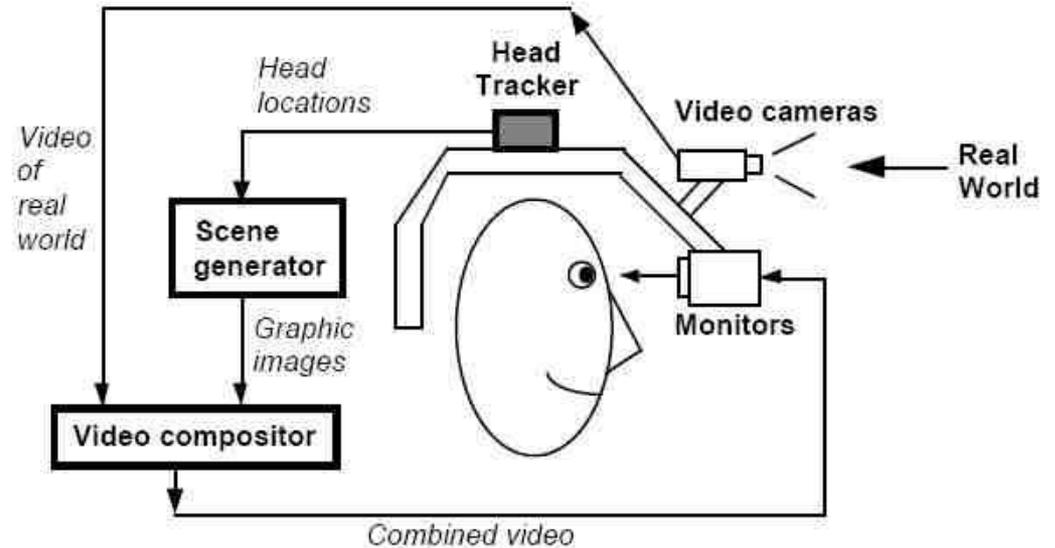
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# Display type (Video see-through HMD)



**Video see through displays**

출처: UX Collective



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# Display type

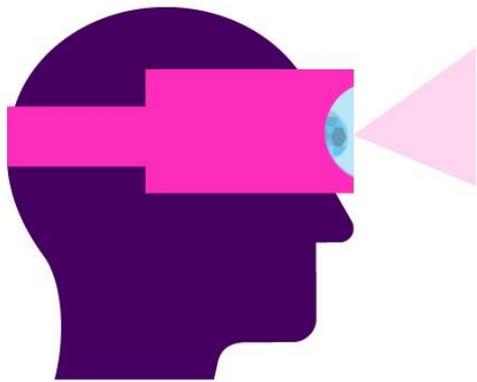
## (Video see-through HMD)

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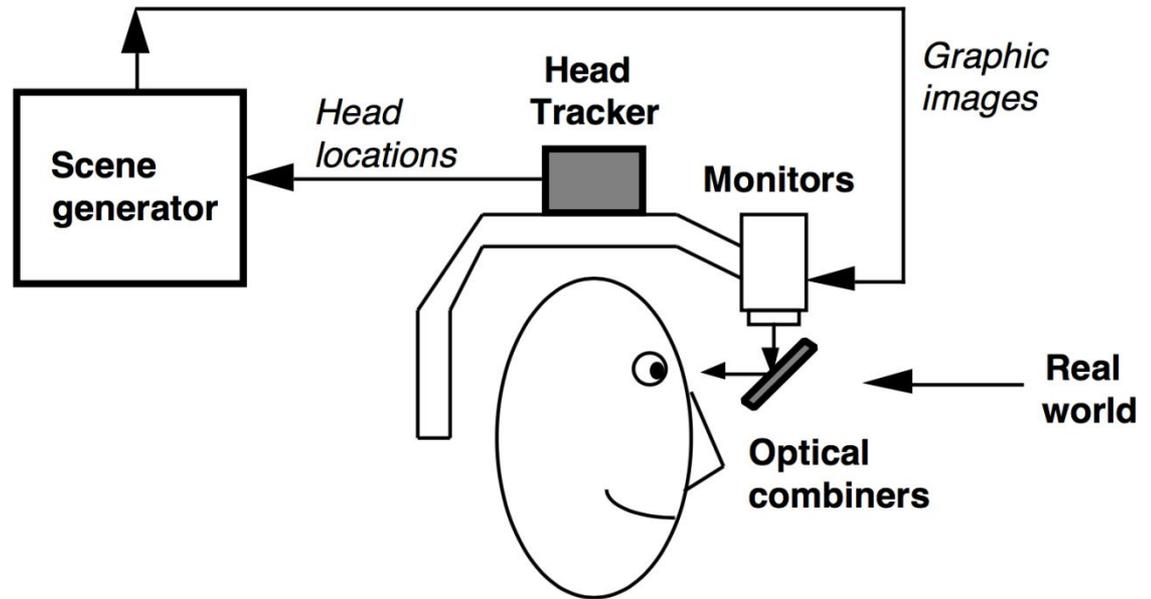
<http://ovrvision.com/entop/>

# Display type (Optical see-through HMD)



Optical see through displays

출처: UX Collective

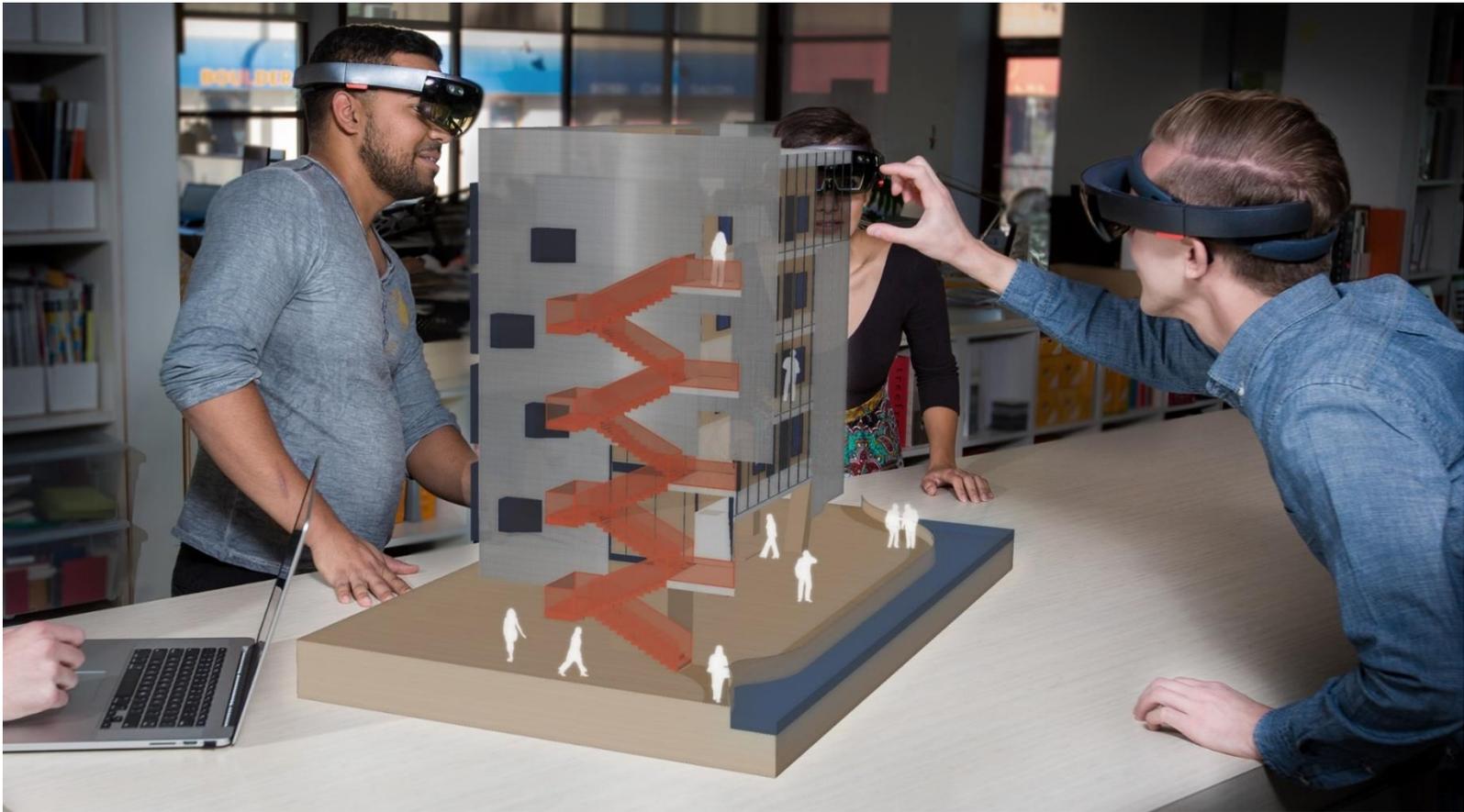


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# Display type

## (Optical see-through HMD)

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<https://www.microsoft.com/en-IE/hololens>

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# Display type (Optical see-through HMD)

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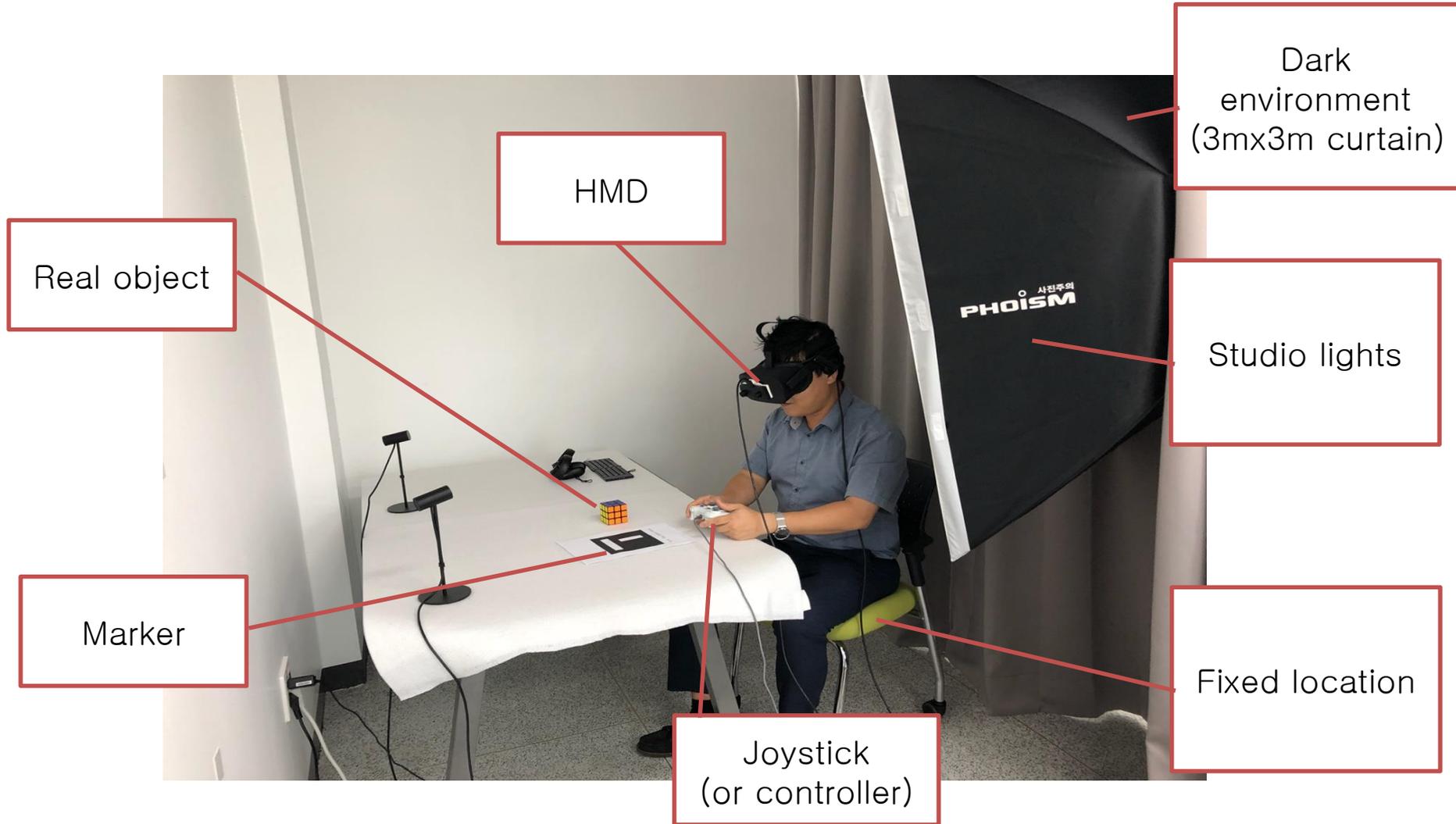
MS Hololens

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# Experimental configuration

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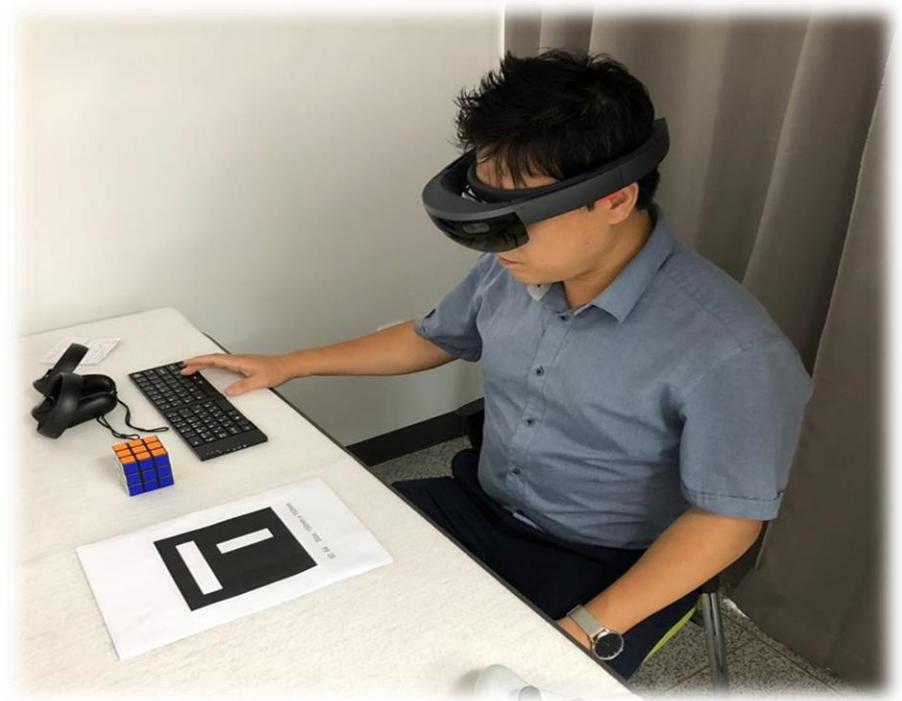
# Experimental configuration



# Experimental configuration

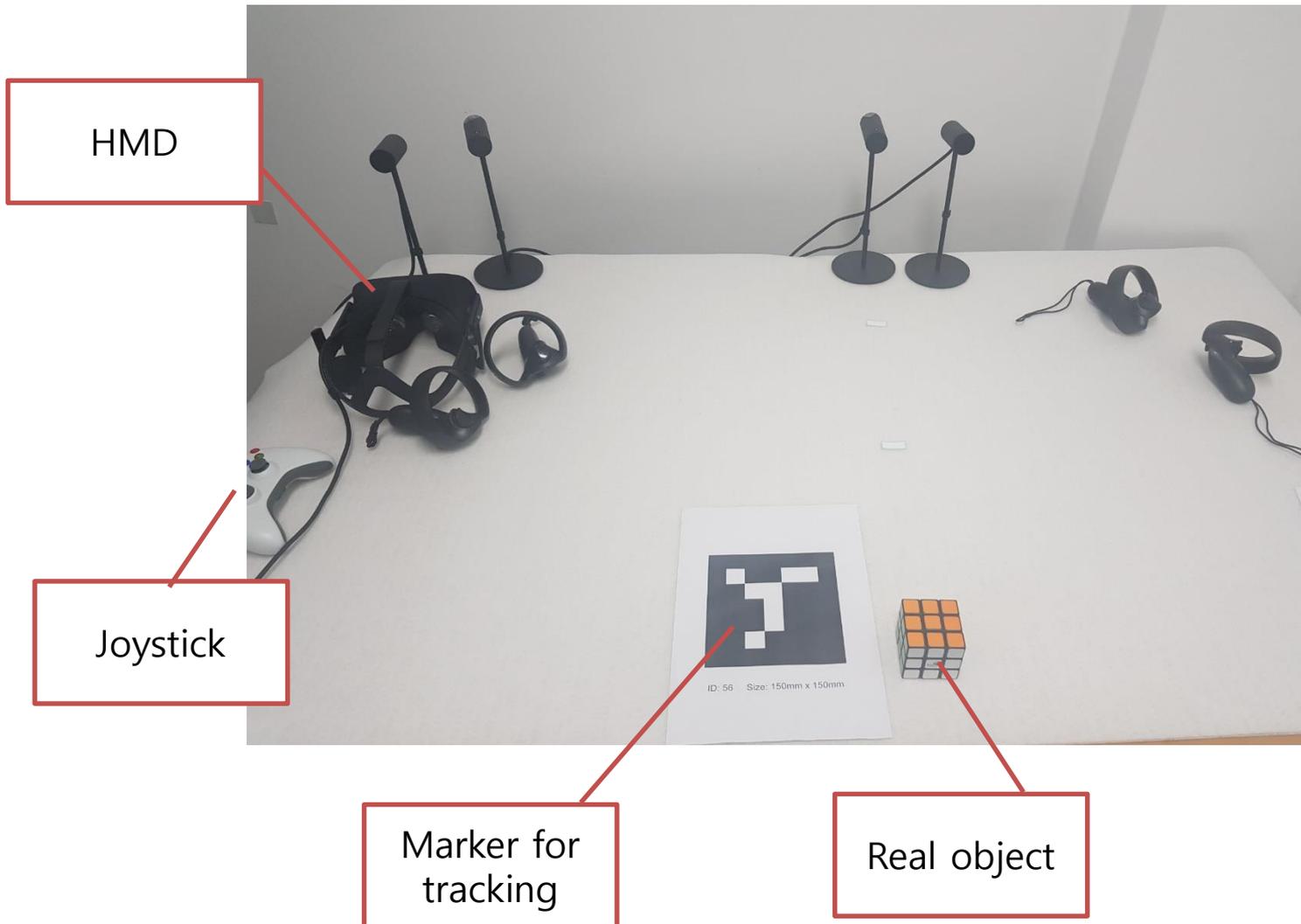


Video see-through  
HMD



Optical see-through  
HMD

# Experimental configuration

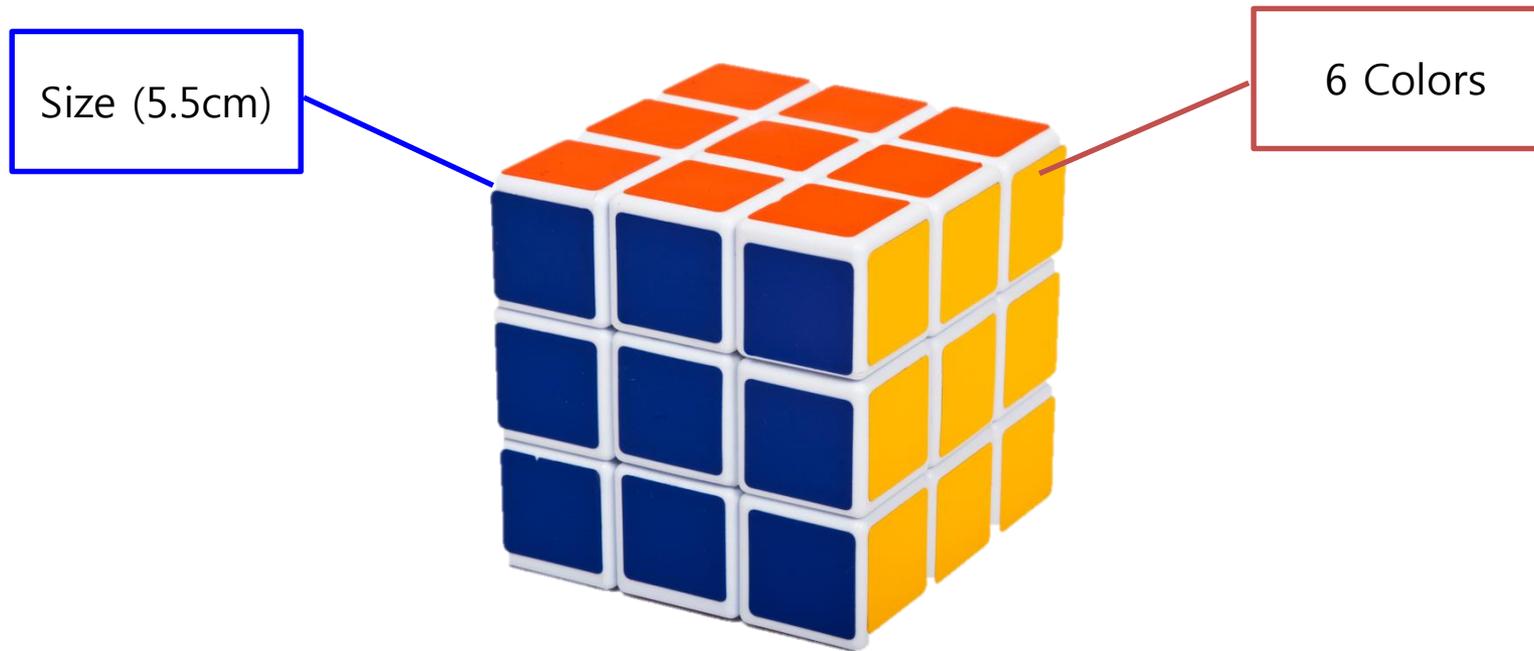


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# Real object for comparison

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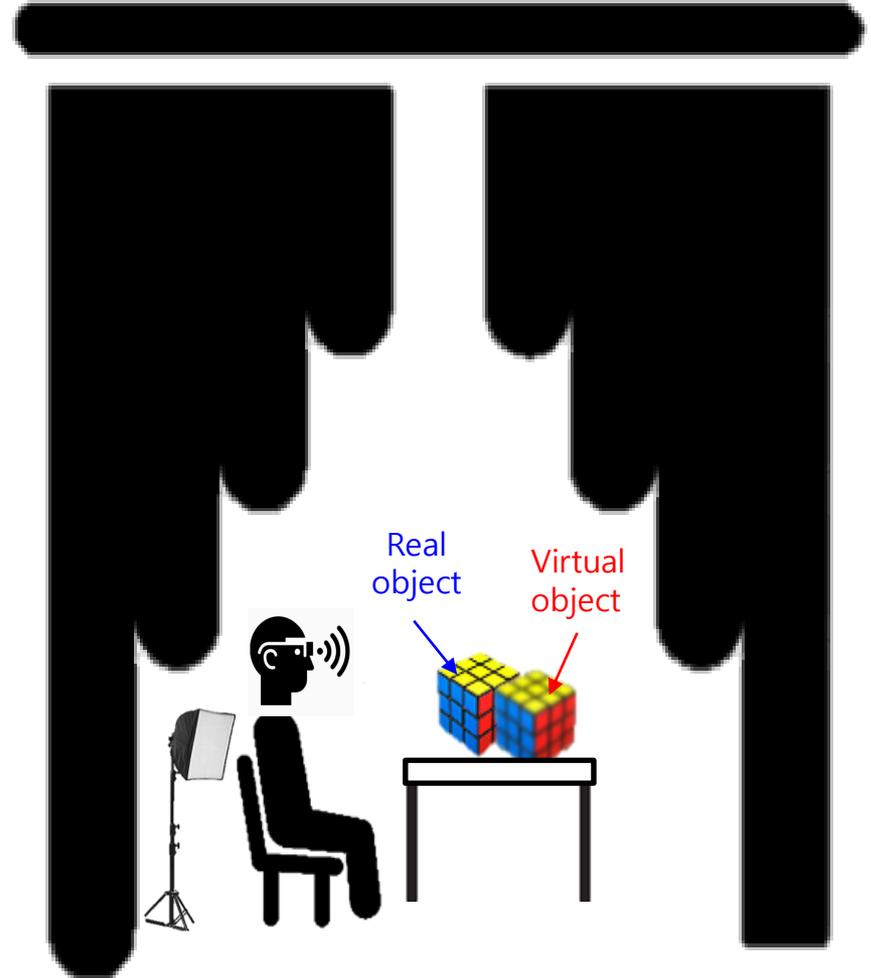
- Real Cube



✓ Use cubic puzzle for scale/color comparison

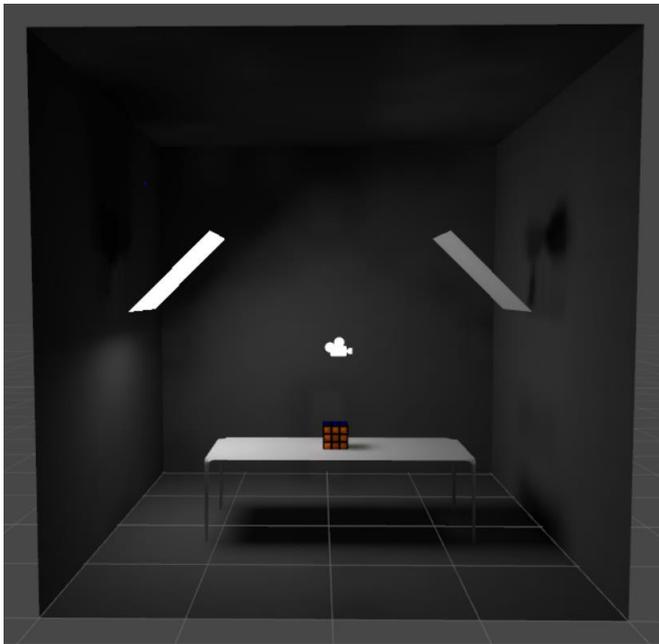
# Control variables

- **Light condition**
- ✓ Install curtain to match light condition
- ✓ Install studio lights
  - Same light condition

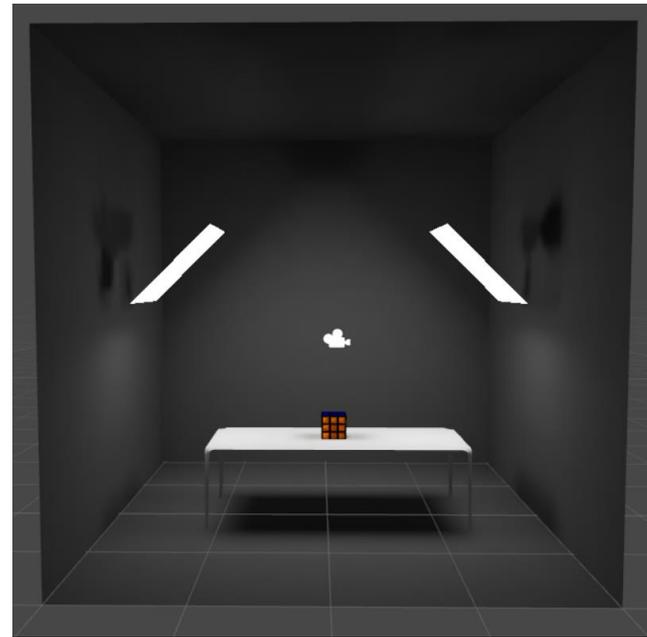


# Realistic Rendering

- ✓ Matching between real and virtual environments
  - Same lights and shadow
  - e.g. Create the same shadow in virtual environments as real-life shadow with the same light conditions



Light : #1 (left)

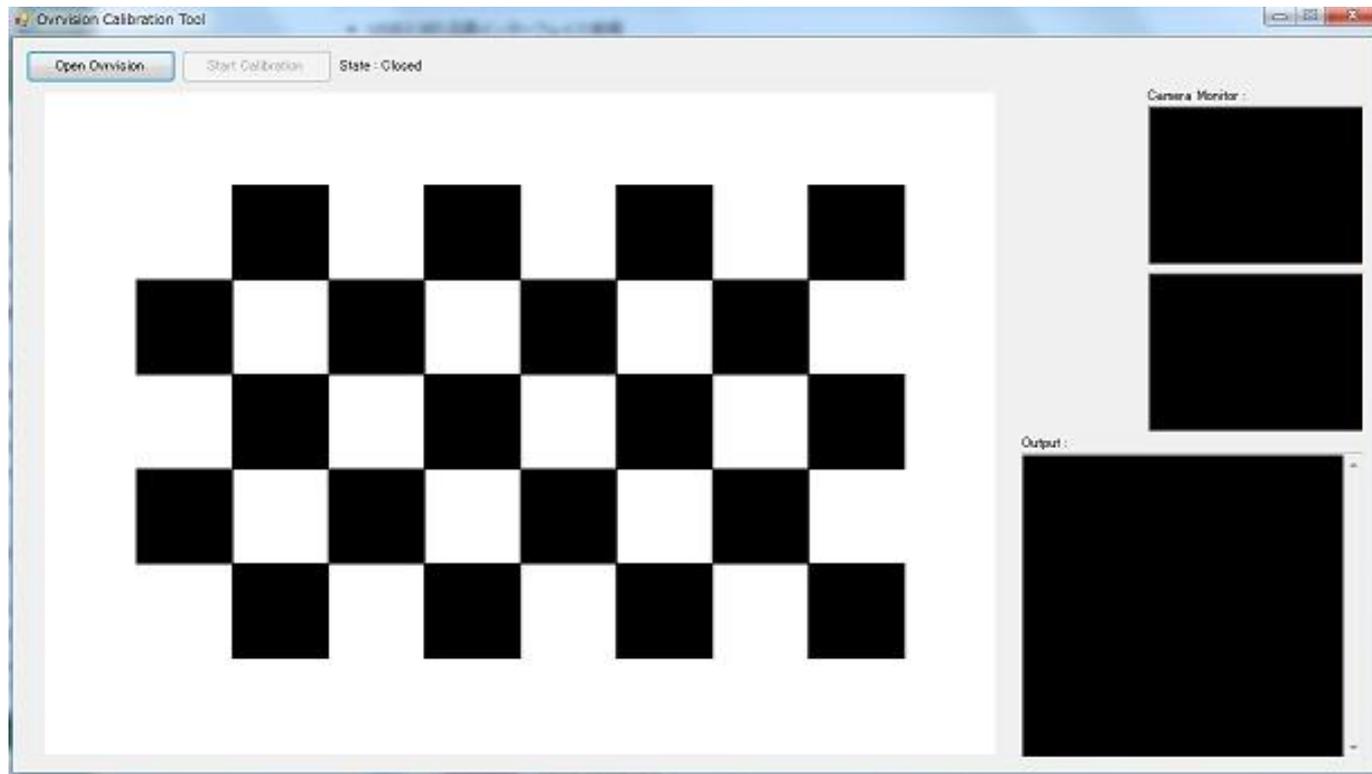


Light : #2 (left, right)

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# Stereo camera calibration for the video see-through HMD

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<https://www.youtube.com/watch?v=wSjqImFmxDY>

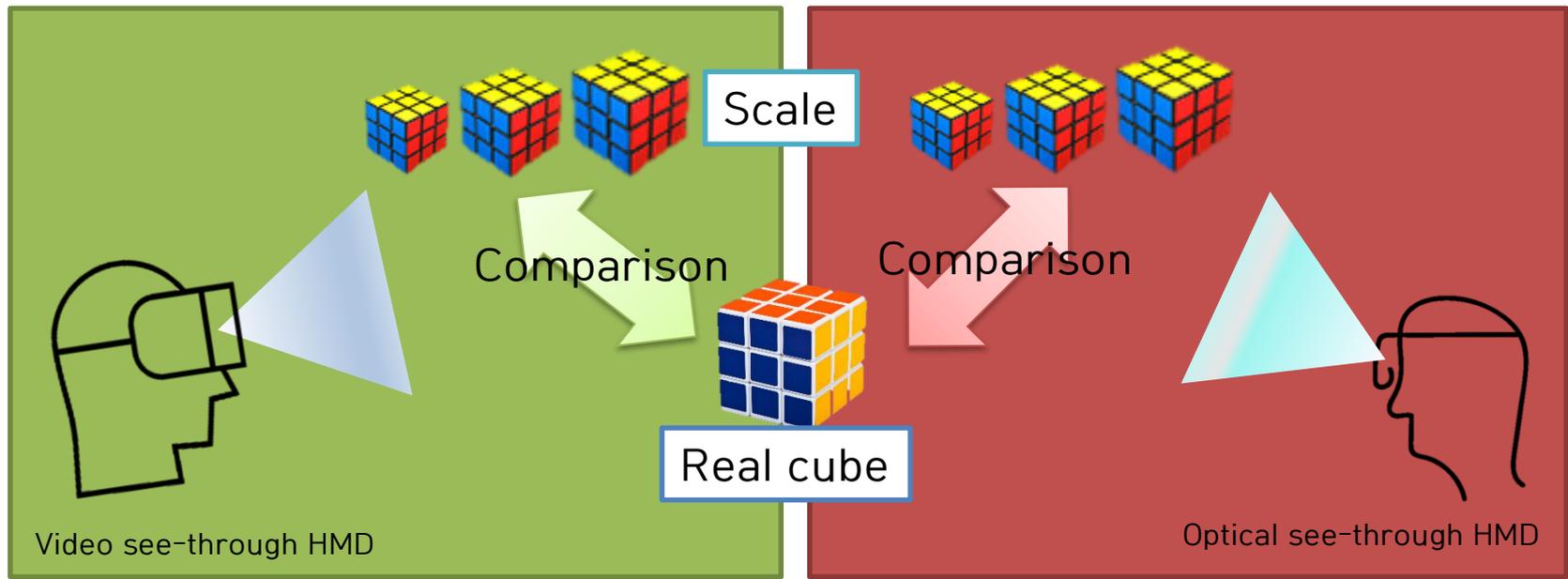
# Movie

이종 AR 디바이스간 인지 측정 실험

Video see-through HMD  
&  
Optical see-through HMD

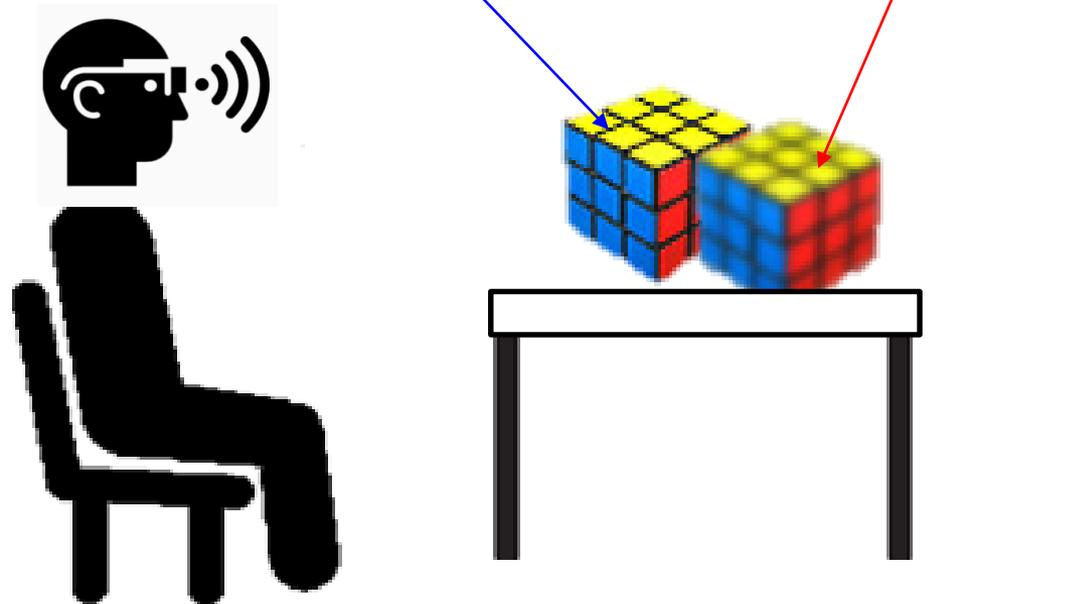
# Experiment 1: Scale perception

- ✓ Video see-through HMD VS. Optical see-through HMD
  - Independent variables: Display type
  - Dependent variables: User's scale perception
  - Participants: Total 60 people (Between-subjects, each 30 people)

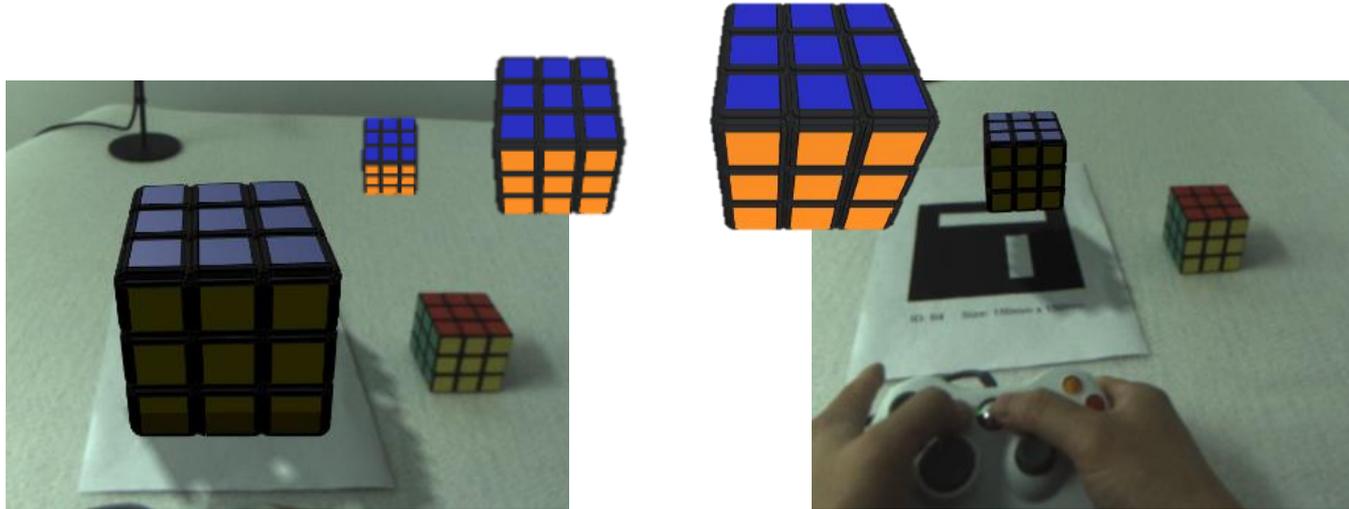


# Procedure

- ✓ Look at a real cube on a desk
- ✓ The subject is sitting on a chair in a fixed position and wears a MR HMD
- ✓ Compare the size with a virtual cube next to a real cube
  - for removing the user's mental load



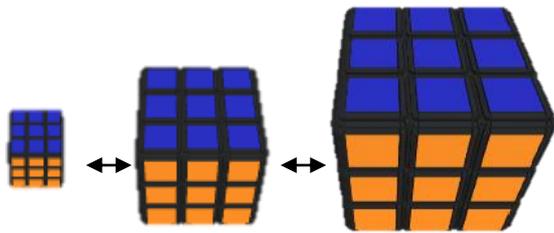
# Scale Adjustment



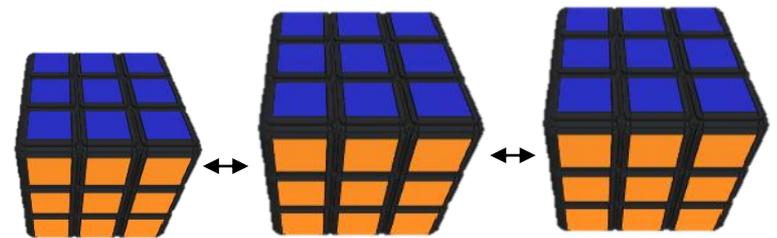
- ✓ Initial size of the virtual cube : 150mm x 150mm
- ✓ The size of the real cube : 55mm x 55mm
- ✓ Distance between the subject and the real cube (& the virtual cube)  
- 10cm, 40cm, 70cm (3 cases in our experiments)
- ✓ Scale adjustment using a joystick
- ✓ Until the subject controls the virtual cube equal to the size of the actual cube

# Joystick Interaction

✓ Try to fit the virtual cube to the same size as a real cube using a joystick



large scale



small scale



- ✓ Button 4/5: large scale control
- ✓ Button 6/7: small scale control

# Results: Scale

## Video see-through HMD

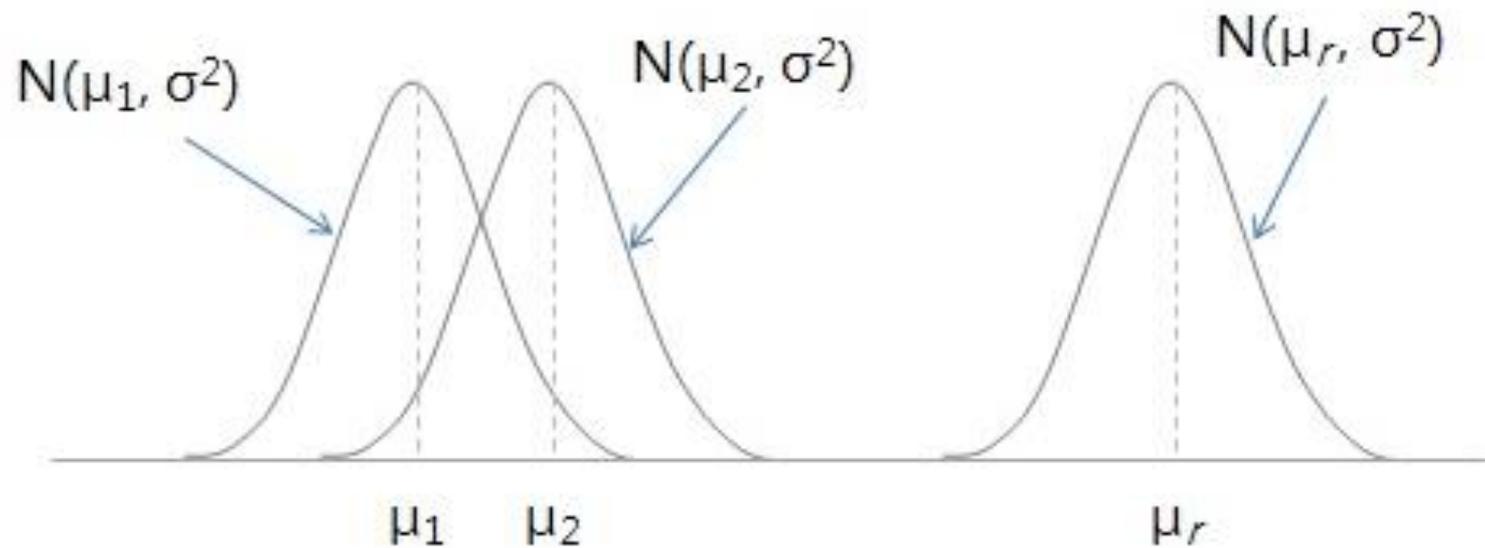
	10cm	40cm	70cm
피실험자 1	5.7cm	5.7cm	5.4cm
피실험자 2	5.4	5.4	4.4
피실험자 3	5.4	5.0	5.1
피실험자 4	4.9	5.3	4.8
피실험자 5	5.6	5.2	4.8
피실험자 6	5.4	5.7	5.4
피실험자 7	5.4	6.0	6.0
피실험자 8	6.6	6.0	6.5
피실험자 9	6.0	6.0	5.8
피실험자 10	30 people		6.2
피실험자 11			9.3
피실험자 12	5.9	7.4	6.5
피실험자 13	6.2	6.1	5.6
피실험자 14	7.0	6.4	6.2
피실험자 15	5.8	6.6	6.0
피실험자 16	6.4	6.5	6.4
피실험자 17	7.4	6.8	7.3
피실험자 18	6.2	6.2	5.9
피실험자 19	6.6	7.0	6.0
피실험자 20	5.9	6.3	6.1
피실험자 21	6.3	6.7	6.2
피실험자 22	7.2	7.3	5.9

# Results: Scale

## Optical see-through HMD

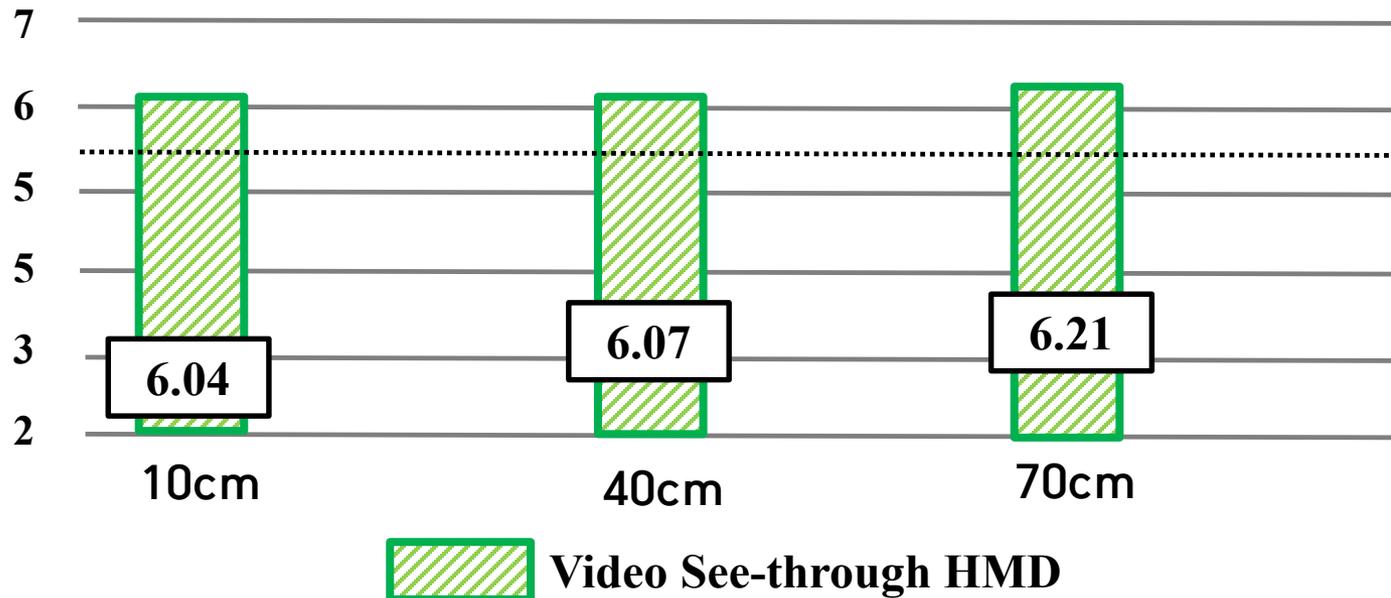
	10cm	40cm	70cm
피실험자 1	5.7cm	5.7cm	5.4cm
피실험자 2	5.4	5.4	4.4
피실험자 3	5.4	5.0	5.1
피실험자 4	4.9	5.3	4.8
피실험자 5	5.6	5.2	4.8
피실험자 6	5.4	5.7	5.4
피실험자 7	5.4	6.0	6.0
피실험자 8	6.6	6.0	6.5
피실험자 9	6.0	6.0	5.8
피실험자 10	30 people		6.2
피실험자 11			9.3
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피실험자 21	6.3	6.7	6.2
피실험자 22	7.2	7.3	5.9

# One-way Anova



# Results: Scale

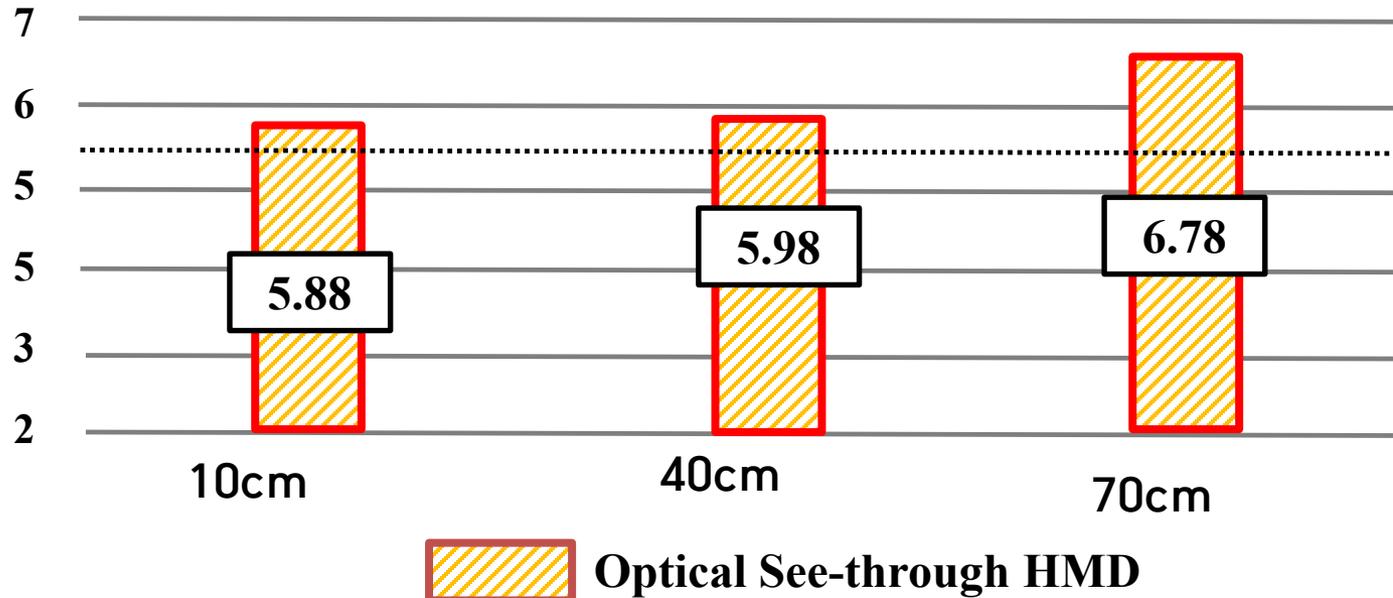
## Video : Difference by Distances



✓ No statistically significant difference by distances ( $p\text{-value} > 0.05$ )

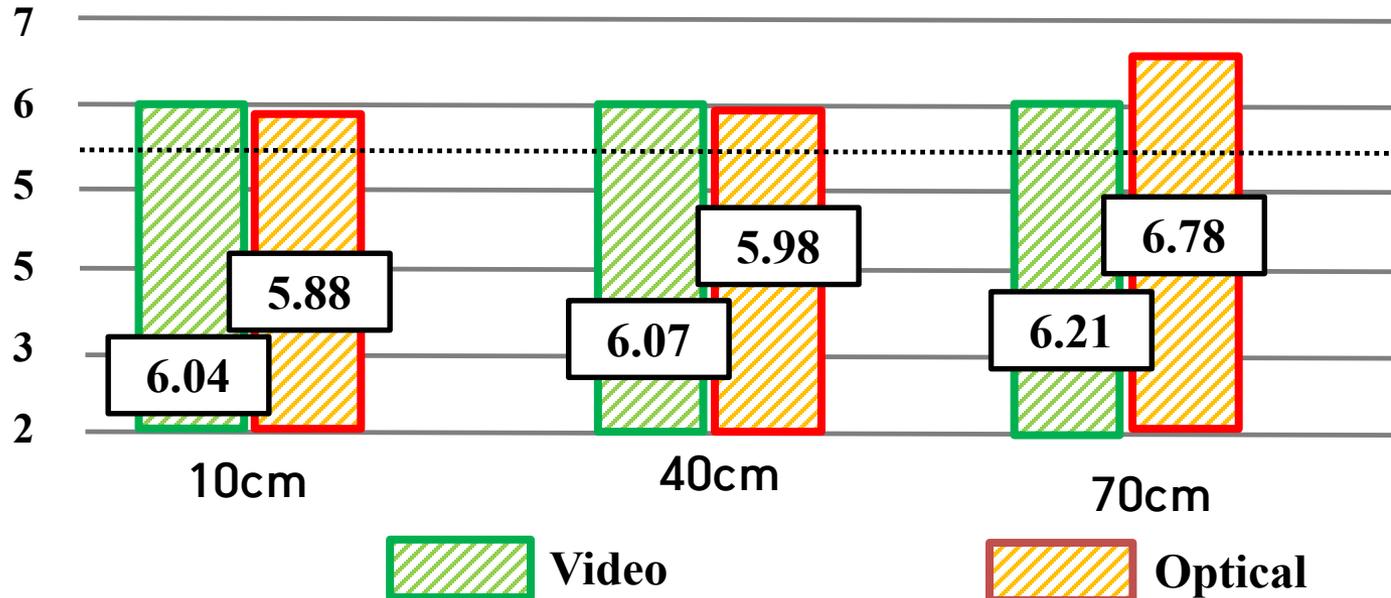
# Results: Scale

## Optical : Difference by Distances



✓ No statistically significant difference by distances ( $p\text{-value} > 0.05$ )

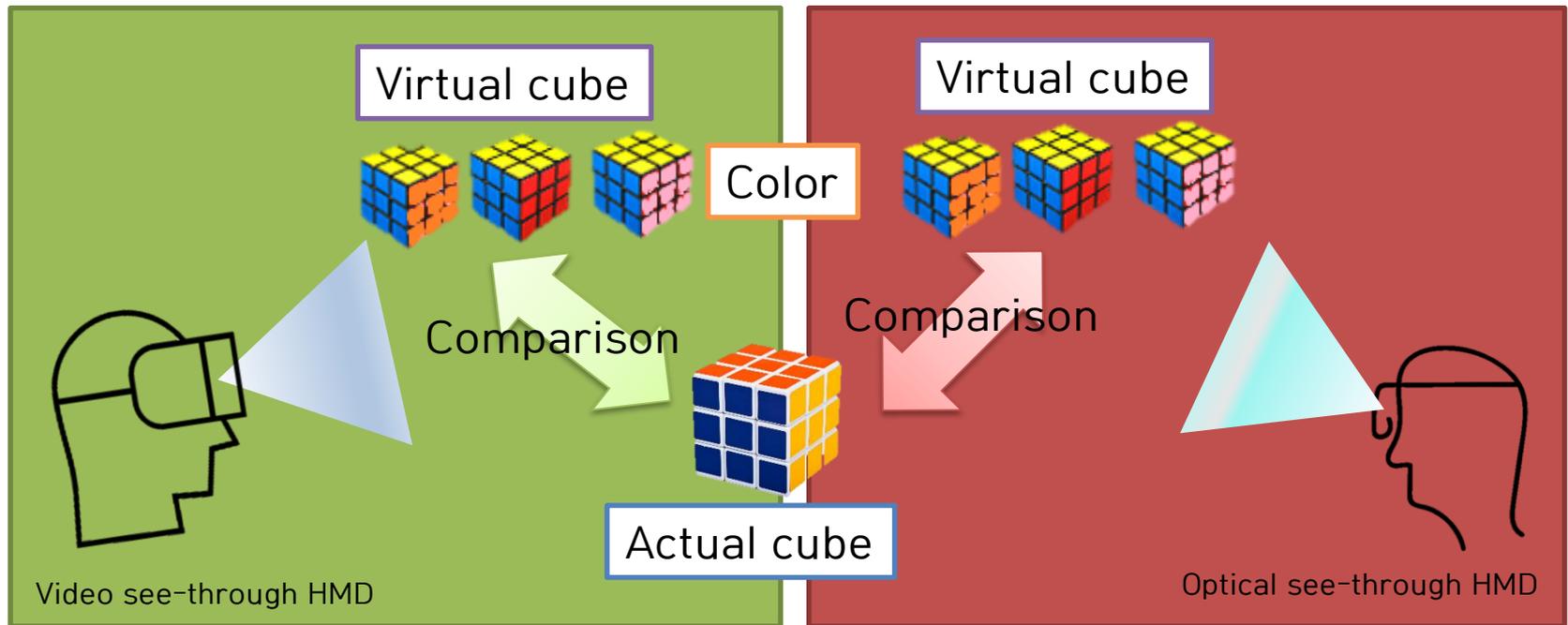
# Result: Scale



- ✓ No statistically significant difference by distances and display types ( $p$ -value  $> 0.05$ )
- ✓ But, Optical/video see-through HMD : tend to look bigger than the real cube
  - Under-estimate
  - e.g. In case of the video see-through HMD, people feel that the size 6.04 is equal to 5.5 cm.
  - Scale gain : video 1.11, optical 1.13

# Experiment 2: Color perception

- ✓ Video see-through HMD VS. Optical see-through HMD
  - Independent variables: Display type
  - Dependent variables: User's color perception
  - Participants: Total 60 people (Between-subjects, each 30 people)

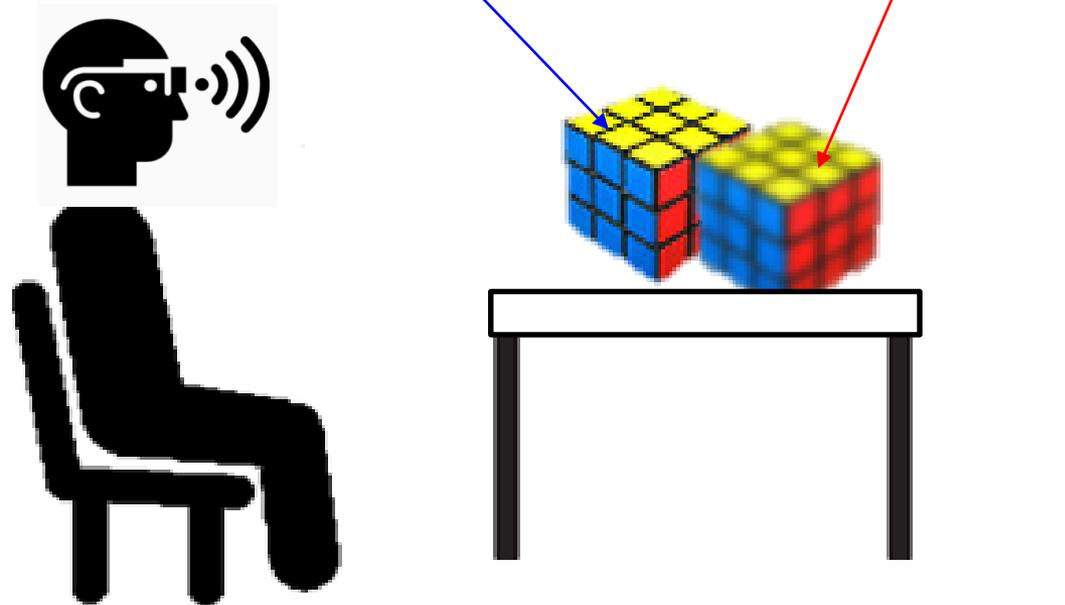


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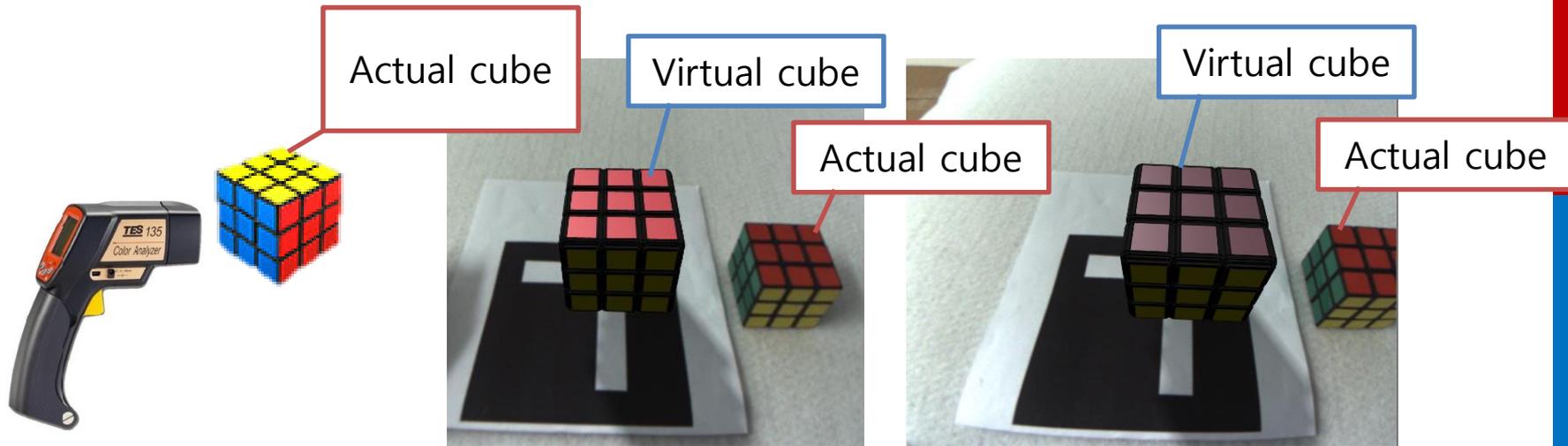
# Same Procedure

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- ✓ Look at a real cube on a desk
- ✓ The subject is sitting on a chair in a fixed position and wears a MR HMD
- ✓ Compare the size with a virtual cube next to a real cube
  - for removing the user's mental load

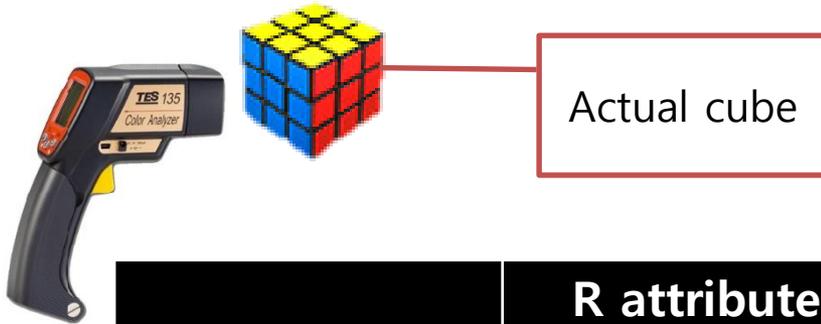


# Color Values



- ✓ Using a color meter, we estimated RGB colors in the real cube
- ✓ To create virtual cubes, each RGB is set to 7 levels.
  - Total 21 (R 7 + G 7 + B 7)
  - Adjusted material color values

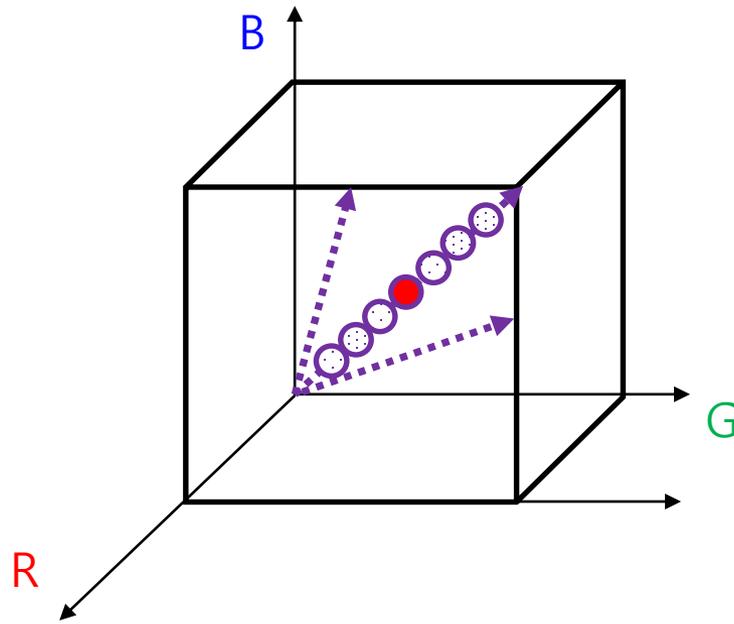
# Color Values



	<b>R attribute</b>	<b>G attribute</b>	<b>B attribute</b>
R section	189	30	44
G section	49	115	56
B section	57	90	142

- ✓ Average RGB values in the real cube
- ✓ Measured 5 times, Omit decimal point

# Color values for experimental setting



The formula for 3D distance is:  
 **$\text{Sqrt}(dr^2+dg^2+db^2)$**

Where dr, dg and db are the difference on the r, g and b axis.

- ✓ Create 7 virtual cubes with different colors
  - R/G/B 3 color : total 21 setting
- ✓ Try to select the virtual cube to the same color as a real cube using a wireless keyboard

# Color mapping table

	B1	B2	B3	B4	B5	B6	B7
R	38	40	42	44	46	48	50
G	50	52	54	56	58	60	62
B	121	128	135	142	149	156	163

	G1	G2	G3	G4	G5	G6	G7
R	27	28	29	30	31	32	33
G	100	105	110	115	120	125	<del>130</del> 130
B	118	82	86	90	94	98	102

	R1	R2	R3	R4	R5	R6	R7
R	162	171	180	189	198	<del>207</del> 207	216
G	43	45	47 <del>48</del>	49	51	53	55
B	51	53	<del>55</del> 55	57	59	61	63



# Color 측정 실험 결과

## Video see-through HMD

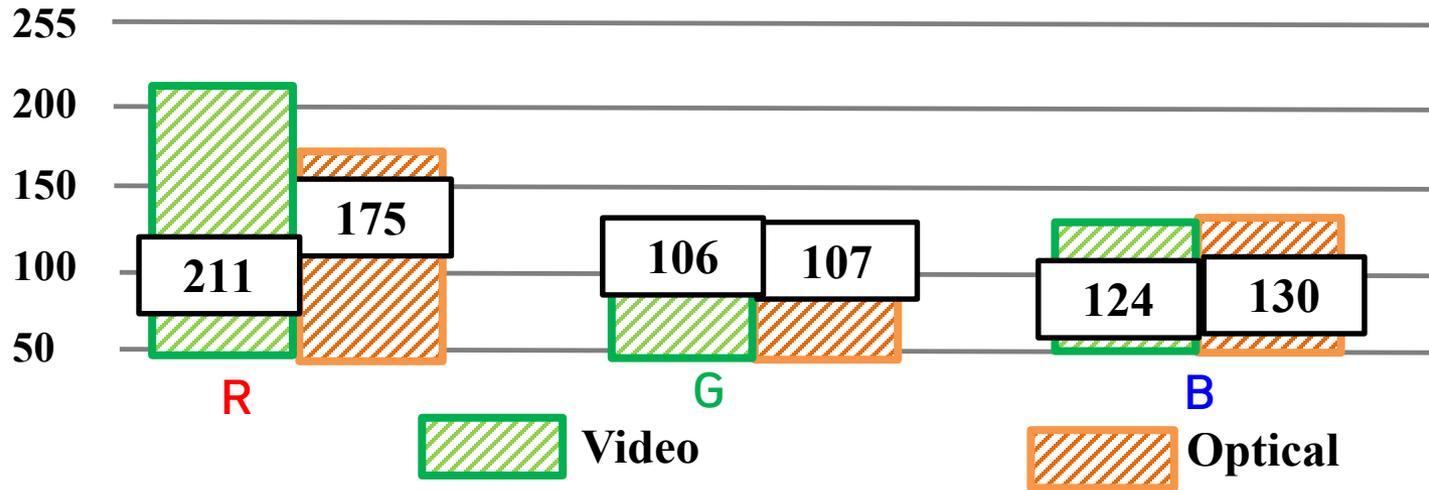
	R	G	B	
피실험자 1	7	1	1	
피실험자 2	5	2	2	
피실험자 3	6	1	2	
피실험자 4	6	1	1	
피실험자 5	6	2	1	
피실험자 6	6	2	1	
피실험자 7	7	3	1	
피실험자 8	6	1	1	
피실험자 9	7	2	1	
피실험자 10	30 people			1
피실험자 11			2	
피실험자 12	7	2	2	
피실험자 13	6	1	2	
피실험자 14	7	1	1	
피실험자 15	6	5	1	
피실험자 16	6	1	1	
피실험자 17	7	2	1	
피실험자 18	7	2	3	
피실험자 19	7	6	2	
피실험자 20	6	2	1	
피실험자 21	5	2	1	
피실험자 22	7	6	3	

# Color 측정 실험 결과

## Optical see-through HMD

	R	G	B
피실험자 1	7	1	1
피실험자 2	5	2	2
피실험자 3	6	1	2
피실험자 4	6	1	1
피실험자 5	6	2	1
피실험자 6	6	2	1
피실험자 7	7	3	1
피실험자 8	6	1	1
피실험자 9	7	2	1
피실험자 10	30 people		1
피실험자 11			2
피실험자 12	7	2	2
피실험자 13	6	1	2
피실험자 14	7	1	1
피실험자 15	6	5	1
피실험자 16	6	1	1
피실험자 17	7	2	1
피실험자 18	7	2	3
피실험자 19	7	6	2
피실험자 20	6	2	1
피실험자 21	5	2	1
피실험자 22	7	6	3

# Results : Color

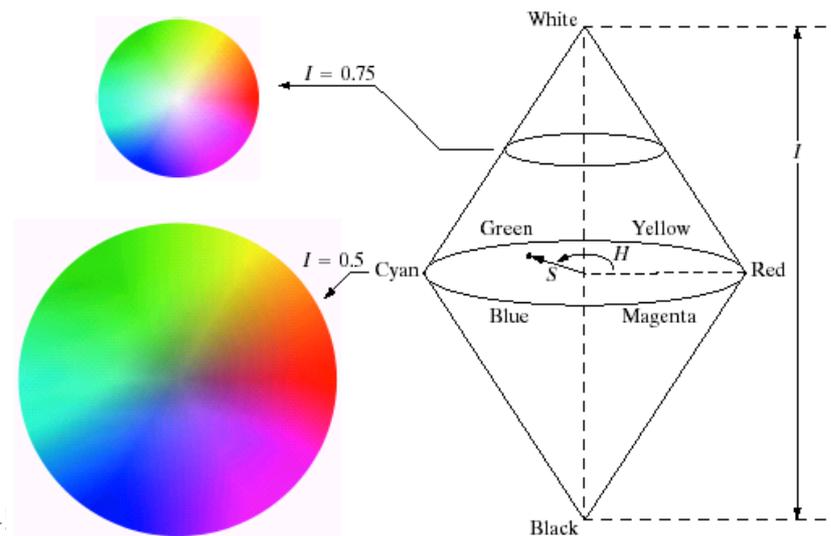
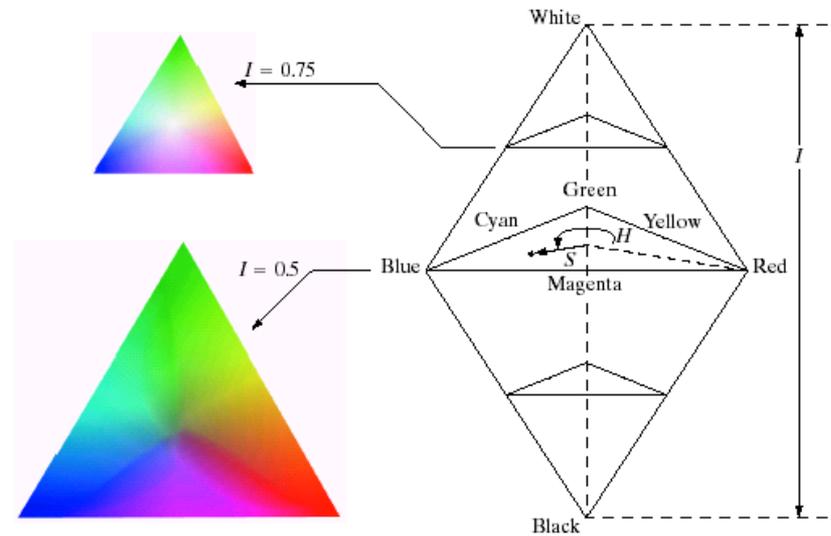


- ✓ Red color only had statistically significant difference by display types (p-value < 0.05)
  - Initial Red color :189 → result : 211(Video), 175(Optical)
- ✓ In case of the optical see-through HMD, people feel that red 189 is equal to 175.
  - color under-estimation

# Future works

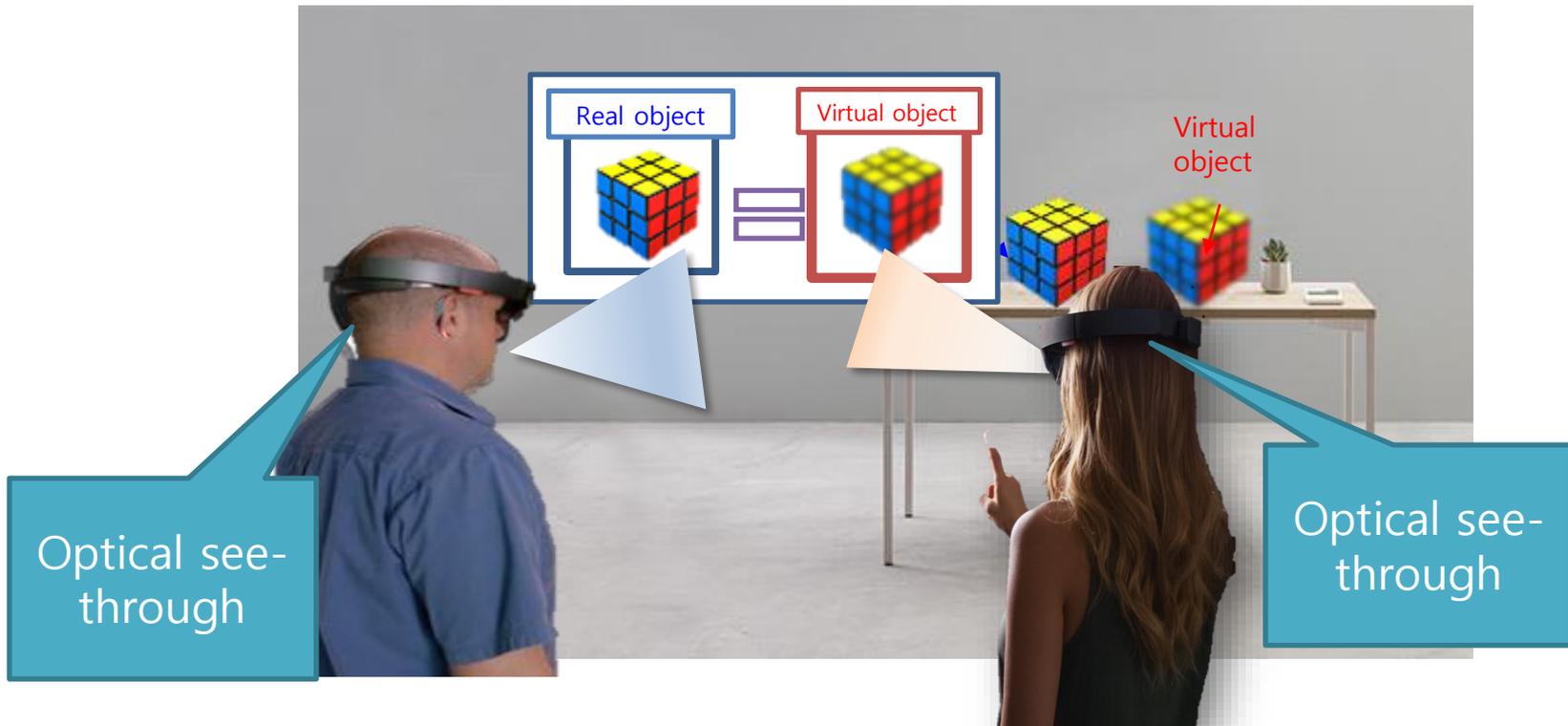
# Color values for experimental setting

- HSI
  - Hue, saturation, intensity
  - Correspondence to the way humans describe and interpret color
- Optical see-through
  - Lower intensity
- Video see-through
  - Higher intensity



# AdaptAR

- ✓ Participants perceptions of virtual object according to **same** mixed reality devices (e.g. color or scale)



- ✓ e.g Disparity depending on each person

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# Acknowledgement

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- This research is supported by Ministry of Culture, Sports, and Tourism (MCST) and Korea Content Agency (KOCCA) in the Culture Technology (CT) Research & Development Program 2018 (본 연구는 문화체육관광부 및 한국콘텐츠진흥원의 2018년도 문화기술연구개발 지원 사업으로 수행되었음)