Virtual Reality / Augmented Reality Devices and PC Cooperation

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Part 2	**VR Product Development Trend Update**
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Part 4	**AR/VR's Potential Market**

Part 1 : What's AR / VR

What's AR / VR

AR

Image credit: credencys

VR

Image credit: Samsung

> With AR, users continue to be in touch with the real world while interacting with virtual objects around them. (Mixed Reality is defined as Augmented Reality in presentation)

> With VR, the user is isolated from the real world while immersed in a world that is completely fabricated.

Augmented Reality (AR)

Augmented reality combines digital information with actual surroundings.
It enhances our visual and hearing by adding graphics and sound onto actual surroundings in real time.

Example: Google Glass, Pokémon Go Mobile Application

Mixed Reality (MR)

Mixed reality merges the with the real world to create a connected environment. AR objects are more static, whereas MR is able to create spatial experience. For instance when you lean forward, the virtual object would appear closer.

Example: Microsoft HoloLens

Virtual Reality (VR)

Virtual reality is a technology that creates the entire environment and allows the user to interact with the artificial world. Along with sensors, 3D graphics and surround sound, the content is able to make users feel as though the fabricated object or environment is real.

Example: Oculus Rift / HTC Vive

Product Categories of AR / VR

Virtual

Hand-Held VR

(*Smartphone Adaptor Headsets*)

Cardboard

Image credit: Google

Gear VR

Image credit: Samsung

Hand-Free VR

(*Integrated display headsets*)

Oculus Rift

Image credit: Oculus

HTC Vive

Image credit: HTC

Sony PS4 VR

Image credit: Sony

Real

Hand-Held AR

Image credit: credencys

Image credit: credencys

Hand-Free AR

Microsoft HoloLens

Image credit: Microsoft

Google Glass

GL/SS

Image credit: androidcommunity

Hand-Held

Hand-Free

[Note] AR : Augmented Reality ; VR : Virtual Reality

Part 2 : VR Product Development Trend Update

Why Virtual Reality's Commercial Impact is Coming

Evolution of Virtual Reality	
Past (1962)	**Now (2016)**

Past (1962)

Worldwide 1st Virtual Reality Device by Morton Heilig

Image Source: http://www.avadirect.com//

Now (2016)

Sony PlayStation4 VR

Image credit: Sony

HTC Vive

Image credit: HTC

Oculus Rift

Image credit: Oculus

- **Following technological advancements allow virtual reality to be commercialized GPU, OLED display, Motion Sensor, Battery, Game Engine**

# Worldwide Virtual Reality Device Shipment Forecast

Without head tracking function, VR device is just a personal 3D display device, so we remain conservative on the demand for smartphone adaptor headsets.
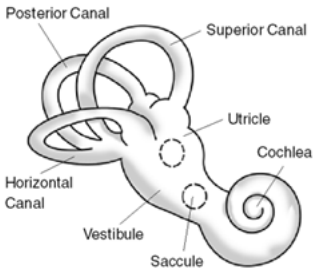
[Note] 3D：3 Dimensions
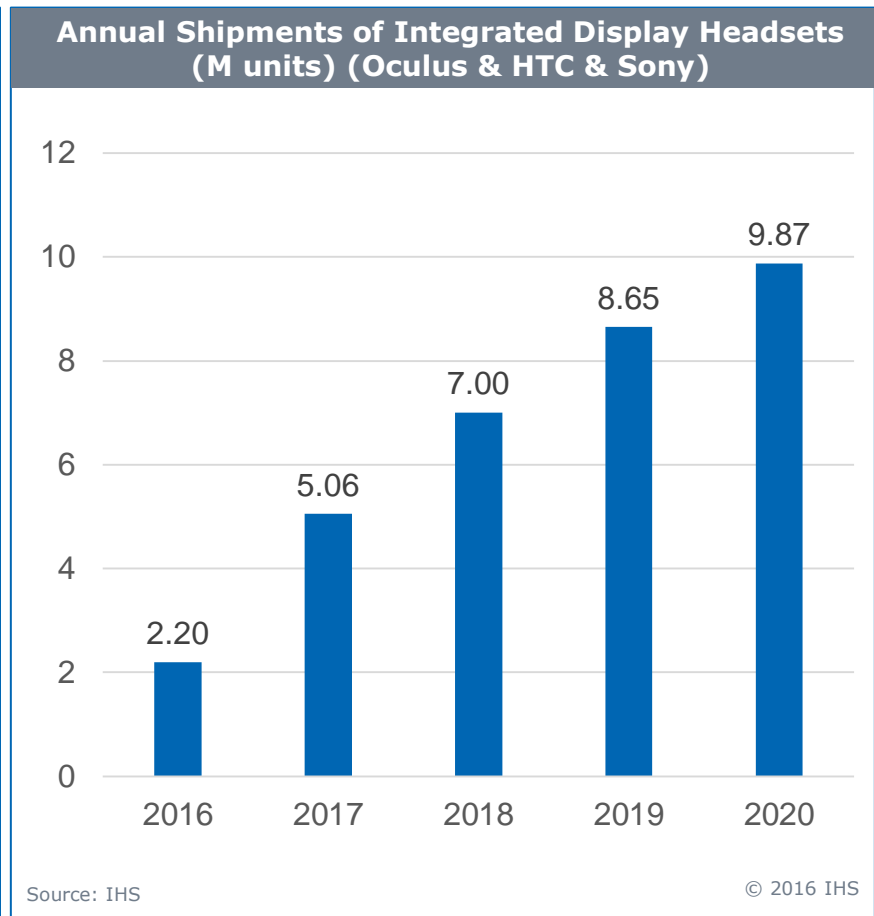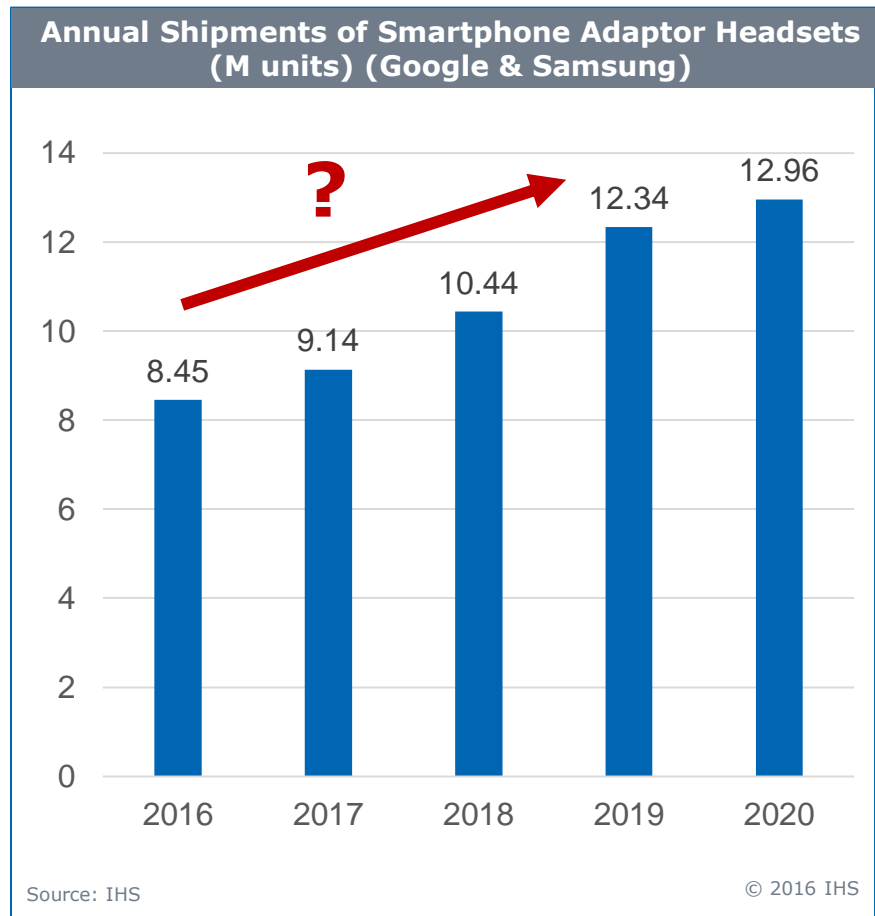
Sensory Integration Introduction

- Children under *16* whose vestibular system have not attain maturity completely.

- Ears are very sensitive on *audio performance* (surround-sound).

Motion Sickness – Conflicting inputs from visual sense, vestibular sense, and proprioception.
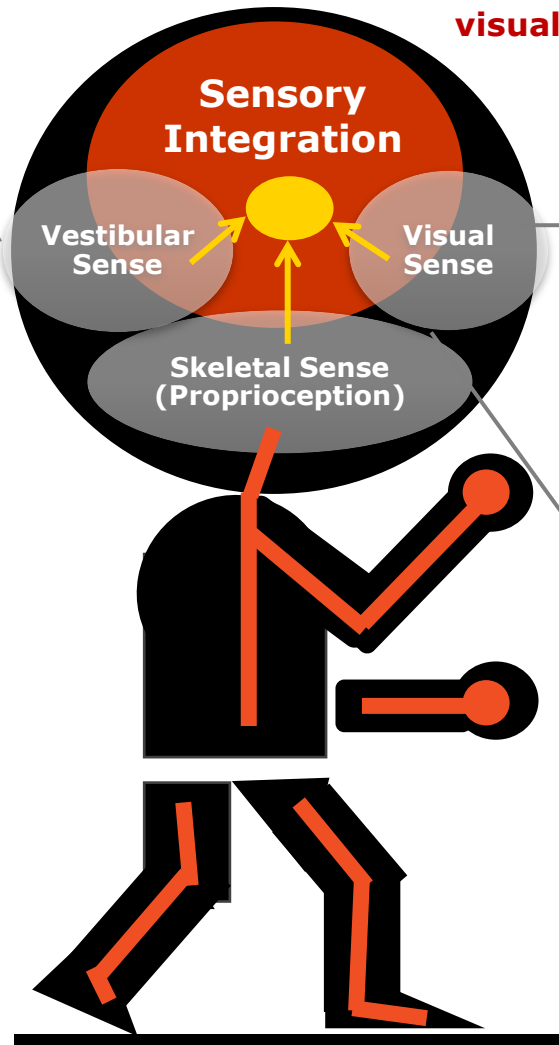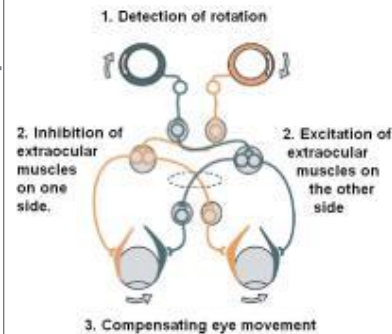
Vestibular System

The vestibular system consists of three semicircular canals and the vestibule, and the three semicircular canals are responsible for detecting rotational movements while the otolithic organs in the vestibule detect linear acceleration (movement in a straight line).

Image and Data Source: http://www.web-books.com/eLibrary/Medicine/Physiology/Ear/Ear.htm

Sensory Integration

Vestibular Sense

Visual Sense

Skeletal Sense (Proprioception)

Vestibulo-ocular reflex (VOR)

1. Detection of rotation
2. Inhibition of extraocular muscles on one side.
2. Excitation of extraocular muscles on the other side.
3. Compensating eye movement

[Vestibulo-ocular reflex] A rotation of the head is detected, which triggers an inhibitory signal to the extraocular muscles on one side and an excitatory signal to the muscles on the other side. The result is a compensatory movement of the eyes

Image and Data source: Wikipedia

How to have a perfect match between head track and eyes movement is very important for VR device.

Immersion - 3 Dimensional Sense of Space
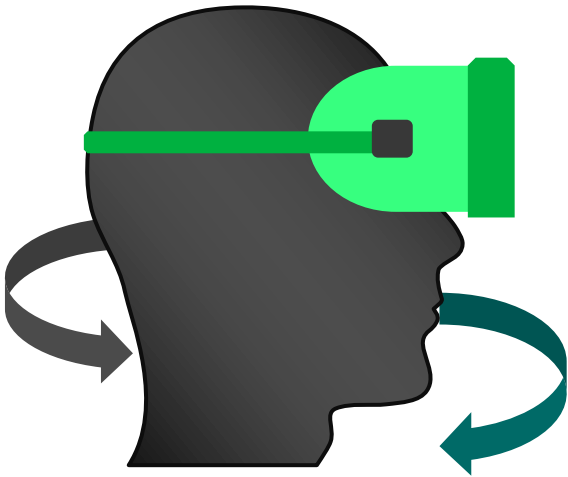

Arm Length

Height

Floor   Floor
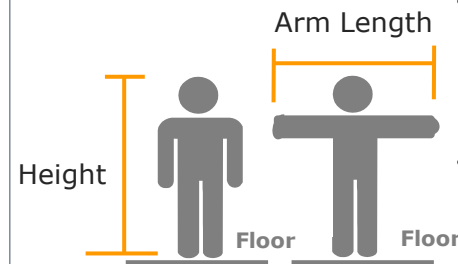
- **Not only ears (vestibular sense), 3 dimensional sense of space is also constructed by proprioception.**
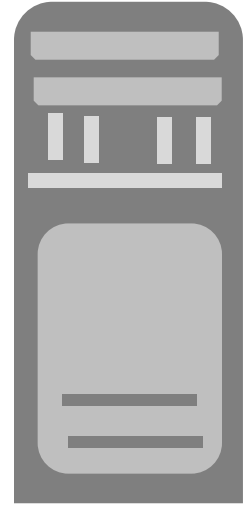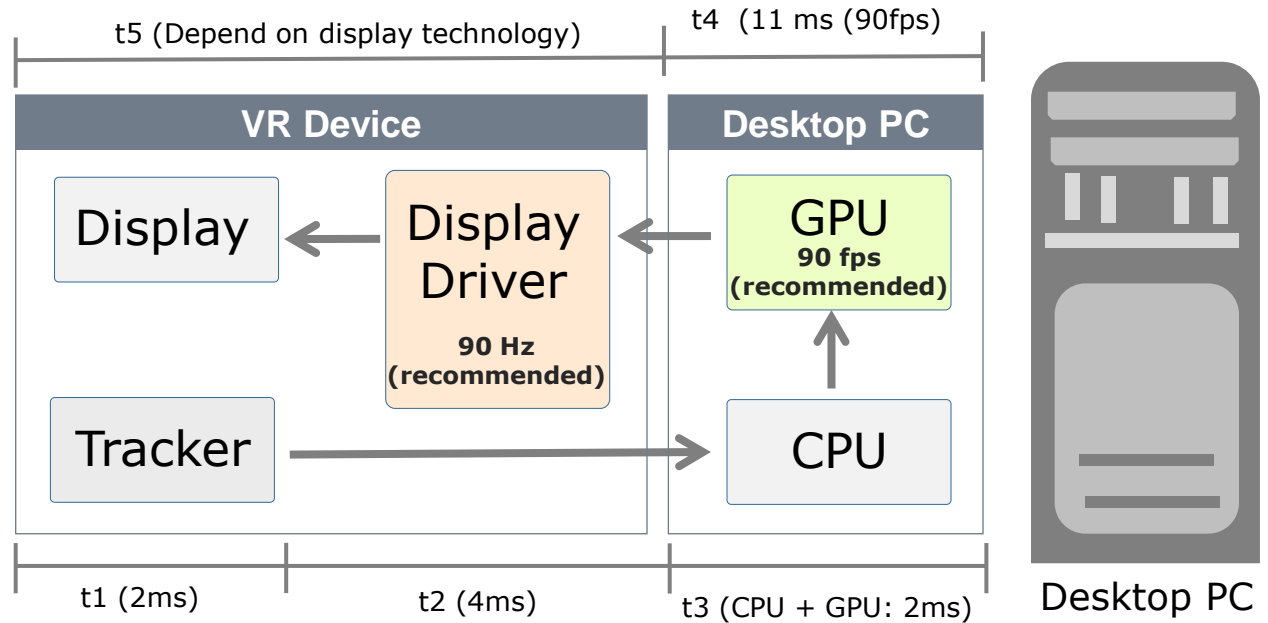
- **Immersion performance of VR device depends on floors**

Why VR Device Adopts OLED Display

Latency Time: Less than 20ms
(t1 + t2 + t3 + t4 + t5)

t5 (Depend on display technology)

t4 (11 ms (90fps)

VR Device		Desktop PC

Display

Display Driver

90 Hz (recommended)

GPU
90 fps (recommended)

Tracker

CPU

t1 (2ms)

t2 (4ms)

t3 (CPU + GPU: 2ms)

VR Device

Desktop PC

Why VR device adopts OLED display
• Reason 1 : Quick response time
• Reason 2 : No display persistence issue
• Reason 3 : No blue light issue
• Reason 4 : Wider color gamut range
• Reason 5 : Slim and light

OLED display's potential issue
• Issue 1: Limit on PPI upgrade
• Issue 2 : Limit on OLED supply capacity
• Issue 3 : Limit on qualified OLED driver vendor and different driver IC manufacturing process between OLED and LCD.

[Note] PPI : Pixels Per Inch ; GPU: Graphics Processing Unit ;
CPU : Central Processing Unit ; OLED : Organic Light-Emitting Diode

Viewing Quality Loss – Barrel Distortion

Display (Barrel Distortion)

Warped image required to match optics – enlarged in the center and compressed in the periphery

Optics

Transforms light from display to a wide field of view focused on the eye

User's View

User sees correctly proportioned scene with wide filed of view

Image & Data source: ihttp://www.tomshardware.com/news/nvidia-gameworks-vr,29197.html

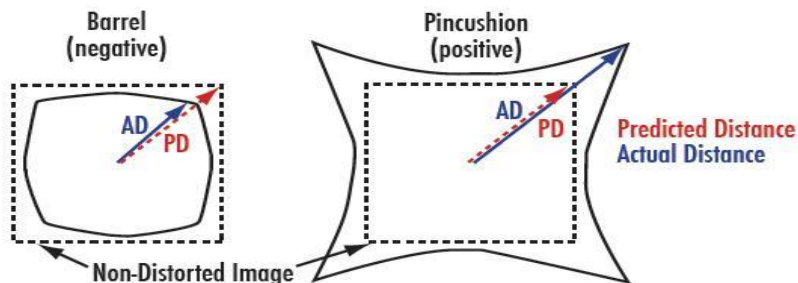## Why VR devices need higher PPI display

Image Source: http://www.edmundoptics.eu/

$$Distortion\ (\%) = \frac{AD - PD}{PD} \times 100$$

Barrel distortion causes loss of viewing quality, affecting approx. 30%~50% of the overall PPI loss. Therefore, VR display requires at least 600 PPI to account for the loss.

[Note] PPI : Pixels Per Inch ; VR : Virtual Reality

OLED Display's PPI Limit Issue

VR OLED Display List			
Panel Spec	**VR OLED Display**		
Size	3.61 inch	3.5 inch	3.81 inch	3.58 inch
Resolution	1080 (RG/BG) x 1200	1440 (RG/BG) x 1600	1080 (RG/BG) x 1200	1920 (RG/BG) x 2160
PPI	447 ppi	616 ppi	423 ppi	806 ppi
Frame Rate	90 Hz	90 Hz	90 Hz	90 Hz
Response Time	< 1 ms	< 1 ms	< 1ms	< 1ms
MP schedule	MP Ready	2H'17	2017	TBD

Source: IHS

© 2016 IHS

Display Requirements

- **Frame Rate: 90 Hz above**

- **Resolution : 1080P** （**Per Eye**）

- **Low Persistence : < 3ms**

- **FOV : 80 degree above**

Solution of OLED Display's PPI Limit Issue : Eye Tracking Technology

Image Source: http://www.wikiwand.com/
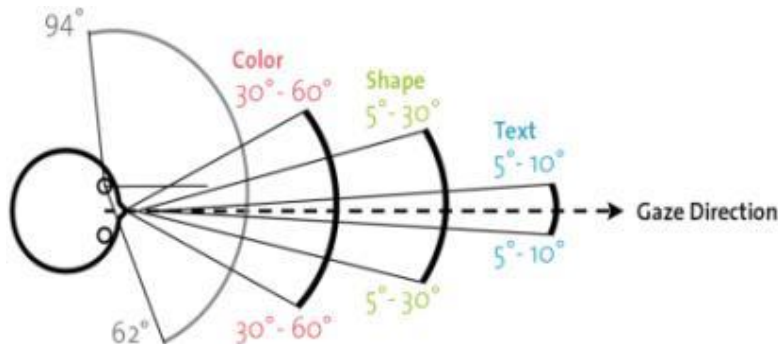
- **The human eye's vision field for eye-focus is 5 to 10 degree.**

- **With eye tracking technology and image upscaling technology, VR headset designers can overcome OLED display's PPI limitation issue. Also, they don't need to use expensive high PPI OLED display.**

[Note] PPI : Pixels Per Inch ; OLED : Organic Light-Emitting Diode
FOV : Field of View; MP : Mass Production; VR : Virtual Reality

VR Usage Scenario Analysis – Single Forward Tracker

1. Controllers replace keyboard and mouse (data input) while using VR devices.
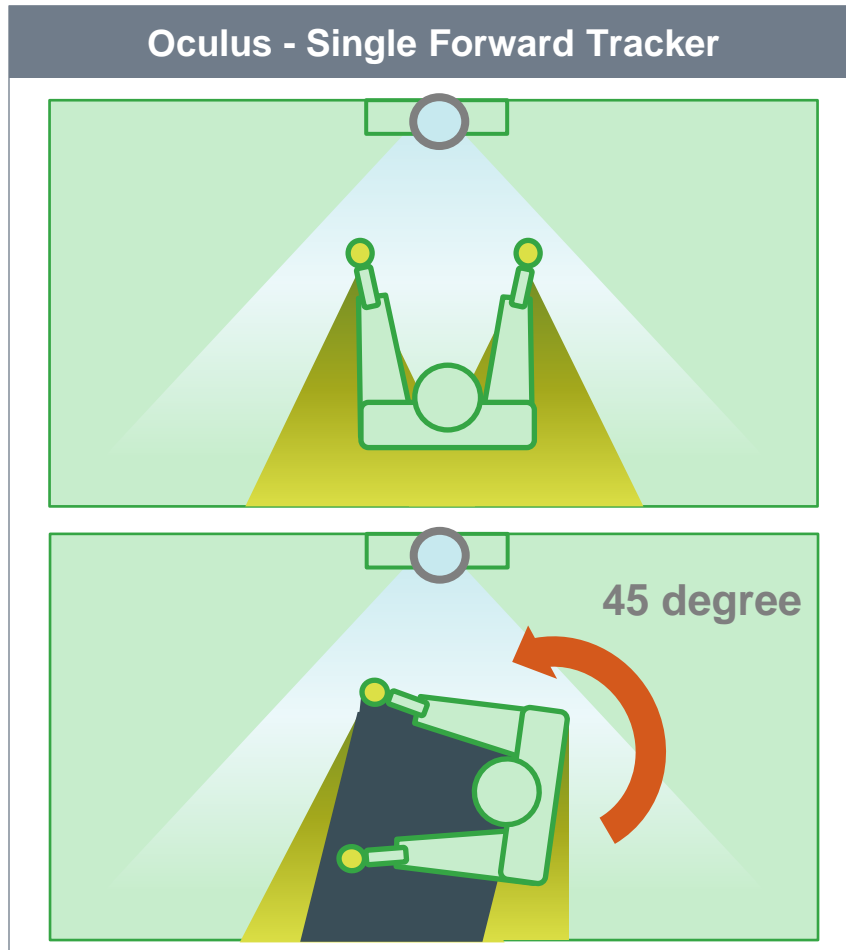**2. VR usage scenario is defined by controller tracking technology.**

Oculus - Single Forward Tracker

45 degree

Image credit: Oculus

Setting the scene of Playing Oculus VR:
User's study room, office, amusement equipment (ex : fighter jet)

Conditions of Playing Oculus VR:

1. Need Oculus VR–Ready–PC and camera

2. User can't turn around over 45 degree while holding controllers.

VR Usage Scenario Analysis – Two Opposing Tracker

Different tracker design impacts software development, especially software developers want to develop one game for multi-platforms (ex: One game for Oculus and HTC).

HTC - Two Opposing Tracker

360 degree

Image credit: HTC

Setting the scene of Playing HTC VR:
In-door environment (Room-scale : 5 m x 3 m)

Conditions of Playing Oculus VR:

1. **Need HTC VR-Ready-PC, base stations, and controllers**

2. **User can have 360 degree turn around while holding controllers.**
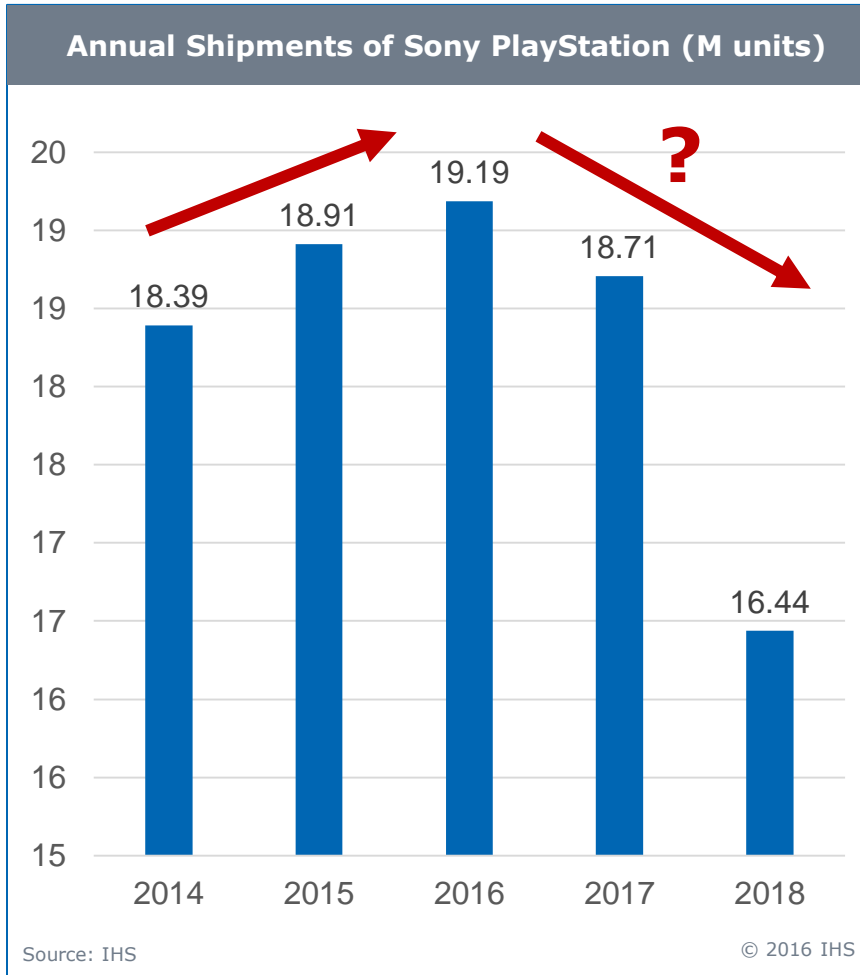
Sony PS4 (Play Station 4) VR Analysis (1/2)

Annual Shipments of Sony PlayStation (M units)

Chart values:
- 2014: 18.39
- 2015: 18.91
- 2016: 19.19
- 2017: 18.71
- 2018: 16.44

?

Source: IHS

© 2016 IHS

Image Source: Sony

[Why Sony Needs VR Device]

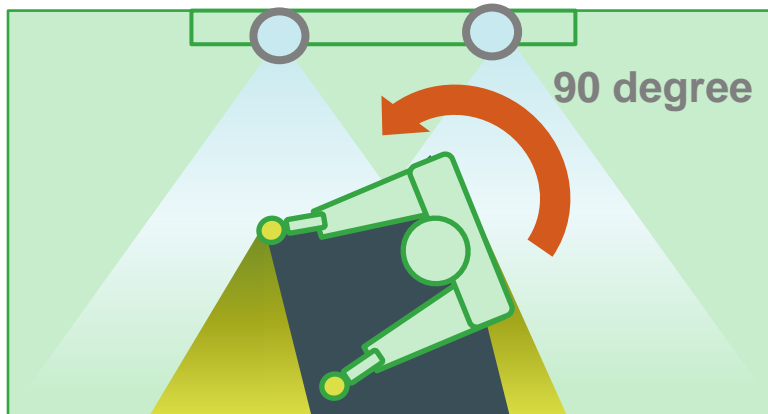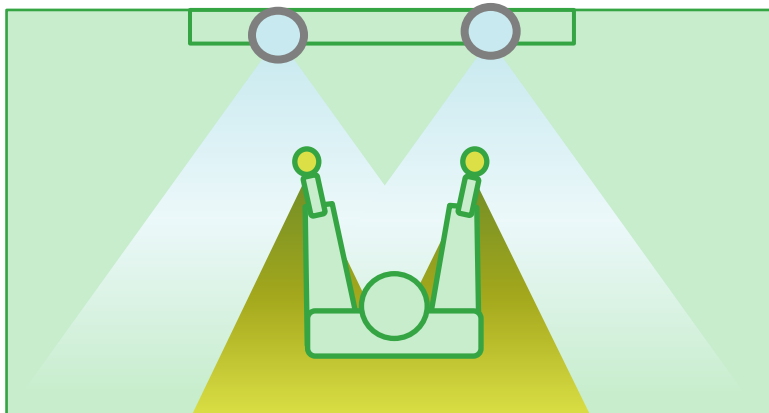**Reason 1 : Weak replacement demand of Sony PlayStation game console (hardware) after 2016.**

Reason 2 : Over qualified PlayStation4 for current game software requirement

Due to above two reasons, Sony wants end-users to spend money on Sony PS4 VR, camera, and controllers by VR application.
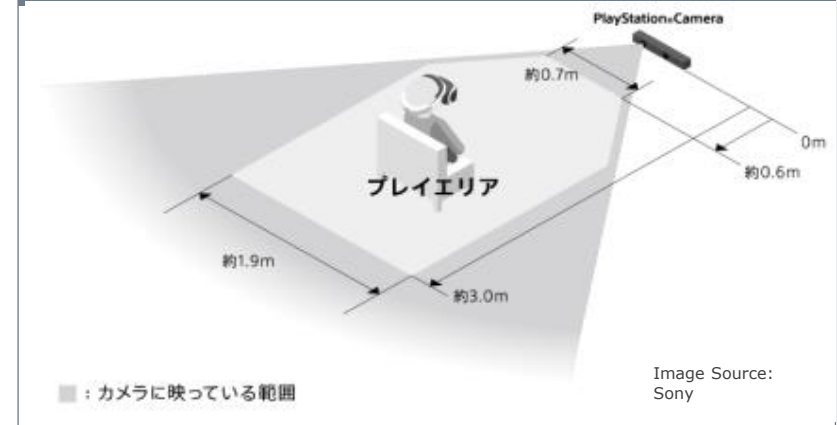
Sony PS4 (Play Station 4) VR Analysis (2/2)

Standing Play VR can have better immersion experience. However, if you can't turn around over 90 degree, you only can sit on seat to play VR device. (Just like a personal TV device).

Sony PS4 VR – 2 Forward Tracker

90 degree

Activity Area of Using Sony PS4 VR

PlayStation Camera

約0.7m

0m

約0.6m

プレイエリア

約1.9m

約3.0m

■ : カメラに映っている範囲

Image Source: Sony

Setting the scene of playing Sony PS4 VR : User's living room (Room-scale : 3 m x 1.9 m)

Conditions of Playing Sony PS4 VR:

1. One Sony PS4 only can support one VR device

2. User can't turn around over 90 degree while holding PS Move (controllers).

Backpack VR PC – Wireless Solution ?

MSI Backpack VR PC Specification

Image credit:: MSI

- CPU : Intel **Skylake Core i7 Processor**
- GPU : Nvidia GTX 1070
- **Weight : around 3.6 kg**
- **Battery Life time : around 1.5 hours**

Before wire specification improved, backpack PC becomes current wireless solution.

However, not only heavy (3.6 kg) and short battery life time (1.5 hours) issue, Backpack PC also have thermal issue which is caused by GPU.

At this moment, NVidia doesn't have any improvement plan on VR GPU's thermal issue because Nvidia prefers to spend more GPU development resources on automotive application instead of VR application.

Without NVidia's support , VR GPU's thermal issue will still impact portable VR device development.

VR Device - Wire Specification Review			
VR Experience	**Good**	**Great**	**Perfect**
Video Spec	4K full view with 2D Video (resolution : 3840 x 1920)	12K full view with 2D Video (resolution : 11520 x 5769)	24K full view with 3D Video (resolution : 23949 x 11529)
View Spec (Per Eye)	960 x 960 (FOV : 90 degree)	3840 x 3840 (FOV : 120 degree)	7680 x 7680 (FOV : 120 degree)
PPD (Pixel Per Degree)	11	32	64
Compression ratio (by H.265)	120	160	200 (2D video), 350 (3D vide)
FPS (Frames Per Second)	30	60	120
Wire Spec Requirement (per second)	about 25 Mbps	about 400 Mbps	about 3 Gbps

Source: IHS © 2016 IHS

[Note] FOV : Field of View

Google VR Strategy Analysis : Cardboard vs. Daydream

Forward View
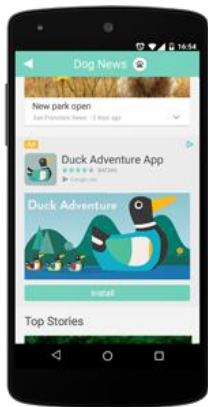
Forward / Up / Down / Left / Right View

x **5**

Advertising Amount

Image credit:: Google

Image credit:: Google

Cardboard vs. Daydream		
Platform	Cardboard	Daydream
Type	Entry Level of Smartphone VR Platform	Advanced Level of Smartphone VR Platform
Smartphone Requirement Recommend	For All Smartphones	For High Performance Smartphones (ex: Smartphone : Pixel & Pixel XL)
VR Experience Time	Short VR Viewing Experience	Longer VR Viewing Experience by Abundant VR contents
Headset Accessory Requirement	Low Cost (ex: Cardboard)	Higher Quality of Headset Accessory

Source: IHS

© 2016 IHS

**Google Strategy:
Increase advertising amount by VR application**

**Google Action:
Offer more free or attractive VR contents by 360 degree camera**

**Potential Issue:
Motion sickness issue**

[Note] VR : Virtual Reality

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Part 3 : AR Product Development Trend Update

Microsoft HoloLens Review (1/2)
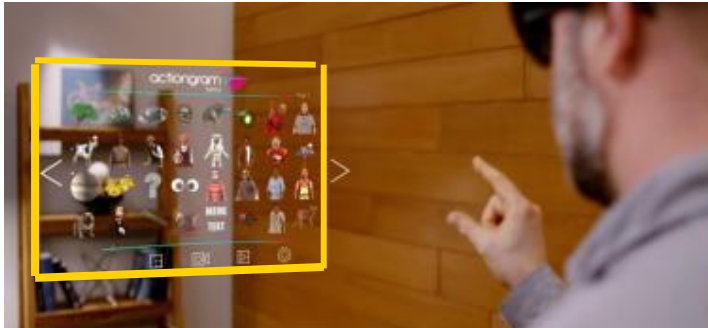
Image credit:: Microsoft

AR Device - FOV Specification Review	
AR Device	**FOV (Field of View)**
Google Glass	**13 ~ 14 degree**
Lenovo Smart Glass	**15 ~ 16 degree**
Hitachi Smart Glass	**18 ~ 19 degree**
Epson Smart Glass	**23 ~ 24 degree**
Microsoft Hologram	**33 ~ 34 degree**
Lumus Smart Glass	**38 ~ 40 degree**

Source: IHS   © 2016 IHS

Microsoft HoloLens Display Technology Review

Different lenses for different colors (R/G/B)

Image credit:: IHS

In-Coupling Hologram

Microdisplay

Out-Coupling Hologram

Image credit:: IHS

Out-coupling hologram

In-coupling hologram

Cover Glass

Lens (for Blue color)

Lens (for Green color)

Lens (for Red color)

Cover Glass

Collimator

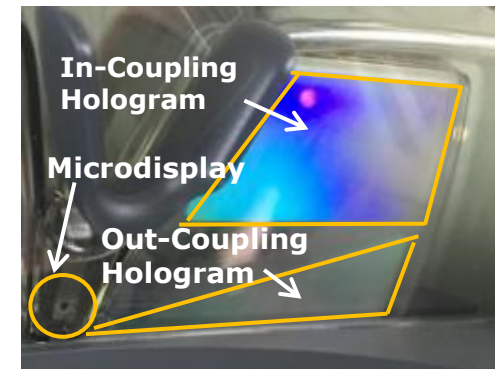**Optical engine**
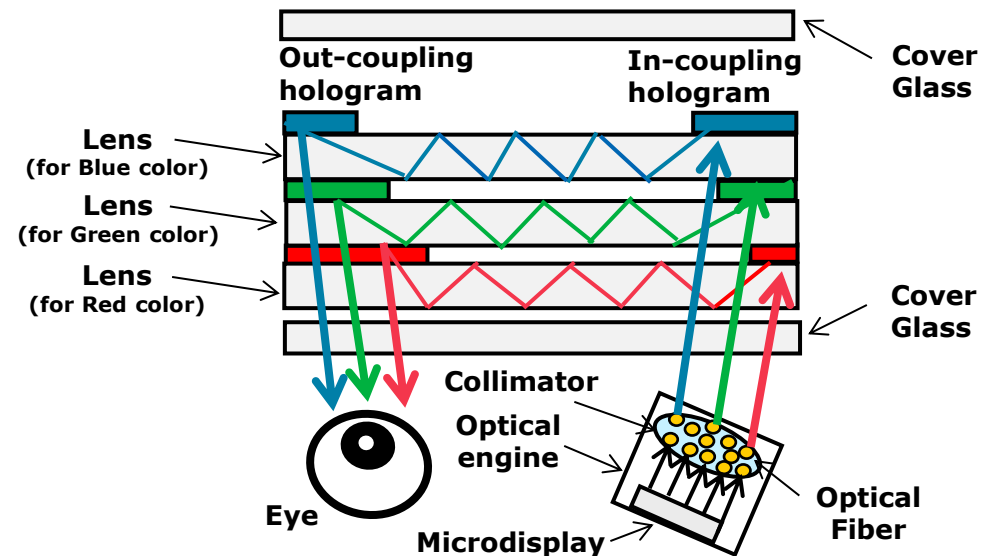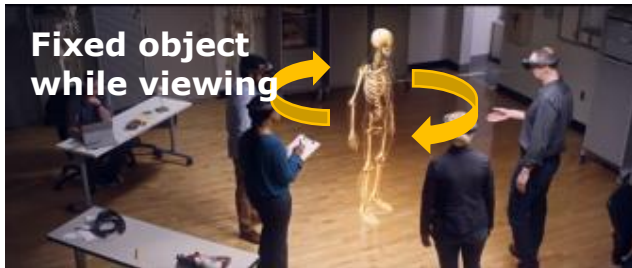
Eye

Microdisplay

Optical Fiber
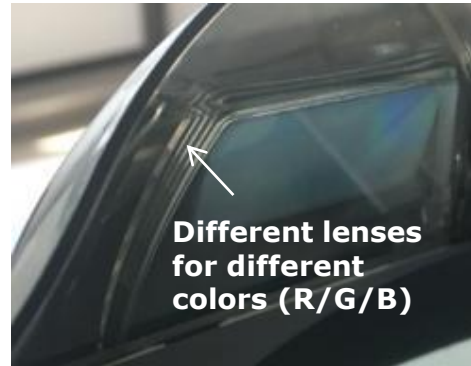
Image credit:: IHS

Microsoft HoloLens Review (2/2)

User Interface (UI) Review

Fixed object while viewing

Image credit: Microsoft

[Viewing fixed object]

a. Stereo vision Technology to create depth mapping using the left and right side camera.
b. SLAM (Simultaneous Localization And Mapping) technology to fix object position.

Camera & IR (similar to Kinect)

Camera

Camera

Image credit:: Microsoft

Speaker

Gesture Control & Voice control

Image credit: Microsoft

[User interface technology]

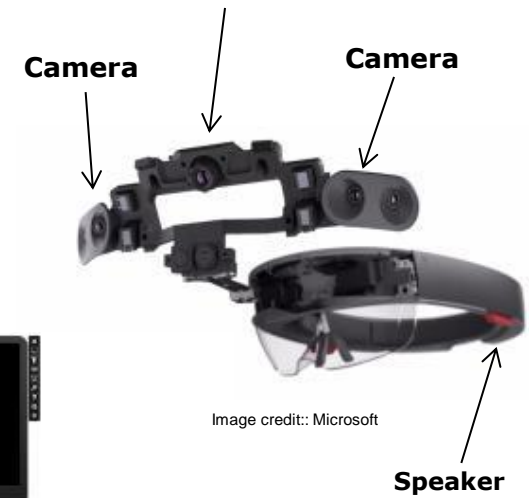**Gesture control (similar to Kinect) and Voice control by Cortana for data input on the main window.**

Main window

Image credit: Microsoft

Battery Life Review

Microsoft HoloLens 's battery life is below 2-3 hours of active usage and 3D modelling.

Battery Specification Review					
Device	**Smartphone**	**Microsoft HoloLens**	**Google Glass**	**Lenovo Smart Glass**	**Epson Smart Glass**
Battery Specification (Ampere-hour)	3000 mAh	about 2000 mAh	600 mAh	1300 mAh	2500 mAh

Augment Reality (AR) : AR Apps on Portable Devices

Pokémon GO : AR App + Camera + GPS + Map + Mobile Payment

Outdoor AR Apps issue : Camera can't capture outdoor objects because of Infrared (IR) interference issue.
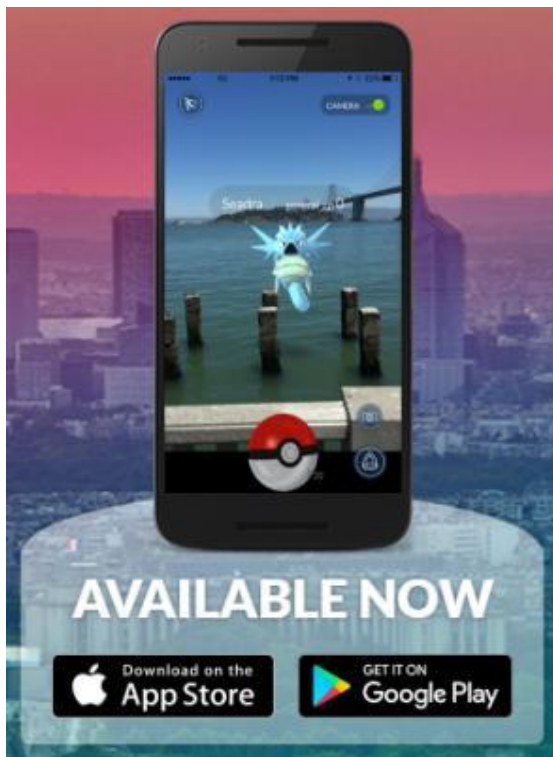
Pokémon GO is a free-to-play location-based augment reality mobile game released in July 2016 by Niantic. It allows players to capture, battle, and train virtual creatures between real world and the virtual world of Pokémon for iPhone and Android devices.

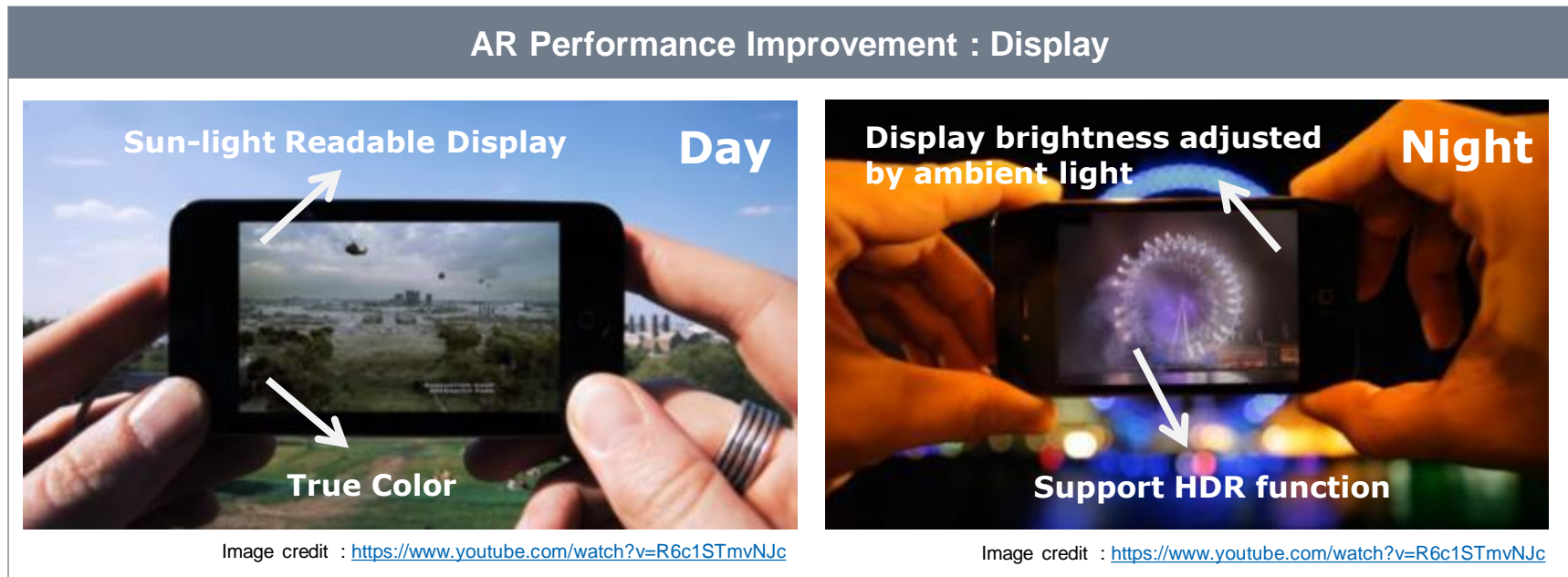| Introduction of Pokémon GO |
| --- |
| **Developer : Niantic**
Game Engine : Unity
Platforms : iOS, Android
Release date : July 6th, 2016
Play Mode : Single-Play, Multiplayer |

Image credit : http://www.pokemon.com/

AR : Display Performance Improvement

AR Performance Improvement : Display

Sun-light Readable Display **Day**

True Color

Image credit : https://www.youtube.com/watch?v=R6c1STmvNJc

Display brightness adjusted by ambient light **Night**

Support HDR function

Image credit : https://www.youtube.com/watch?v=R6c1STmvNJc

When users start to play AR Apps out of door, display quality will be the first concern. Therefore, we point out four potential issues on display design.

Issue 1 : Could display be sun-light readable ?

Issue 2 : Could display have true color performance?

Issue 3 : Could display have clear dark picture (HDR) especially late evening?

Issue 4 : Could display brightness be adjusted by ambient light?

[Note] AR : Augment Reality; Apps :Application Software; HDR: High-Dynamic Range

AR : Camera Performance Improvement

AR Performance Improvement : Camera

Better Depth/Shallow of Field

Image credit : https://www.youtube.com/watch?v=R6c1STmvNJc

Distance Measurement for

Image credit : https://www.youtube.com/watch?v=R6c1STmvNJc

If users want to have great experience of playing AR Apps, camera design will be 2nd concern when seeing virtual objects in real world. Therefore, we point out two potential issues on camera design.

Issue 1 : How to have better view quality of depth and shallow of field at same time?

Issue 2 : How to help AR software developers to detect the distance between camera and specified location of virtual object?

[Note] AR : Augment Reality; Apps :Application Software;

AR : Feedback Engine Performance Improvement

When viewing quality of playing AR Apps improved (display & camera), feedback engine design should be considered as well. Therefore, we point out two potential issues on feedback engine design.

Issue 1 : Will it have timely vibrating feedback design when playing AR Apps?

Issue 2 : Will it have different touch feeling feedback?

[Note] AR : Augment Reality; Apps :Application Software;

AR : New Business Model (AR Apps + Mobile Payment)

Preview by AR Apps

Image credit : IKEA

Mobile Payment

→

Planning Realized

Image credit : IKEA

Apple Strategy Analysis : Hardware + AR Apps + Mobile Payment

metaio

Metaio acquired by Apple

Add dual camera design

Add 3D cover glass (front cover for borderless design)

5G

Add ambient light sensor

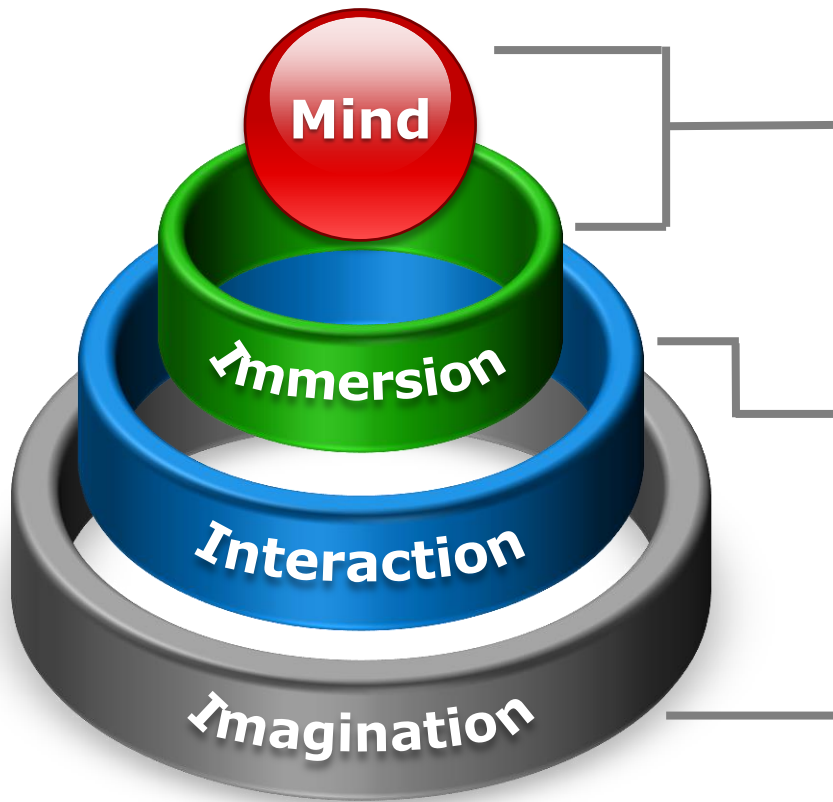**Add OLED display**

| 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
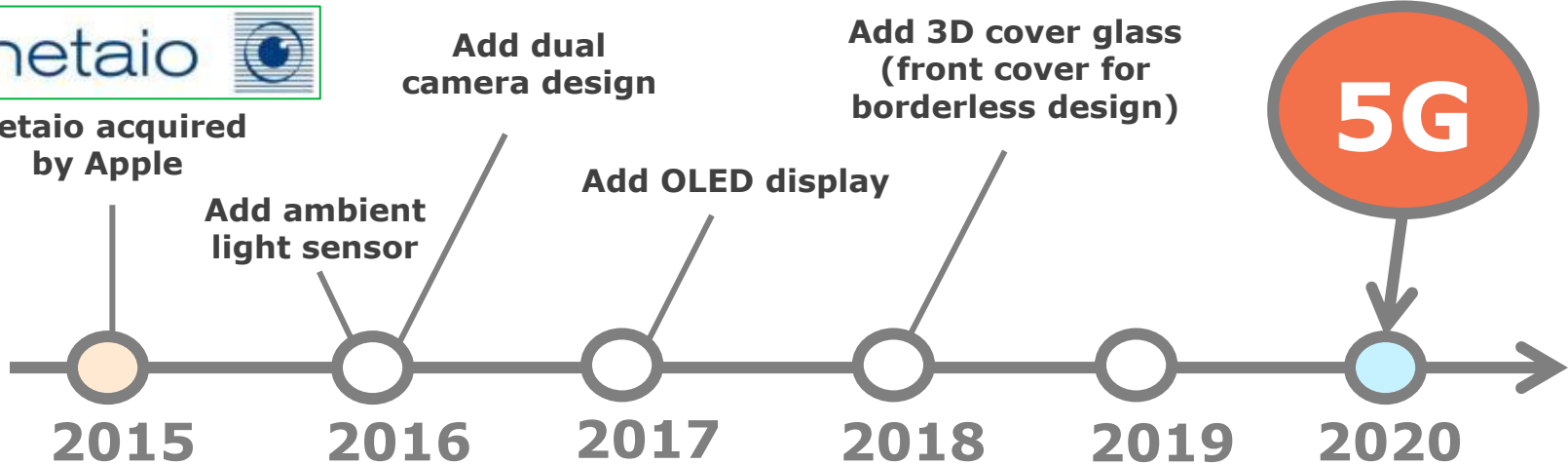
[Note] AR : Augment Reality; Apps :Application Software; 5G: 5th generation mobile networks

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Part 4 : AR/VR's Potential Market

AR / VR's Potential Market

VR / AR's Potential Market			
Level	Technology	Device	Potential Market
Mind Immersion	VR technology	Integrated Display Headsets	**Medical / Education**
	AR technology	Optical fiber by Light Field Image technology	Education / Office workplace / Television
Interaction	VR technology	Integrated Display Headsets	**Education** / Sports and entertainment / Television
	AR technology	Wearable Device (ex: Microsoft Holo Lens)	Gaming / Sports / Education / Navigation / Translation / Office workplace
Imagination	VR technology	Smartphone Adaptor Headsets	Television
	AR technology	Smartphone / Tablet	Gaming / Education / Advertisement / Navigation / Translation

Source: IHS

AR Notebooks: "See" Presentation w/o Projector

Core Value of AR Application : **See-through** - See real world with virtual objects / info

Image credit : www.workboard.com/

Share your ideas by AR notebooks in F2F meeting (without projector).

AR Notebooks

[Hardware requirement]

- **Display with True Color**
- **Camera & IR**
- **Powerful GPU Chip**
- **High-Speed Connectivity (wire or wireless)**
- **Narrow Border Design**
- **Haptics Engine in Notebook's A/B Cover**

Using VR from User Role : Medical (Mind Rehabilitation)

Core Value of VR Application for user role : Offer immersion experience
For example : Physical therapy and rehabilitation combined with VR (mind rehabilitation)

Physical Therapy and Rehabilitation	VR : Mind Rehabilitation

Replace monitor by VR device while doing rehabilitation

Image credit : www.trabzonmedicaltourism.com/

Image credit: Nike

See your future

Image credit: Oculus

Using VR from Outsider Role : Experienced Learning

Core Value of VR application for outside role : Solve distance limit issue
Distance Learning : Joining and learning skills by VR devices, even though you're not there
Participatory Entertainment: Joining TV show by VR devices, even though you're at home

Distance Learning

Haircut Learning out of School /Hair Salon

Image credit : www.michaelanthonysalondc.com

Surgery Learning out of Emergency Room

Image credit : www.surgicaledcenter.uci.edu

Seeing it like you're be there

Image credit: Oculus

Participatory Entertainment

Experienced Cooking While Watching TV

Image credit : www.foodgal.com

Experienced Traveling While Watching TV

Image credit : www.tourism.australia.com

VR Application on Education Market (Language Lab)

Return on the investment (ROI) is a potential issue for VR software developers, so they think VR application on education market (ex: Language Lab) will be a feasible solution when voice control technology is ready for VR products.

Traditional Language Lab (w/o immersion)	English Learning by VR (with immersion)

The best English learning way is to live in the US or the UK, but the cost is too high for students.

Therefore, students only can learn English in language lab (ex: Classroom cubicles)

Image credit : http://www.calstatela.edu/

Shopping

Hotel Check-in / Check -out

Image credit: http://www.coupons.com/

Image credit: http://www.hotelroomsearch.net/

Seeing it like you're be there

Easy way to learn language w/o living oversea.

If VR device with voice control feature

Image credit: Oculus

Conclusion

- Motion sickness is caused by conflicting inputs from visual sense, vestibular sense, and proprioception.

- Children under 16 whose vestibular system have not attain maturity completely, so AR will be better option for children's education market.

- Without head tracking function, VR device is just a personal 3D display device, so we remain conservative on the demand for smartphone adaptor headsets.

- Controllers will replace keyboard and mouse while using VR devices, and track design will influence VR software development.

- Future VR hardware development will focus on display (OLED & Micro LED), display driver, audio receiver & speaker (ex: de-noise function), wire technology, and motion sensor (ex: gloves with haptic feedback function)

- Future AR hardware development will focus on display (hand-hold AR: OLED; Hand-free AR: LOCS & Prims & Lens), camera, and haptic device.

- Education and medical market will be potential market for VR device because VR device can help end-users to see what they want to see.

Thank you for your attentions

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