Brunel University London

Immersion and Multisensory Interaction in Games

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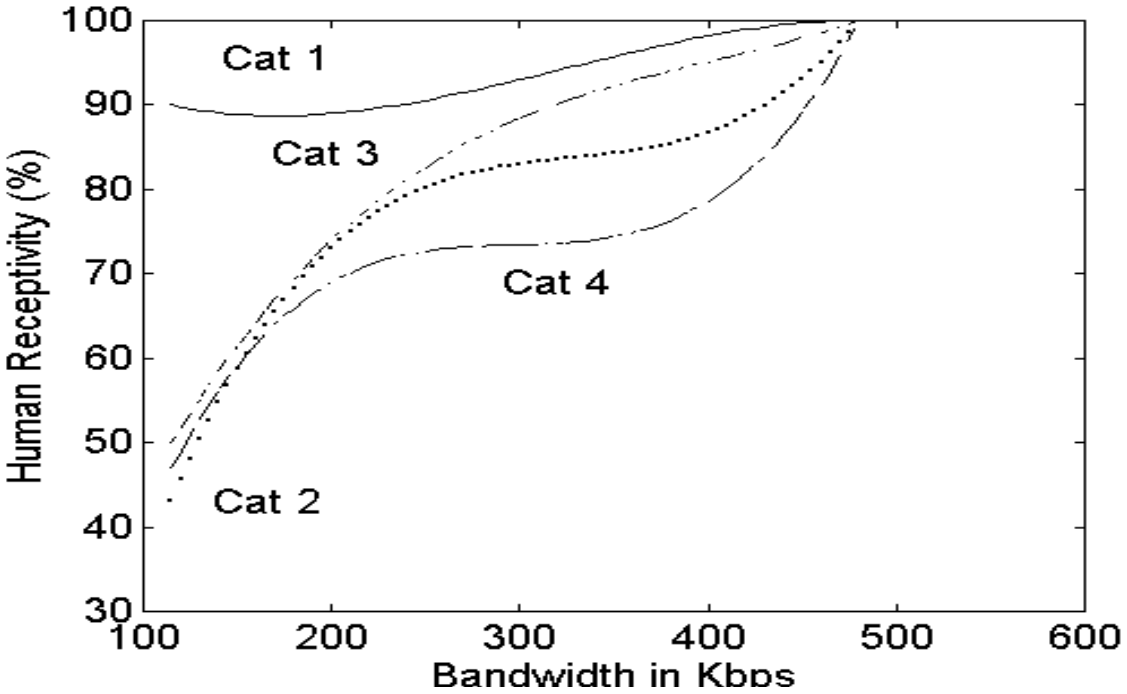
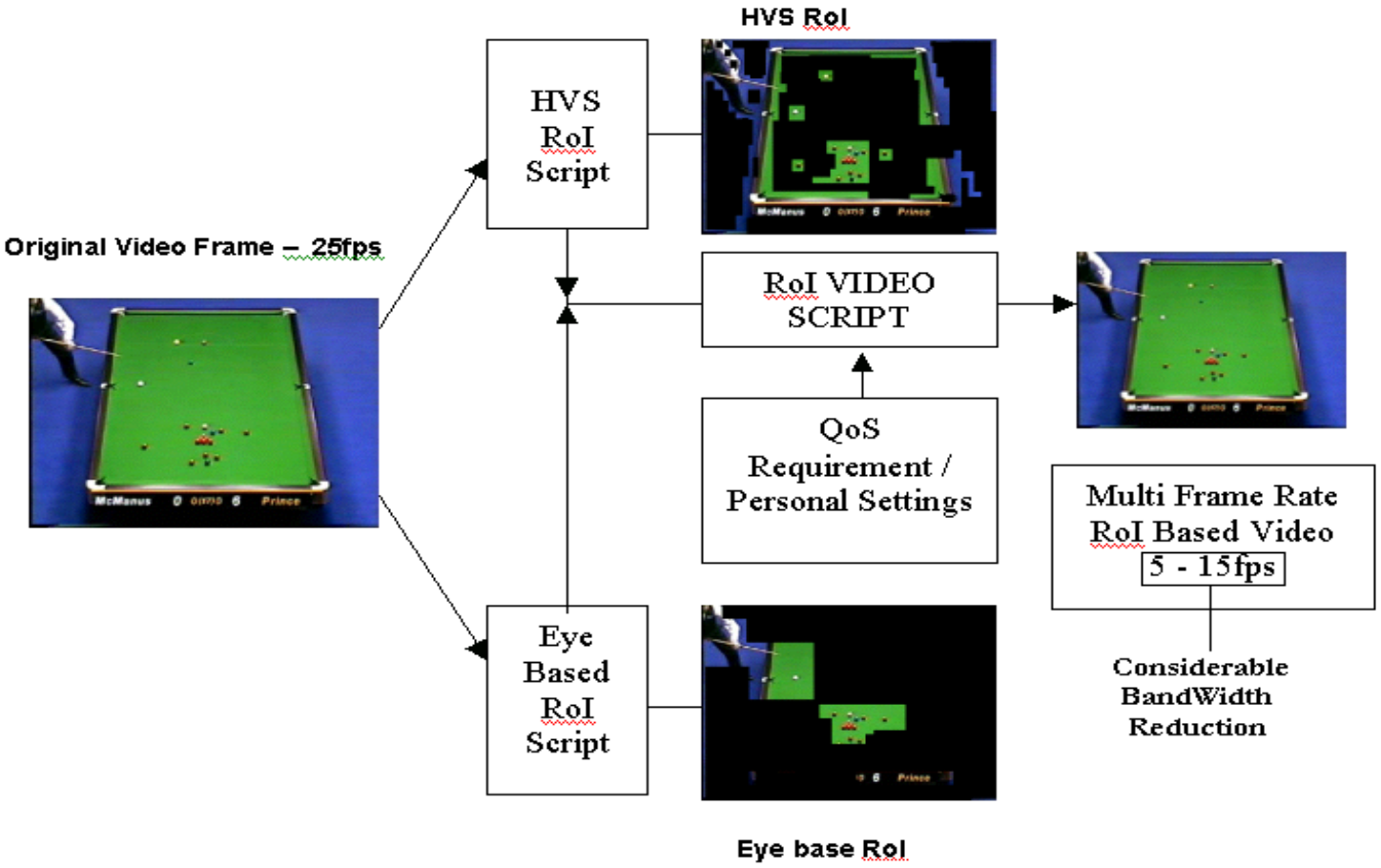
Quality is in the Eyes of the Beholder…

Quality of Perception Illustration



WYS<>WYG


HVS RoI
HVS RoI Script
Original Video Frame – 25fps
RoI VIDEO SCRIPT
QoS Requirement / Personal Settings
Multi Frame Rate RoI Based Video
5 - 15fps
Considerable BandWidth Reduction
Eye Based RoI Script
Eye base RoI

What is Mulsemedia?

My contribution: Mulsemedia

- What is Mulsemedia?
  - Multiple Sensory Media (>= 3 senses engaged)
  - Multiple Semantic Media (content is king)
- Our contribution
  - Olfaction-enhanced mulsemedia applications
- Special 2014 Issue on MulSeMedia, ACM Trans. On Multimedia Computing, Communications and Applications
- Edited Multiple Sensorial Media Advances and Applications: New Developments in MulSeMedia

Olfaction and (Multi)Media

- Early attempts for using olfaction in theatre+film
- Most work focuses on olfaction use as an alternative source of output
  - i.e. alternate modality, multi-modal, or but not mulsemedia
- We focus on integration of olfactory data with other media objects in mulsemedia apps.

Olfactory Media Integration

- Media integration = information is conveyed by the relationship between combined media as well as by the independent media itself
- Olfactory data used this way should:
  - enhance meaning of applications
  - provide clarity of user presented information
  - increase the sense of reality and enjoyment in multimedia applications
- True olfactory integration/adaptation is a challenge!


Activ
5000X
Vortex

ideo Name	Burnt	Flowery	Foul	Fruity	Resinous	Spicy
						
ideo escription	Documentary on bush fires in Oklahoma	News broadcast featuring perfume launch	Documentary about rotting fruits	Cookery show on how to make a fruit cocktail	Documentary on Spring allergies & cedar wood	Cookery show on how to make chicken curry
mell Used						

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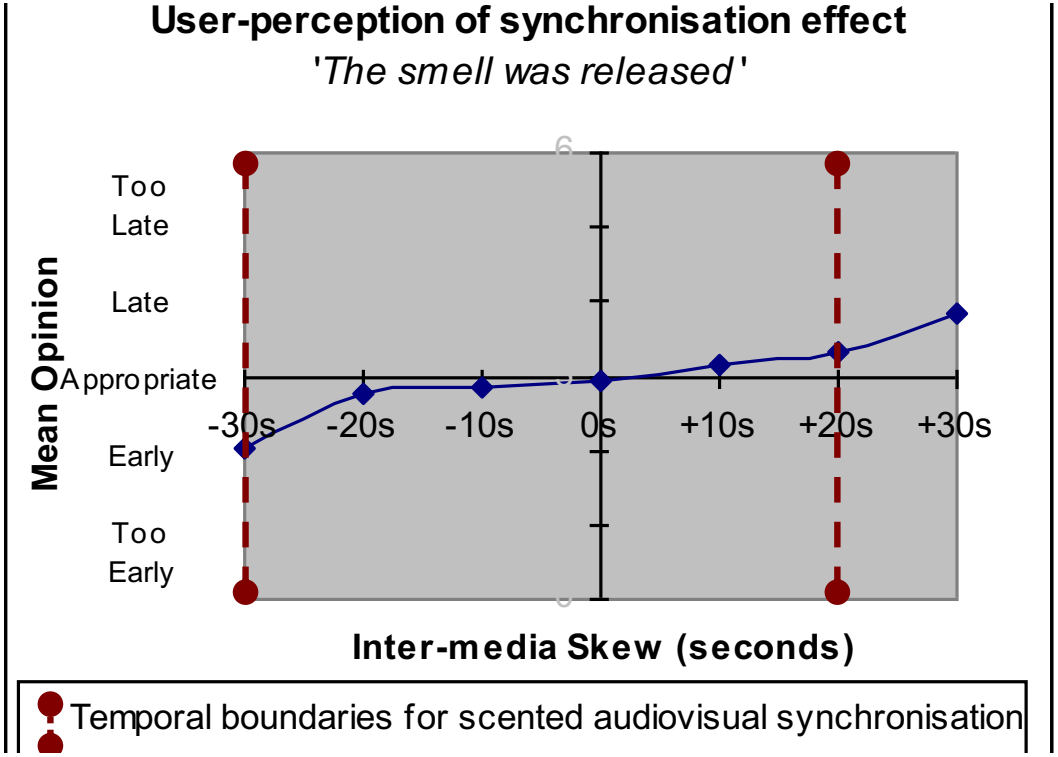
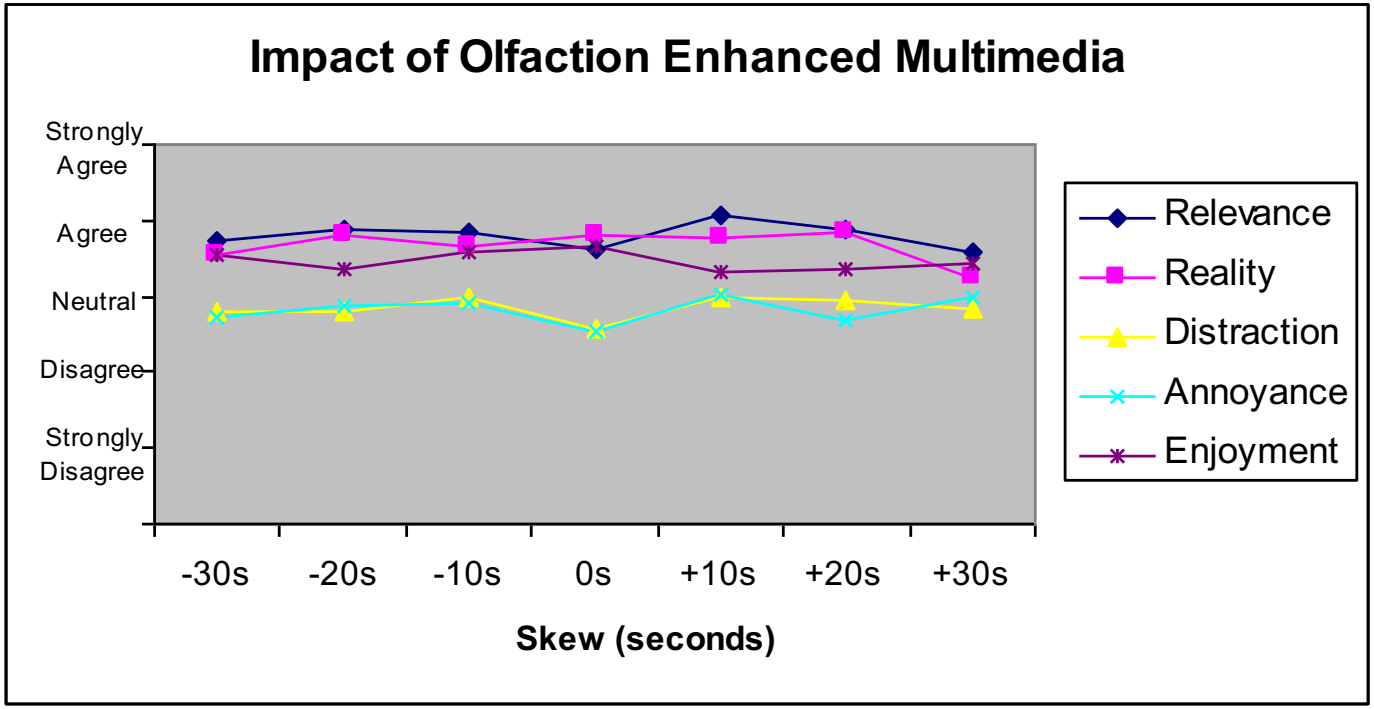
mell Used	***Burning Wood***	***Wallflower***	***Rubbish Acrid***	***Strawberry***	***Cedar Wood***	***Curry***

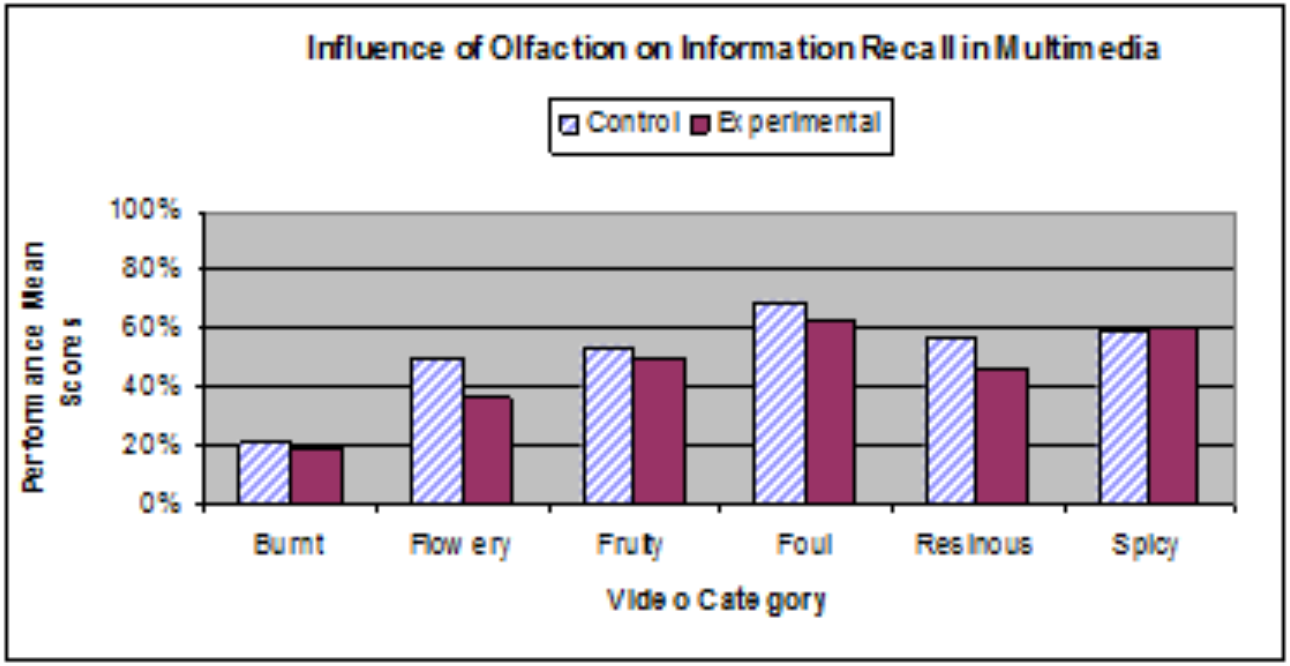

Olfactory Media Content
Video Media Content
00:00:00
00:00:30
00:01:00
00:01:30
Before Olfaction
Olfaction During Video
After Olfaction



- Is much more loosely coupled than traditional media (such as lip synch)

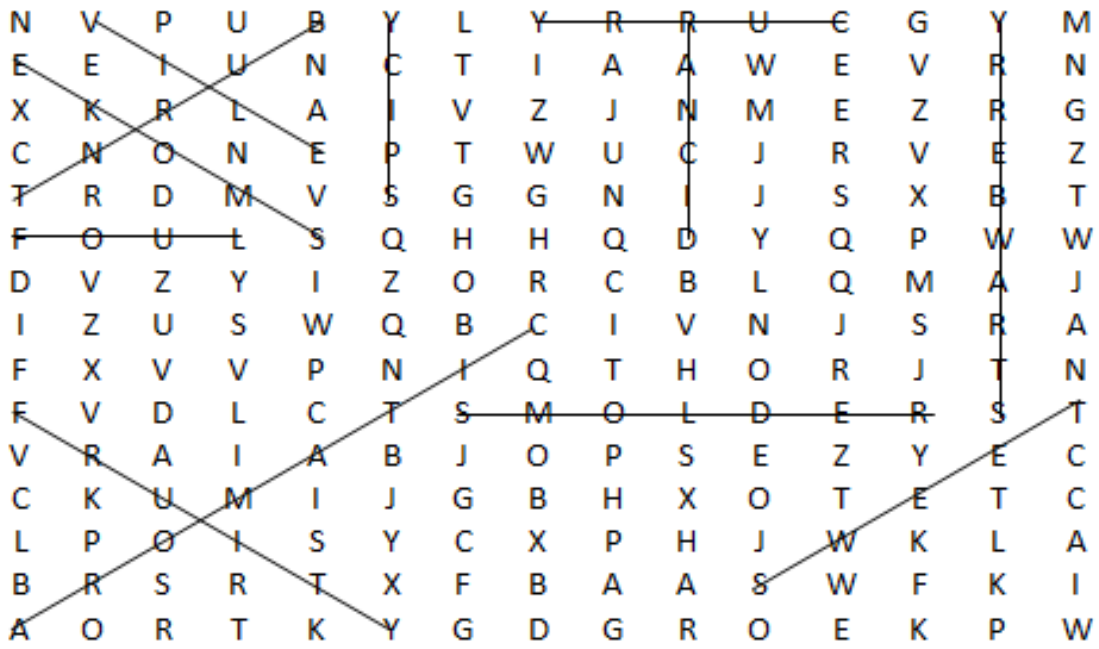


- Olfaction = increased sense of reality and relevance.
- users are tolerant of the interference and distortion effects caused by olfactory effects in multimedia.



- presence of olfaction did not have a significant impact on the task performance of participants in the information recall task
- performance of the information recall task across the three different temporal segments was best in the first segment

- Word-Search Puzzle

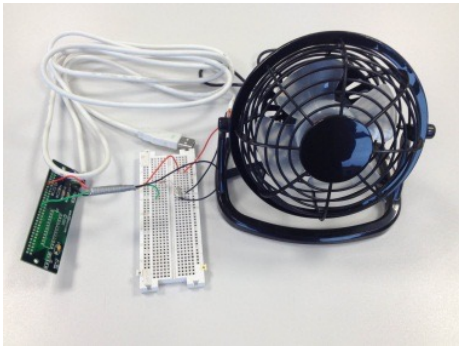


- Word-Search Puzzle solution

Smell used	Associated Words
Strawberry	*Fruity, Strawberry, Sweet*.
Burning Wood	*Burnt, Smolder, Smoke.*
Curry	*Spicy, Curry, Aromatic*.
Rancid/Acrid	*Foul, Vile, Rancid*.

Conclusion: olfactory cues whilst performing a word search increases the number of correct words found, compared to the case when olfactory media cues are absent

Combination of Sensorial Devices



Clips

<<Jurassic Park>>

Haptic (dinosaur attack) Air (wind blowing) Olfaction (champagne)

<<Back To The Future>>

Haptic (car crash) Air (wind blowing) Olfaction (burnt bread)

Encoding Characteristics

Video sequence	Quality	Codec	Frame rate	Resolution	Bitrate (Kbps)
Jurassic Park	High	MPEG-4	30 fps	1280x720	2500
	Avg	MPEG-4	24 fps	853x480	1100
Back To The Future	High	MPEG-4	30 fps	1280x720	2500
	Avg	MPEG-4	24 fps	853x480	1100

Mulsemedia Effects – Jurassic Park

Motion	Video clip	Effects	Movie scenario	Olfaction Aroma
High	1	None	Animal attack	
	2	Haptic	Animal attack	
	3	Air	Wind as car moving fast	
	4	Olfaction	tear gas	Burnt
	5	Haptic, Air	Vehicle vibration and wind	
	6	Haptic, Olfaction	Animal attack and smoke	Burnt
	7	Air, Olfaction	Wind and fire	Burnt
	8	Haptic, Air, Olfaction	Vehicle vibration, wind and forest	Forest
Low	1	None	None	
	2	Haptic	Animal attack	
	3	Air	Subway train comes	
	4	Olfaction	Decomposed animal odor	Rubbish
	5	Haptic, Air	Pull by parasail and wind	
	6	Haptic, Olfaction	Air plane and crash	Methane
	7	Air, Olfaction	Ocean wind and wine	Rock pools, Mulled wine
	8	Haptic, Air, Olfaction	Movement, gas and wind	Methane

Results

- Higher quality multimedia sequences result in higher overall user quality of perception levels.
- When delivering mulsemedia content, there is no statistical difference between user enjoyment levels when exposed to “avg” and “high” quality sequences, respectively.
- There is a definite preferred order in terms of multi-sensorial effects: haptic> air >olfaction.
- ***User enjoyment levels were maintained high when lower multimedia quality sequences have been used in conjunction with multiple sensorial effects***

Mulsemedia and Learning…

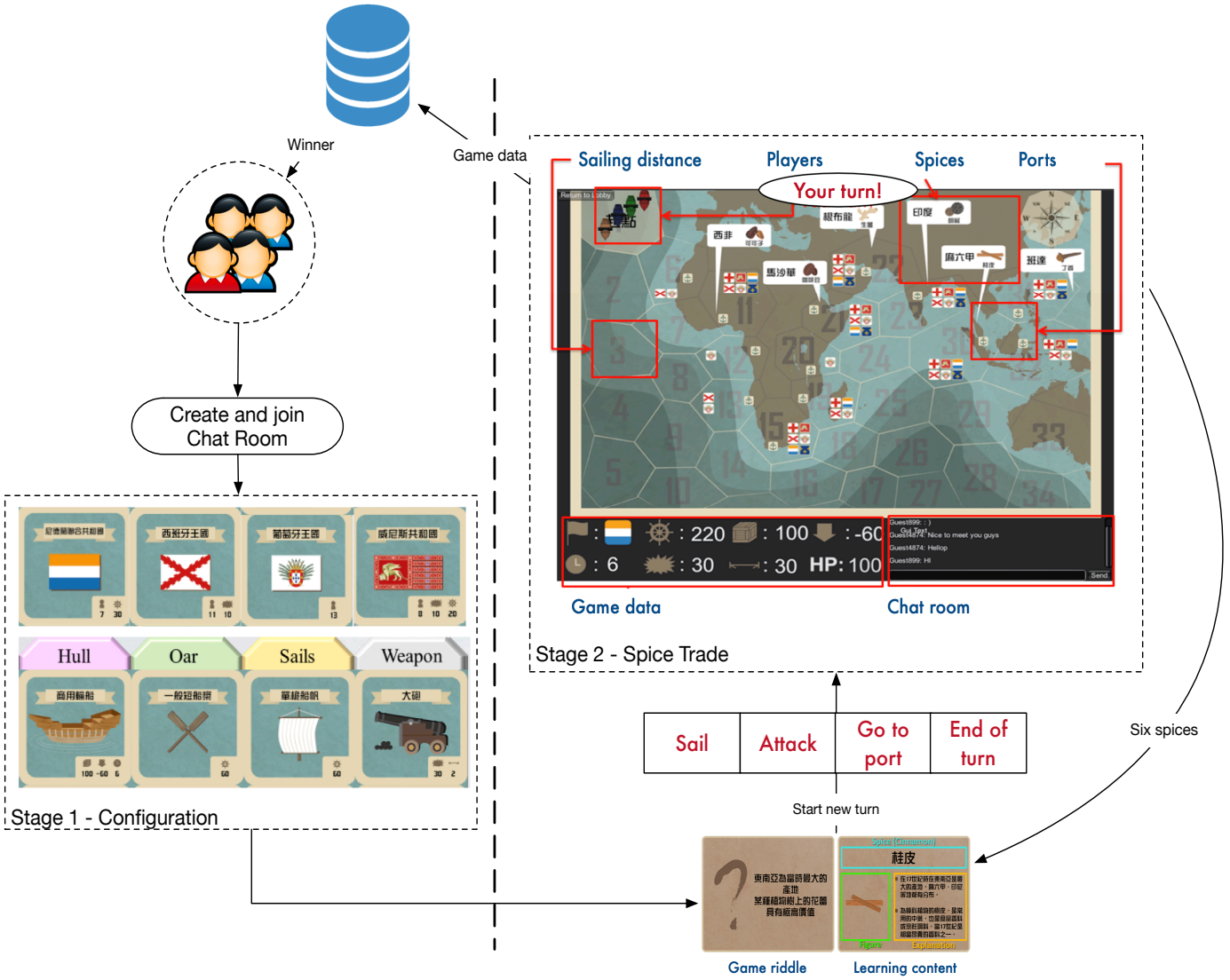
MulSeMedia and Learning

- Studies on learning are often focused on unisensory experiences, although our interaction with our surrounding environment is multisensorial.
- Providing an individual with multiple sensory cues facilitates a representation, thus numerous educational programmes have advocated the benefits of mutually supportive multisensory information
- Research has shown that the facilitative effect in information processing is significantly greater for multisensory stimulus combinations than within-modal combinations

MulSeMedia and Learning (ctd).

- Most interactions with digital information are characterised by a poor usage of sensorimotor capabilities
- Multisensory processes facilitate...
  - memory
  - perceptual and implicit learning and training outcomes
  - training outcomes
  - reduced mental workload
- Multisensory intervention has been successfully used also as a therapy for correcting and improving literacy skills

Fragrance Channel



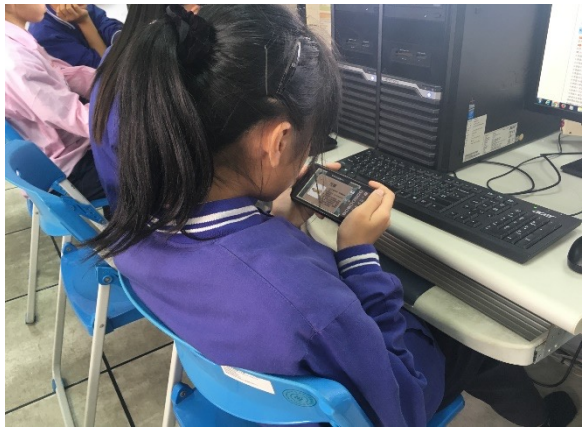
Fragrance Channel Implementation

- Developed in Unity3D
- multiplayer game that connects four people in a single session over the Internet
- To make the game engaging and emotionally arousing we introduced different actions and depicted the consequences of players' errors.
- Actions like *Sail*, *Attack* and *Go to port* come with specific visual effects and textual information.
- Communication between players is also encouraged through an in-game chat room that makes exchanging ideas, strategies and knowledge easy.

Motivation

- Our goal = investigate the existence of possible differences in students' performance while experiencing the game on mobile devices and desktop environments, in the presence or absence of olfactory stimulation.
- 4 test conditions: MobileWithoutOlfaction, PCWithoutOlfaction, MobileWithOlfaction, PCWithOlfaction
- When olfaction was present, players had to smell the corresponding target spice at the start of the round.
- We wanted to observe if the olfactory conditions lead to an increase of performance or if the game experience will be more entertaining and enjoyable.

Participants

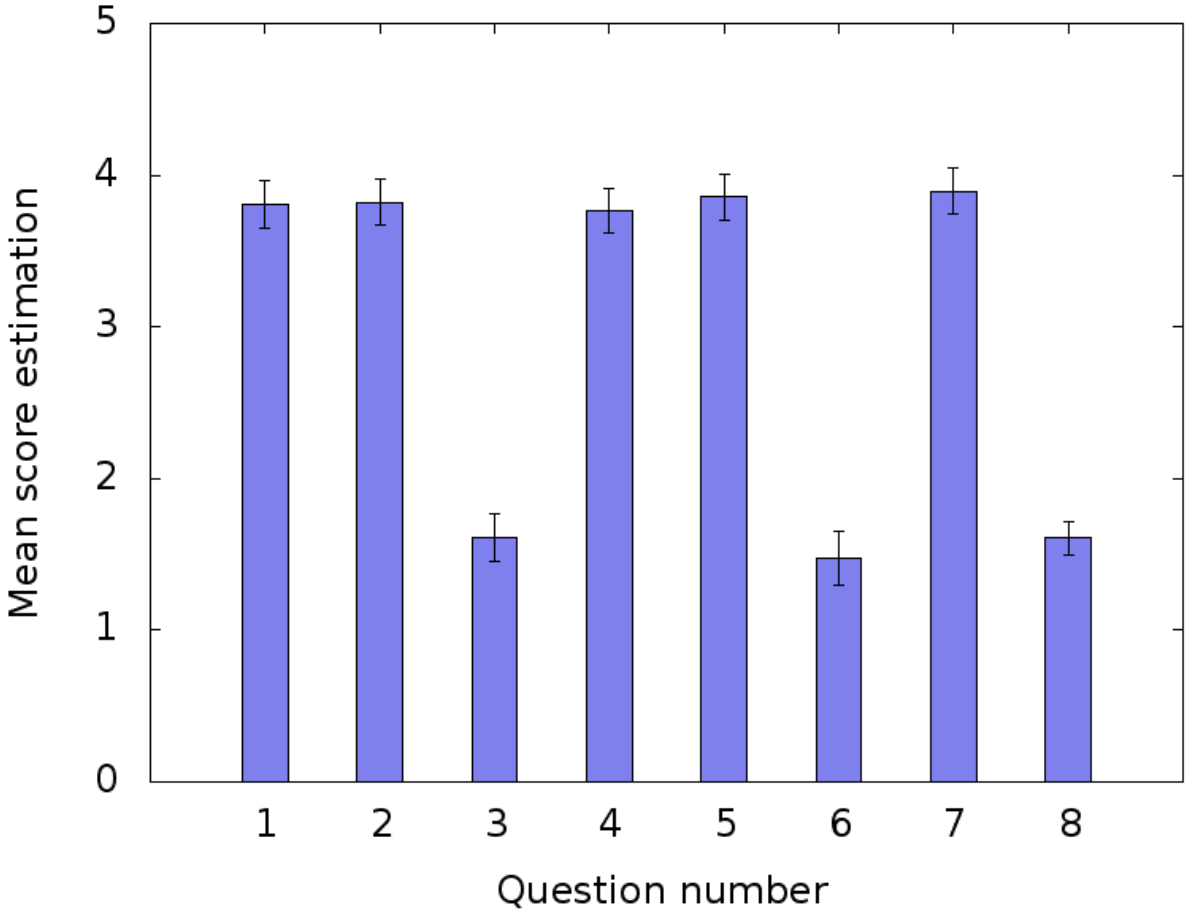


- 117 participants, junior high school students in the southern part of Taiwan.
- They were divided in four groups in order to test the proposed four conditions (n1 = 32, n2 = 29, n3 = 28, n4 = 28)

Self-reported engagement

1. *The multi-sensorial experience helped me to better understand the related concepts taught in the class.*
2. *The multi-sensorial experience helped me to better assimilate the concepts taught in the class.*
3. *The multi-sensorial experience did not improve my learning experience.*
4. *The multi-sensorial experience helped me to better understand the practical experience of the learning process.*
5. *I enjoyed the multi-sensorial experience during the class.*
6. *The multi-sensorial effects were disturbing for me during the class.*
7. *I would like to have more classes/labs/courses that include multi-sensorial experience.*
8. *Please award the game either a gold, silver or bronze medal.*

Results



- Students consider multisensory experiences as a valuable and enjoyable tool.
- Moreover, they are eager to repeat them and they suggest features for improvement.
- Whilst the potential for multisensory effects to deliver a better educational experience is unmistakeable, we still have some way to go in order to understand how to integrate multisensory experiences - involving new media types such as olfaction - in games, in order to be able to achieve better cognoscible targets

My favourite Mulsemedia scenario…

Imagine a chemistry experiment being streamed online to school kids wearing VR headsets. The chemistry teacher carefully measures the desired quantity of substances, one a yellowish liquid, the other blue, with a pipette and combines them in a glass tube. BOOM! FLASH SMOKE! The kids gasp in amazement – for not only did they did they see and hear the exothermic (heat emitting) chemical reaction of the experiment in the VR headset, but they also smelt the pungent odour emitted as a result, felt a whiff of hot air blowing through their hair, as well as a slight vibration on their bodies.

newton

Networked Labs for Training in Sciences and Technologies

www.**newton**project.eu

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 688503

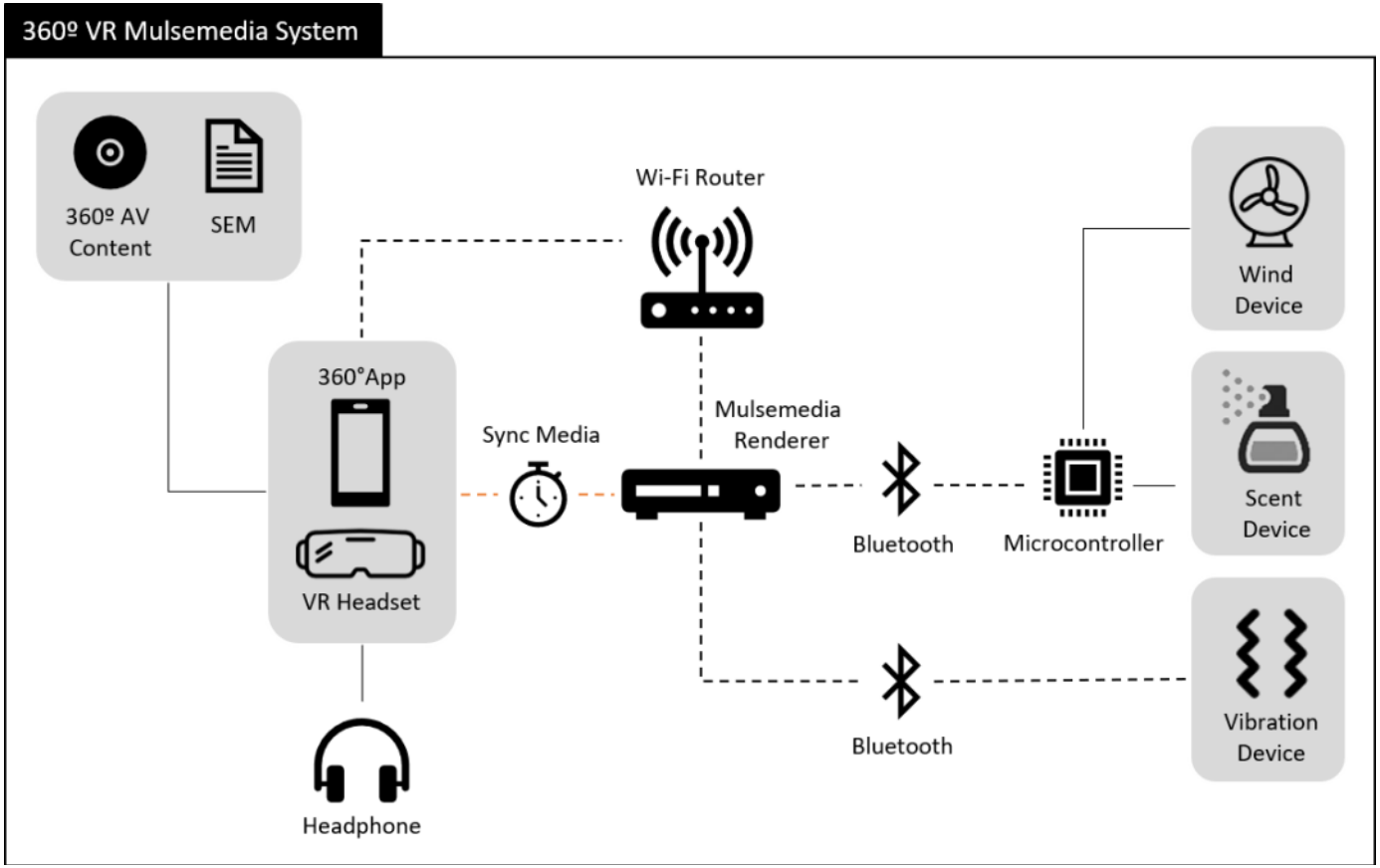
Multisensory Displays (I)

From ARAIG.com

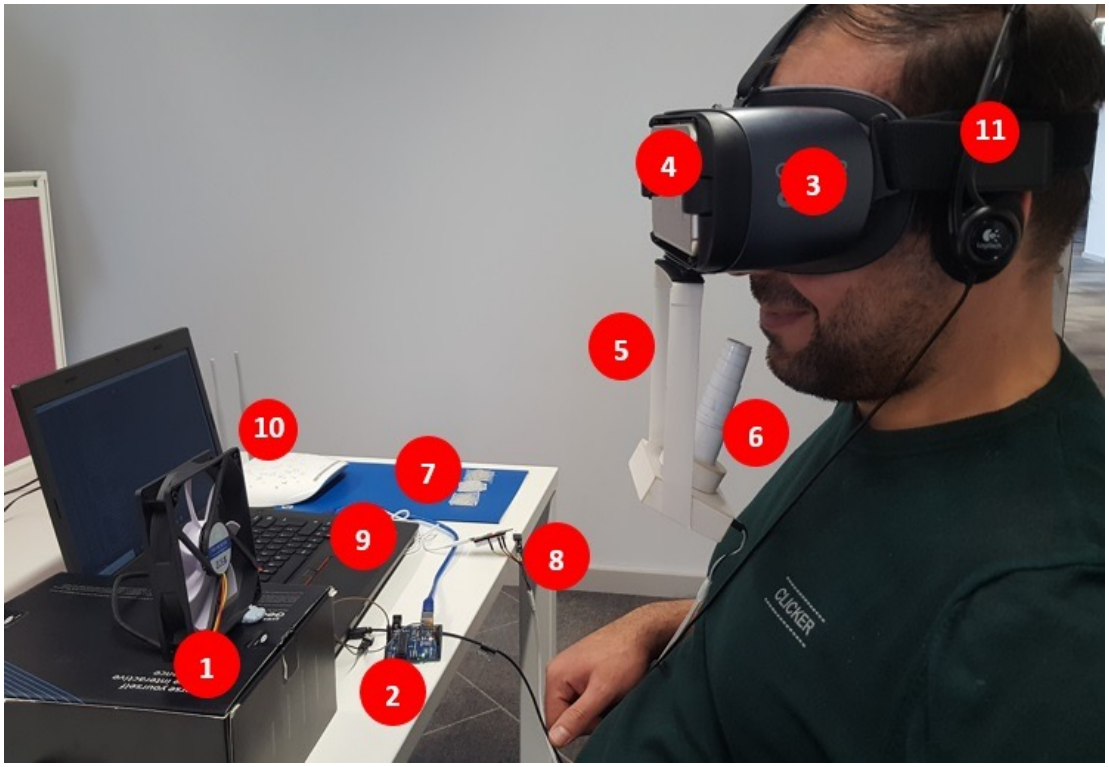
Multisensory Displays (II)

Multisensory Displays (III)

360˚ Mulsemedia DIY Blueprint



DIY 360˚ Mulsemedia Displays



(1) Wind blower fan, (2) Arduino Uno, (3) VR headset, (4) Smartphone, (5) Scent emitter, (6) Conic pipe, (7) Mesh-bags, (8) Arduino Nano, (9) Laptop, (10) Wi-Fi router, and (11) headphones.

360˚ Mulsemedia DIY – Components & Cost

Type of component	Component	Ver.	Goal	Cost (≈)
360◦ App	Unity3D 360◦ App	N/A	Play 360 AV content, read SEM data, and convey to mulsemedia renderer.	£0.00
VR Headset	Samsung VR Gear	2016+	Deliver 360◦ AV content along with the 360◦ App.	£70.00
360◦ AV Content + SEM	360◦ video annotated with MPEG-V SEM	N/A	Provide system with 360◦ AV Content and SEM (wind, smell, vibration).	£0.00
Headphone	Logitech Gaming Headset	G231	Play high-quality audio.	£30.00
Wi-Fi Router	TP-LINK Archer C50	V3	Connect the multimedia application to the mulsemedia renderer and devices.	£35.00
Mulsemedia Renderer	PlaySEM SER	2.0.0	Receive SEM, convert it to hardware commands, synchronize media, and handle devices.	£0.00
Microcontroller	DFRobot Bluno Nano	DFR0296	Receive commands from the mulsemedia renderer and activate physical devices accordingly.	£25.00
Wind Device	Portable Fan Cooler	50mm DC5V 0.2A	Blow airflow to create wind effects in sync with the mulsemedia renderer.	£10.00
Scent Device	Mini Dupont Brush-less Cooling Fan	30mm DC5V 0.2A	Emit scents direct to the user's node from mesh scent bags in sync with the mulsemedia renderer.	£7.00
Vibration Device	Android Smartphone	6.0+	Vibrate smartphone fastened to user's torso or limbs in sync with the mulsemedia renderer.	£100.00

What opportunities are there to apply AI/ML in Mulsemedia?

PROBLEM STATEMENT

Mobile User

Advances in Mobile Devices

Improved: CPU, display, graphics → Better multimedia experience

+

New applications: 3D connectivity, video surveillance, **360˚ video**

Network Operator

- 10^5 times traffic load will need to be supported through all mobile broadband technologies

- Enhanced Quality of Experience (QoE) provision;
- More stringent Quality of Service (QoS): high performance scheduler is required.

360˚ SENSORY MEDIA CONTENT

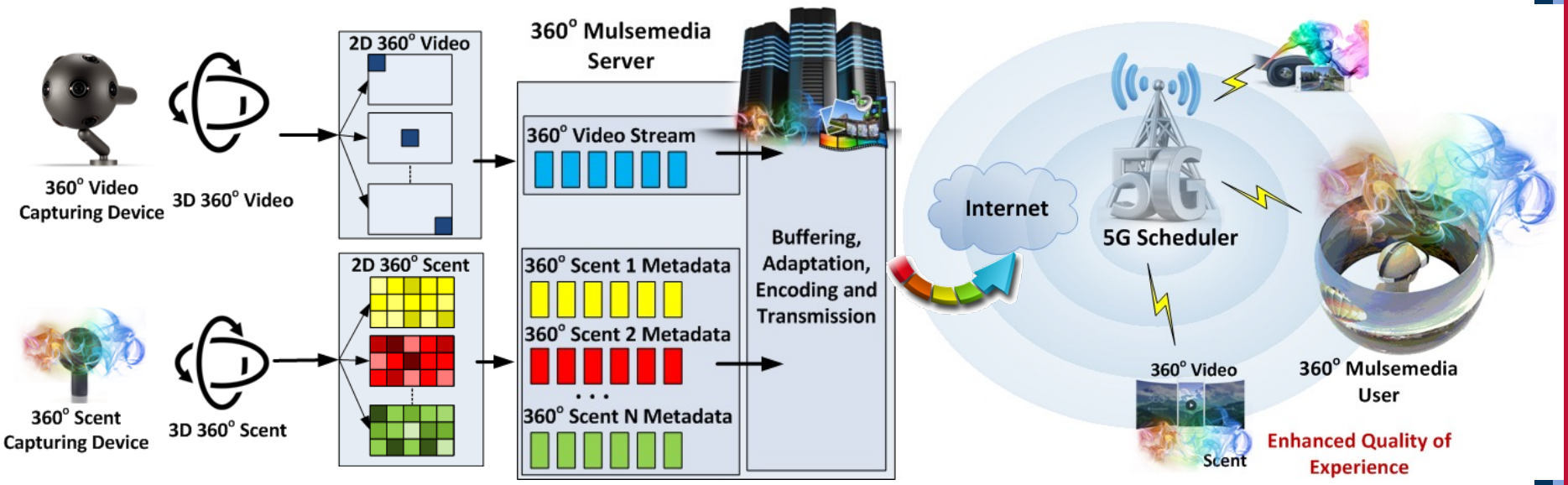
- 360˚ video: large data rates (i.e. > 10Mbps) and extremely low latencies (i.e. < 10ms):
  - poor QoE when experiencing low-level video quality due to fast head movements and unfavorable network conditions.

- **Solution:** use of additional 360˚ media objects (e.g.360˚ olfaction, haptic, and airflow) synchronized and transmitted along with the 360˚ video content**:**
  - users can experience other scenes from the 360˚ video at lower qualities plus additional 360˚ sensory objects.

- **New application:** 360˚ video content and 360˚ **MUL**tiple **SE**nsorial **MEDIA**: **360˚ MULSEMEDIA**

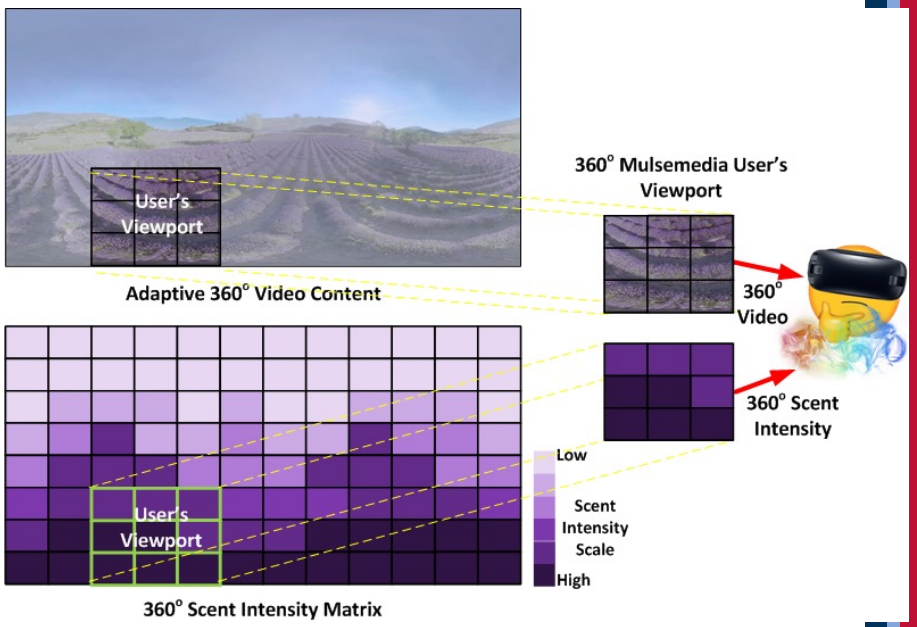
360˚ MULSEMEDIA DELIVERY

- **Proposed Architecture in three steps:**
  - Mapping 360˚ Olfactory Media Objects to 360˚ Video;
  - 360˚ Mulsemedia Server;
  - 5G Scheduler for 360˚ Mulsemedia Delivery;



MAPPING 360˚ OLFACTORY MEDIA

- Equirectangular view:
  - 360˚ panoramic video and captured 360˚ scent are divided in equirectangular tiles;

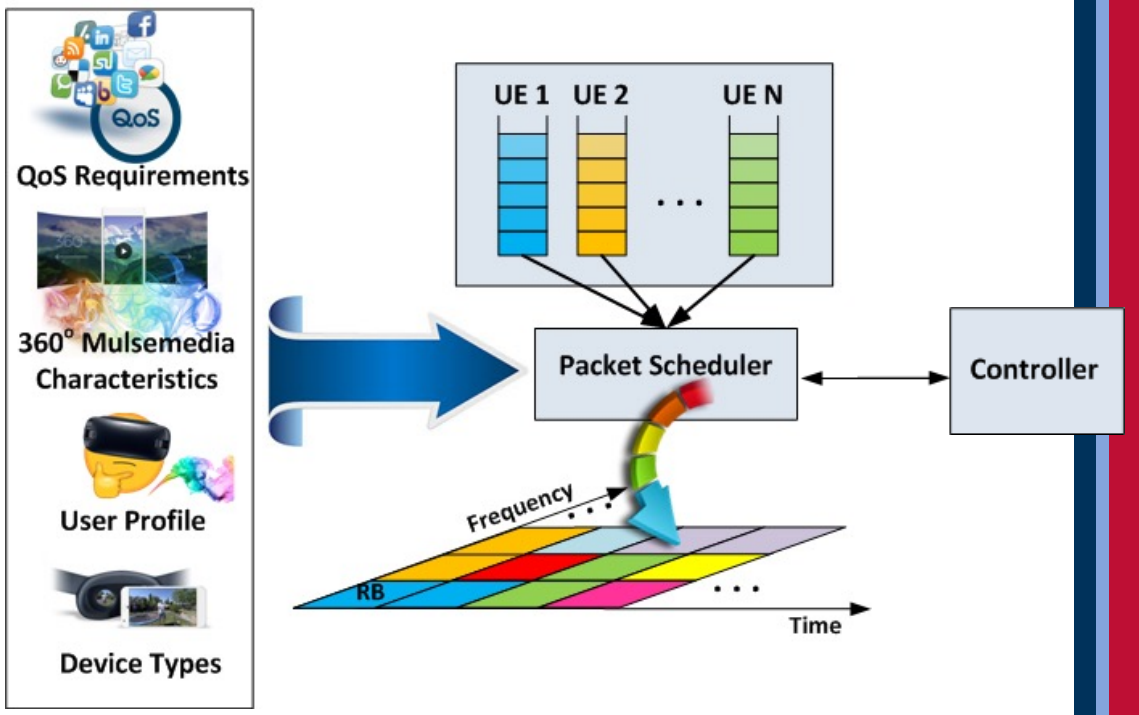


- The assignation procedure of the scent tiles to the panoramic image is called mapping.

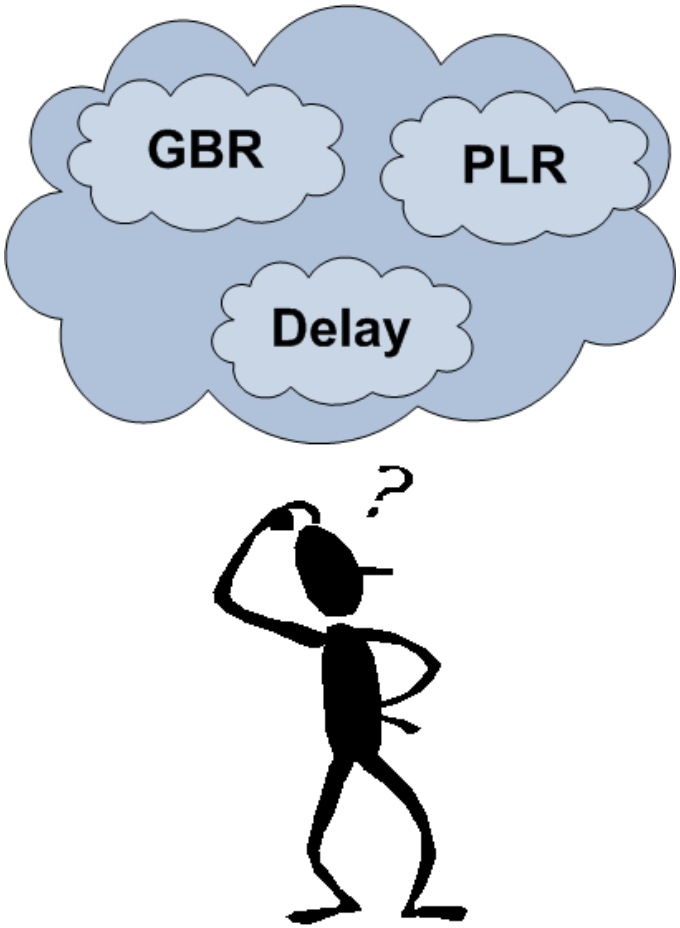
- **360˚ video:** the viewport content and neighboring tiles are transmitted at the highest quality
- **360˚ olfaction:** the whole matrix of intensities is transmitted and reproduced at the reception

5G PACKET SCHEDULER FOR 360° MULSEMEDIA DELIVERY

- Responsible to allocate the available frequency spectrum to maximize the QoS satisfaction;
- **Drawbacks**: standard schedulers are unable to properly adapt to changeable network conditions;
- **Proposal**:
  - Apply each time the best scheduler that maximizes QoS;
  - Learn the decision making – interaction with the controller.



QOS FOR 360° MULSEMEDIA

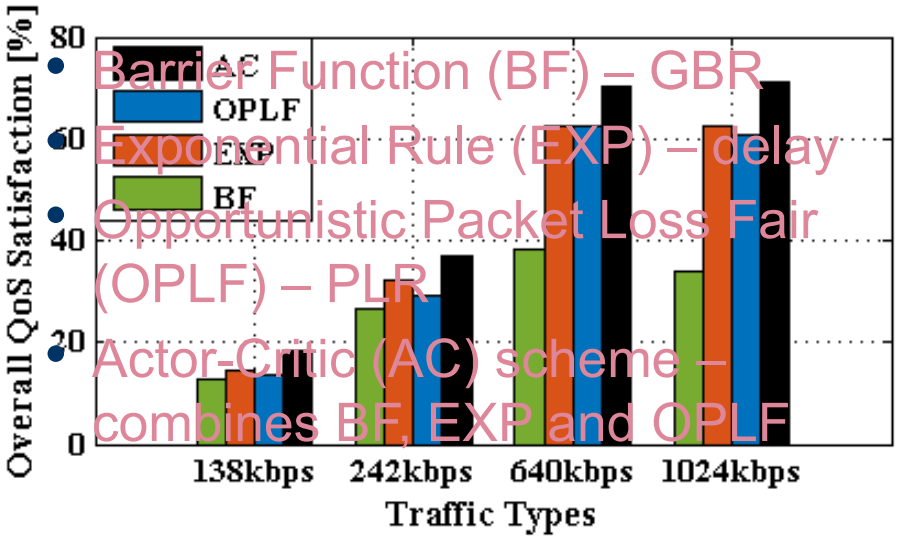


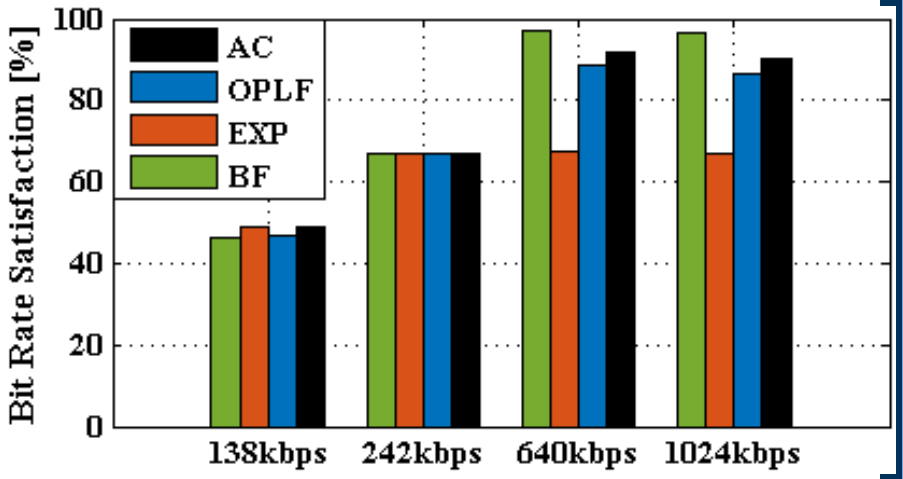
Maximize the Aggregate Multi-Objective Function:

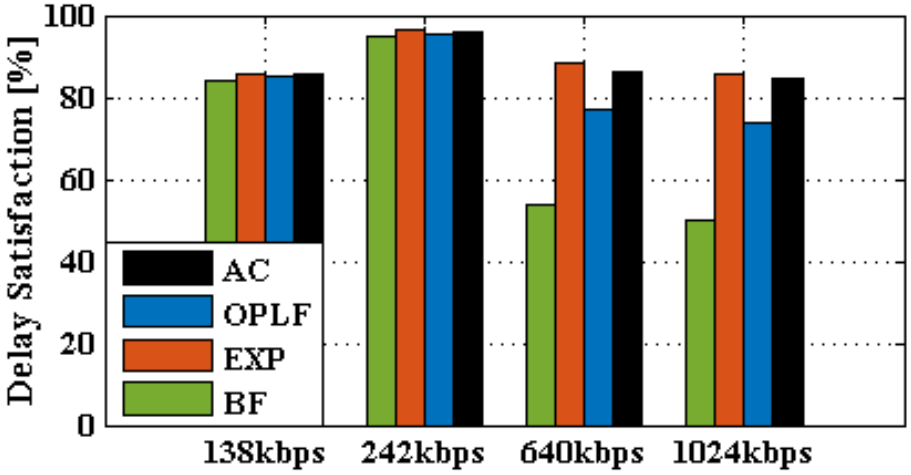
1. **Satisfy the Guaranteed Bit Rate (GBR) requirements (>20Mbps);**
2. **Minimize the Packet Delay (< 10 ms);**
3. **Assure a maximum Packet Loss Rate (PLR) ($< 10^{-6}$);**
4. **Increase the times when objectives (1), (2), (3) are satisfied;**

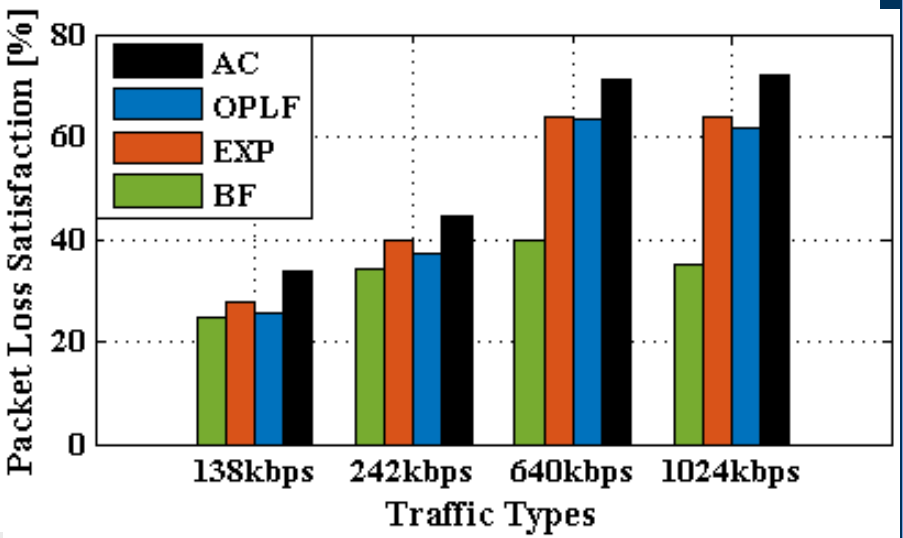
PRELIMINARY RESULTS

- Barrier Function (BF) – GBR
- Exponential Rule (EXP) – delay
- Opportunistic Packet Loss Fair (OPLF) – PLR
- Actor-Critic (AC) scheme – combines BF, EXP and OPLF









Are we able to increase Quality of Experience with a minimal impact on underlying networking resources?

QoE and QoS for 360˚ Videos

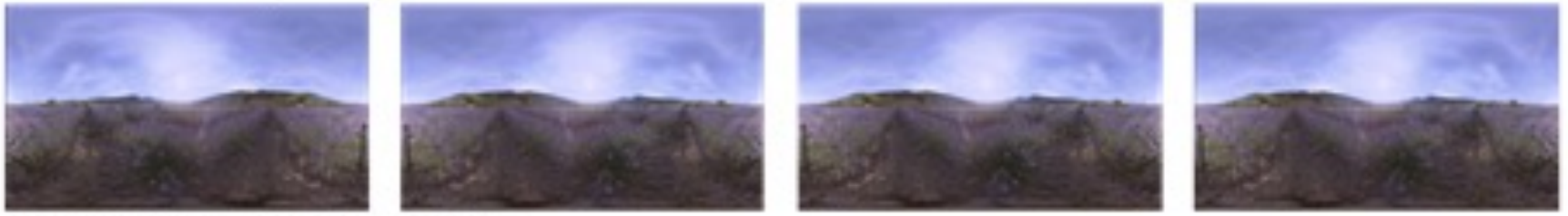
- 360˚ videos are 5 times larger than regular videos and involve complex projections
- Monolithic streaming approach -> growth in data requirements
- Controlling QoS parameters is important
- Caveats which concern the sole focus on QoS assessment:
  - although QoE depends on the QoS delivered by the underlying networks, it also takes further aspects into account;
  - enhancing QoS can lead to increased operating costs for service providers and capital expenditures for network operators.

360˚ Mulsemedia Prototype

- VR Goggles + olfactory device + intensity based fan
- Videos annotated with Sensory Effects Metadata (SEM) of the MPEG-V standard
- PlaySEM Mulsemedia renderer
- 360° VR application deployed in Unity

360˚ Videos

Lavender field (static)



Coffee shop (semi-dynamic)

Roller-coaster (dynamic)

360˚ Video -> 360˚ Mulsemedia

- Olfactory and airflow effects were released with different intensities at different timings

Experimental Design

- Each video – four encoding settings (HD, Full HD, 2.5K, 4K)
- 48 participants (27 male, 21 female)

	360° multimedia			360° mulsemedia		
User 1	LAV	COF	ROL	LAV	COF	ROL
User 2	ROL	LAV	COF	ROL	LAV	COF
User 3	COF	ROL	LAV	COF	ROL	LAV
User 4	LAV	ROL	COF	LAV	ROL	COF
User 5	COF	LAV	ROL	COF	LAV	ROL
User 6	ROL	COF	LAV	ROL	COF	LAV

QoE Evaluation

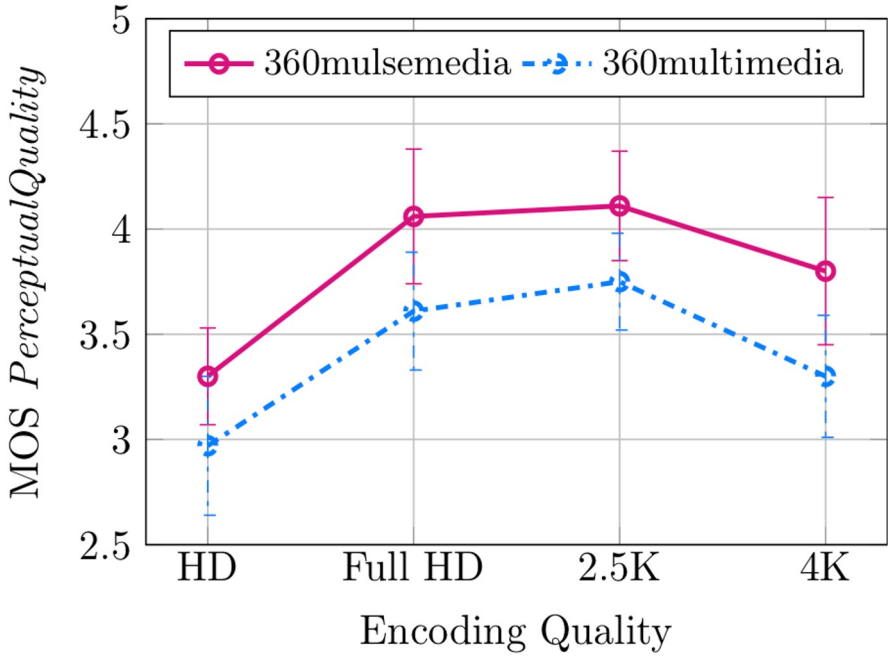
- QoE questionnaire (11 questions)
  - (1) *Please rate the overall quality of the video clip*
    {Bad, Poor, Fair, Good, Excellent}
  - (2) *The quality of the visual display is appropriate*
    {Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree}
  - (3) *I enjoyed the 360^0 experience*
    {Strongly Agree, Agree, Neutral, Disagree, Strongly Disagree}

- + questions targeting the olfactory and wind effects (4 each)
  - (1) *The olfactory effects enhance the sense of reality*
  - (2) *The olfactory effects are distracting*
  - (3) *The olfactory effects are annoying*
  - (4) *I enjoy watching the videos with olfactory effects*

Results

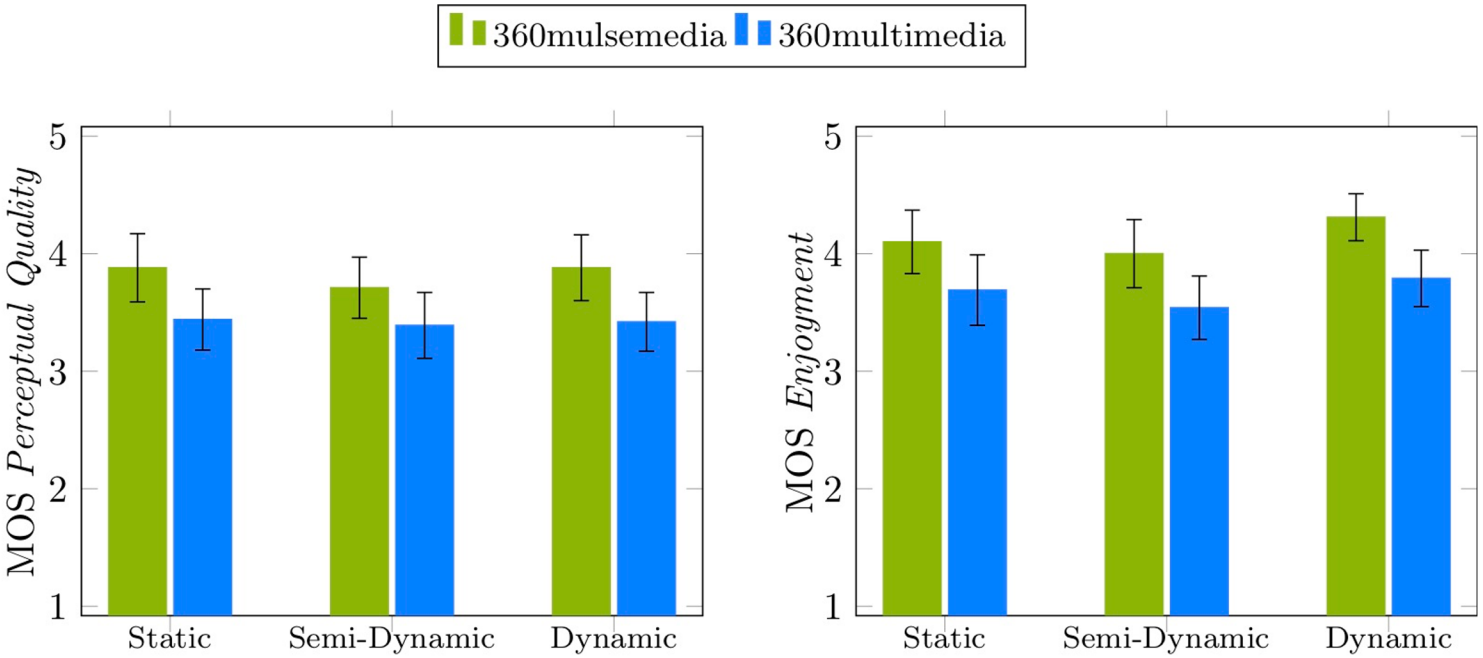
Do multisensory effects impact user-perceived quality of 360° videos?

Overall perceived quality is 12% higher for 360° mulsemedia compared to 360° multimedia for all the considered resolutions



Results

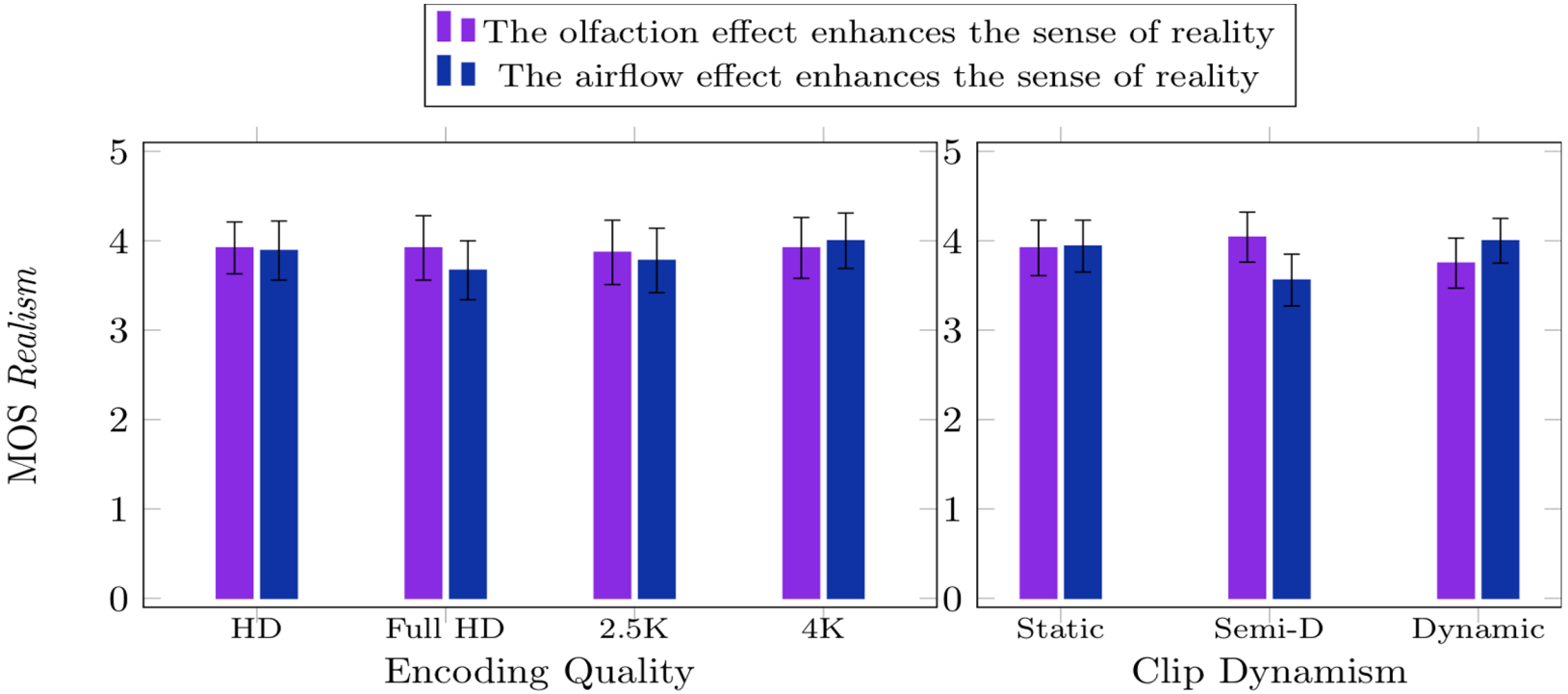
Does video dynamism impact user-perceived quality and enjoyment of 360° videos?



» Clip motion level had a significant effect on the enjoyment factor ($F(2, 282) = 28.89$, $p < 0.05$), but not on perceived quality ($F(2, 282) = 2.12$, $p > 0.05$)

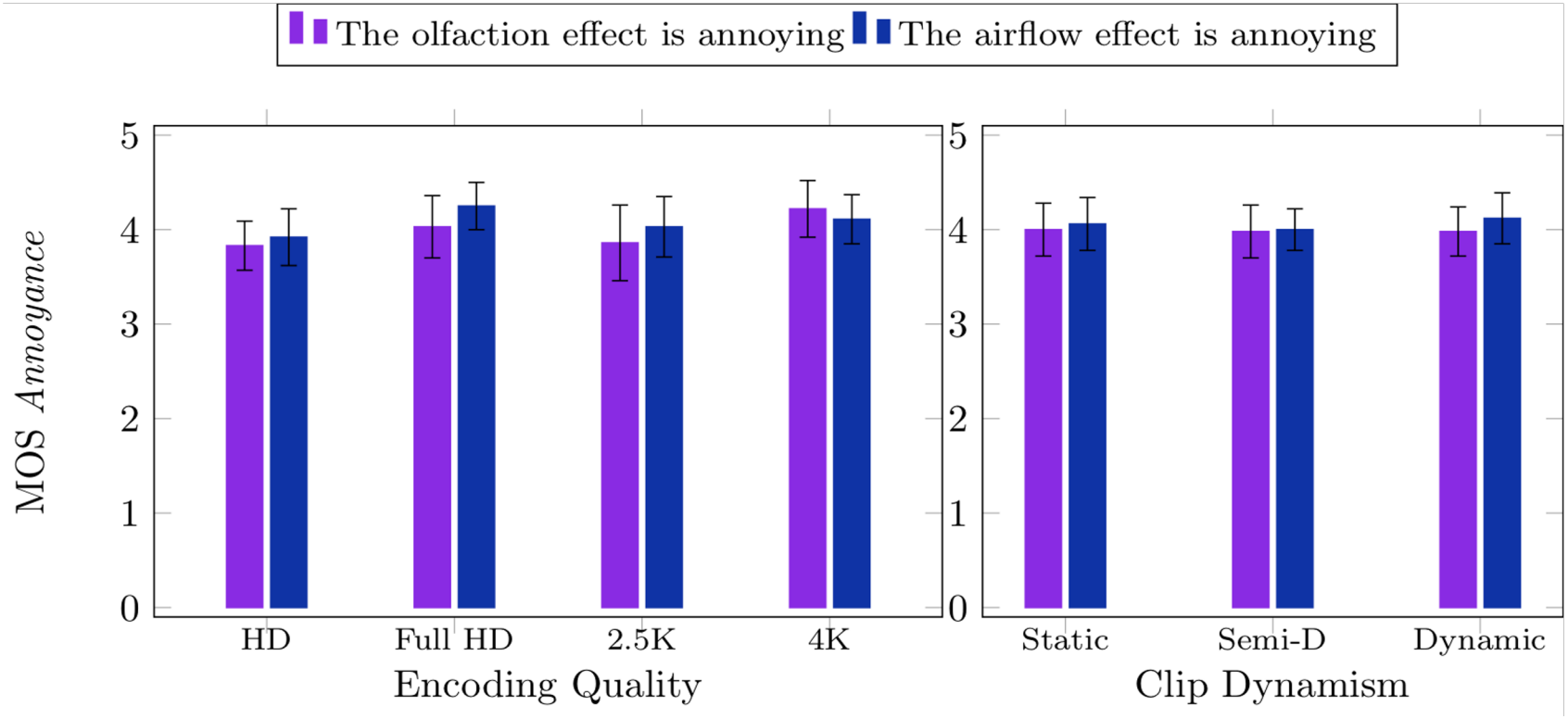
Results

Do multisensory effects enhance the sense of reality in 360° mulsemedia?



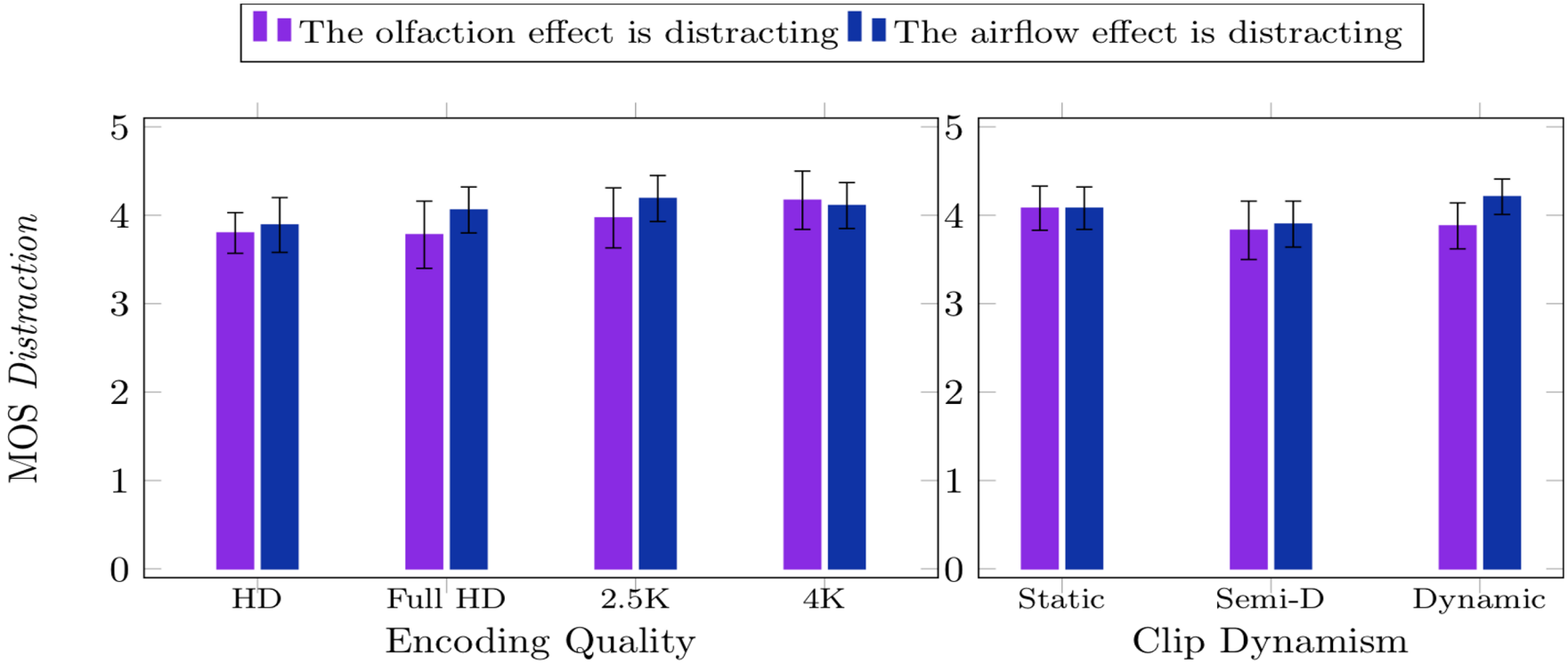
Results

Do multisensory effects annoy users in 360° mulsemedia?



Results

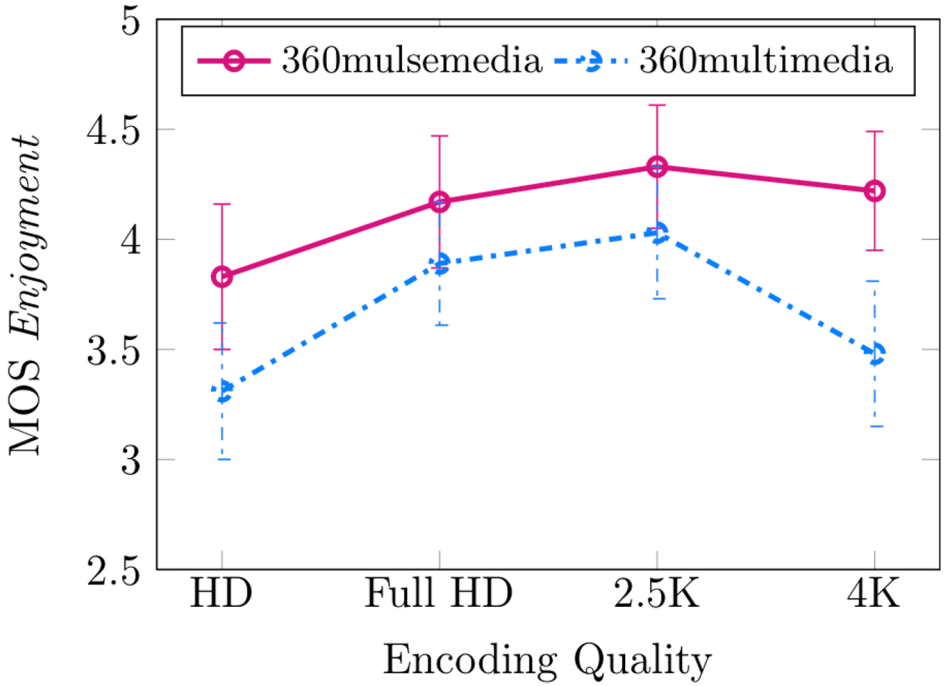
Do multisensory effects distract users in 360° mulsemedia?



Results

Do multisensory effects enhance user enjoyment of 360° videos?

Significant increase of enjoyment in the presence of multisensory effects ($F(3, 280) = 17.84$, $p < 0.05$)

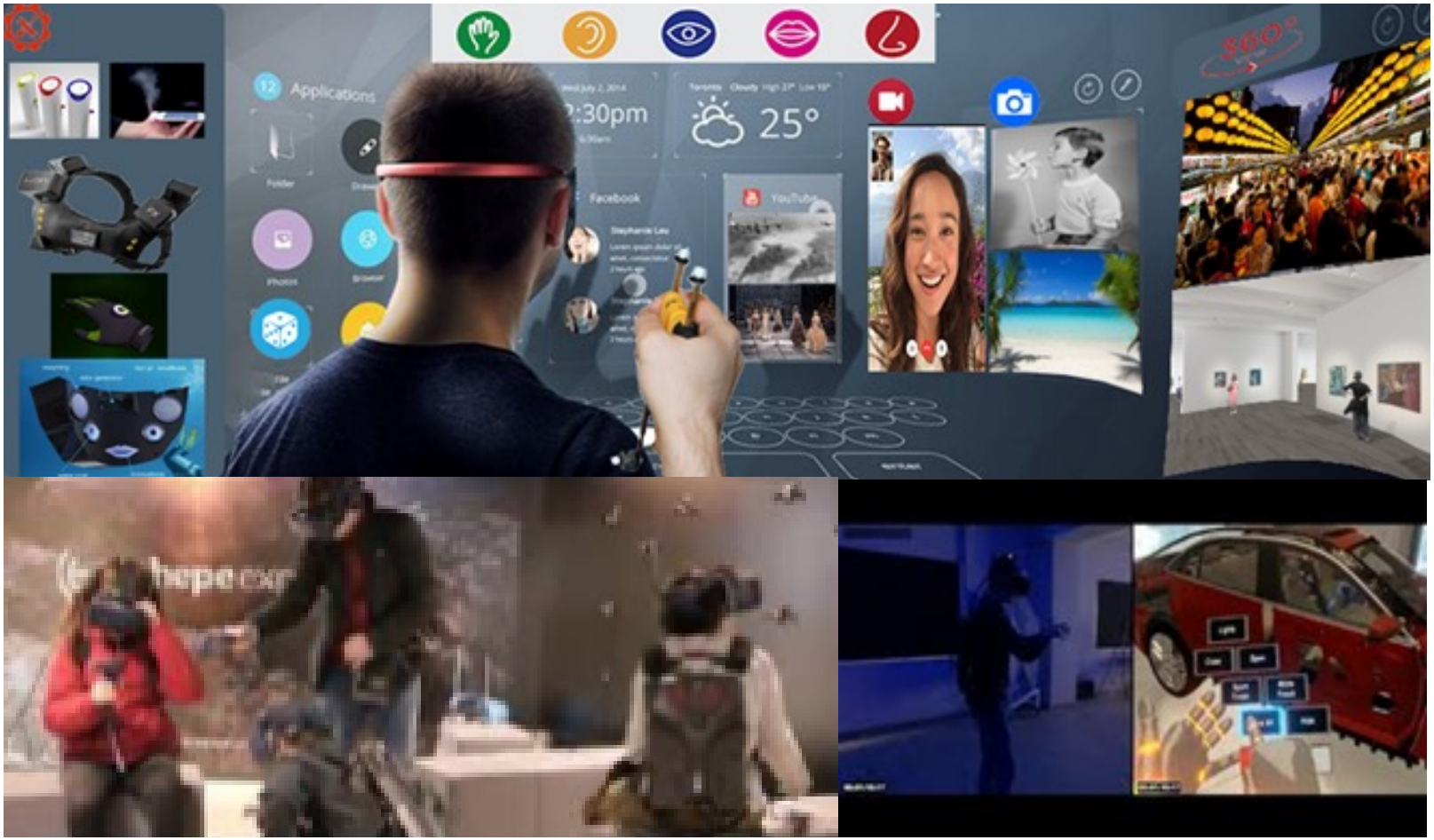


Conclusions

Mulsemedia has the potential to enhance QoE in 360° video

- Overall perceived quality of omnidirectional videos was higher when multisensory effects were employed
- Airflow and olfactory effects boost the overall perceived quality of 360° videos by 12% and enjoyment by 13% across the four encoding qualities
- The improvement in user-perceived quality from HD to Full HD is evident and significant. The gain for transition from Full HD to 2.5K is marginal.
- Encoding quality can be reduced in 360° mulsemedia to Full HD without any detrimental impact on the QoE
- Content is still king: Clip motion level significantly affects user enjoyment of 360° videos in the case of mulsemedia, but not so in respect of user-perceived quality

Mulsemedia future directions…


Applications
25°
Facebook
YouTube
360°

X -Ray tube: X-Ray tube can be moved down, up, back and forward by means of side boom. X-Ray tube requires a clean ground line and therefore connected directly to the factory's main ground line via a ground wire. Distances from the flat panel are an important criterion in the process of obtaining Class A and Class B image quality. The center of the tube is covered with a lead layer. During the test phase, the flat panel and the X-Ray tube must move in syncron.

Flat Panel: Flat panels are used to convert X-Ray to light. Connection with the computers are made through flat panels. Digital image data is taken from the flat panel moving on the cat and transferred to the database.

Main Boom: The cat is moving on this boom. The boom is supported to avoid bending down over time.

Internal structure: The equipments in the test system are in a concrete covered room and the entire inner surface is covered with lead. The pipes are taken through the door, which is covered with lead all around, with the help of the vehicle. There are audible and visual warning devices in the system.

Boom Support: When the vehicle is in the test position, the boom support moves to left or right to support the main bom.

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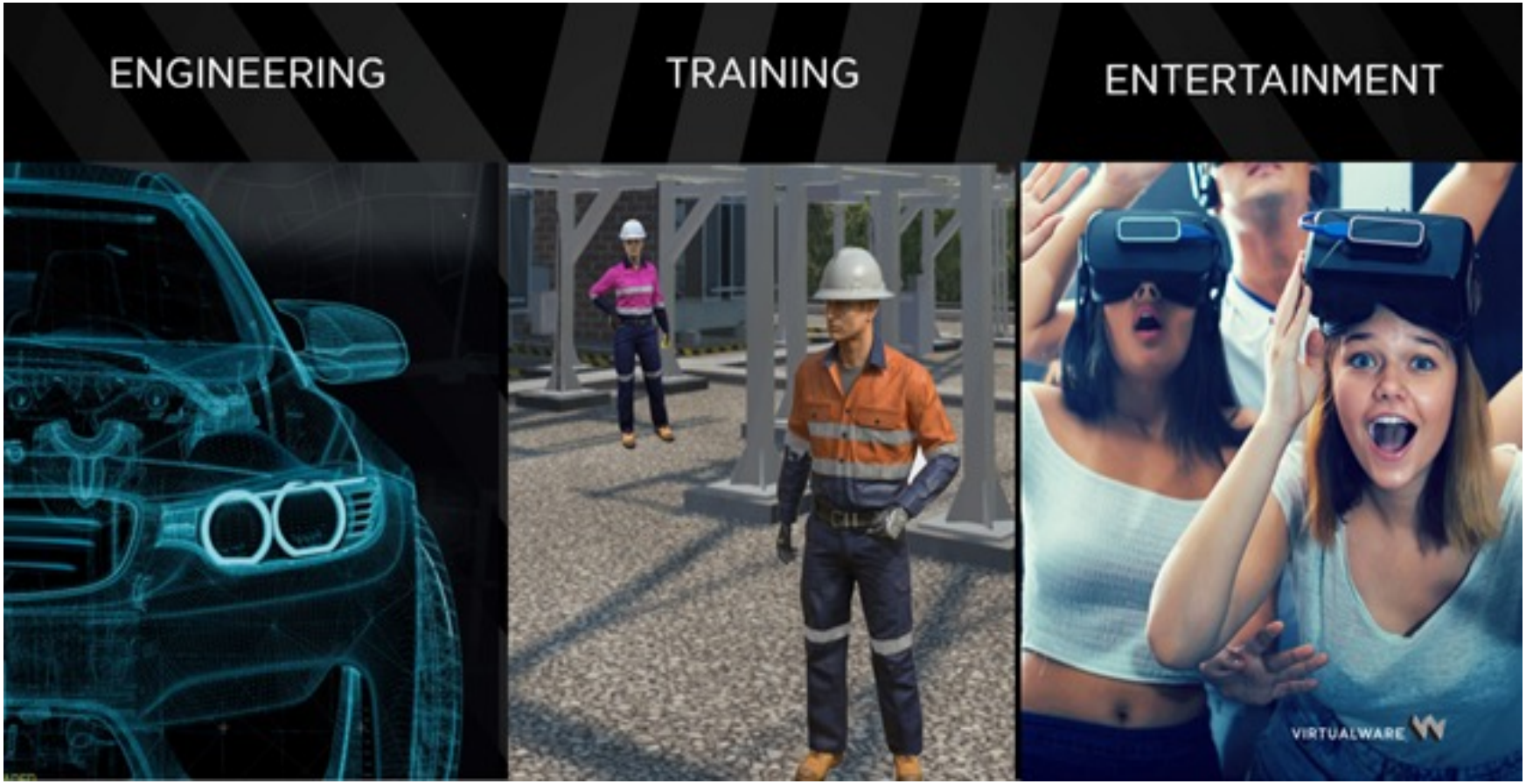
Pallet: The vehicle carrying the pipe moves on this system. The pallet has cables for communication and control between the vehicle and the control panel.


ENGINEERING
TRAINING
ENTERTAINMENT
VIRTUALWARE

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Thank You

Questions?