
# Quality of Experience for Virtual Reality: Methodologies, Research Testbeds and Evaluation Studies

**Mirko Sužnjević**, Maja Matijašević

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# Introduction

- In the past several years, virtual and augmented reality seems to be finally taking off

- Although neither technology has yet gained a widespread adoption there are devices on the market which are affordable for a wide range of consumers

- New ways of interaction with the VR have been added – controllers and contactless sensing (e.g., Leap Motion, Microsoft Kinect)

# Problem: What? How? Why?

- Impact of different system, user, and context parameters on Quality of Experience (QoE) for VR services (very broad area)
- We performed two user studies inspecting different aspects of the QoE problem for VR
- VR is still an emerging technology, but according to Digi-Capital it is predicted that VR and AR markets will grow to 108 billion USD by 2021

# Research questions

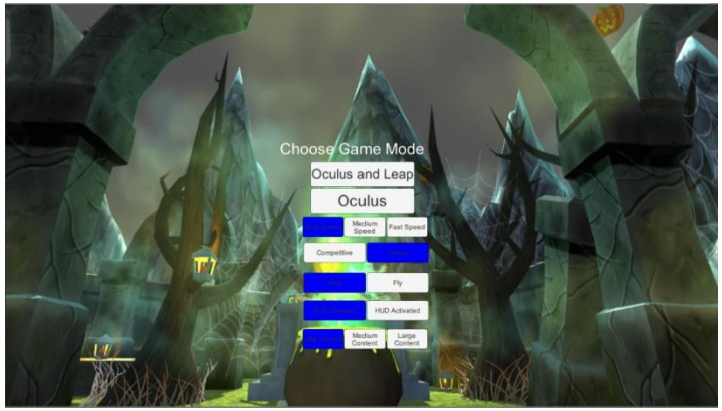
- How the parameters within the virtual world impact the perceived QoE? (RQ1)
  - Speed of movement
  - Type of movement
  - Level of detail
  - Head Up Display (HUD)
- How the interaction devices impact the perceived QoE? (RQ2)
  - Keyboard and mouse
  - Leap motion
  - Gamepad
- How different systems for VR impact the perceived QoE (with the focus on the interaction)? (RQ3)
  - Oculus Rift
  - HTC Vive

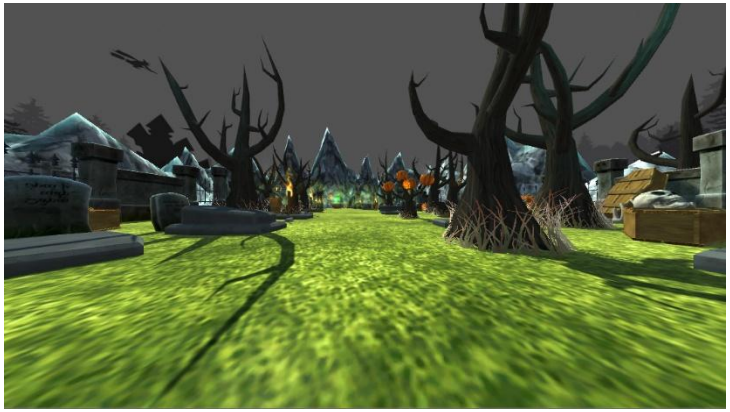
# Studies

- Two separate studies performed to answer research questions
- Study 1 – answers RQ1 and RQ2
  - 15 users
    - 10 male and 5 female
    - Average 24 years old
  - Oculus Rift DK 2
  - Custom application developed for the purpose of testing
- Study 2 – answers RQ3
  - 13 users
    - 8 male and 5 female
    - Average 26 years old
  - Oculus Rift and HTC Vive compared
  - Custom application developed for the purpose of testing

# Study 1 - methodology

- Developed an VR application using unity with modular capabilities
- Modifiable parameters
  - Speed of movement
  - Type of Movement
  - Level of detail
  - HUD
  - Interaction devices
  - Competitive element



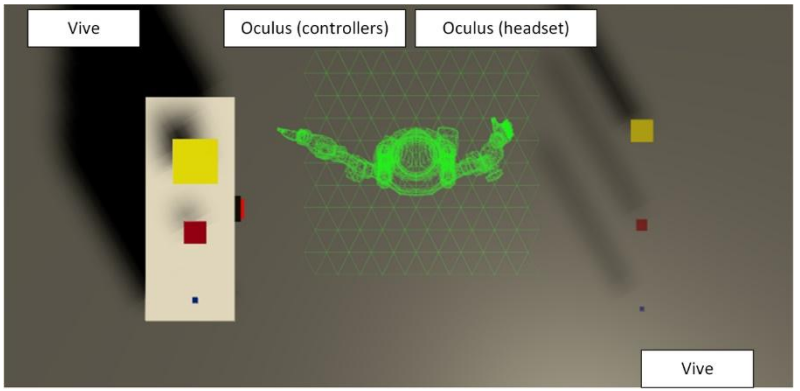
- Each user tested all values of all parameters (not all combinations)
- Default combination of parameters was: Oculus, walk, medium speed, large content, no HUD, keyboard and mouse, and no competitive element
- User reported QoE and ease of use for input devices, while on other parameters they just reported the preferred setting

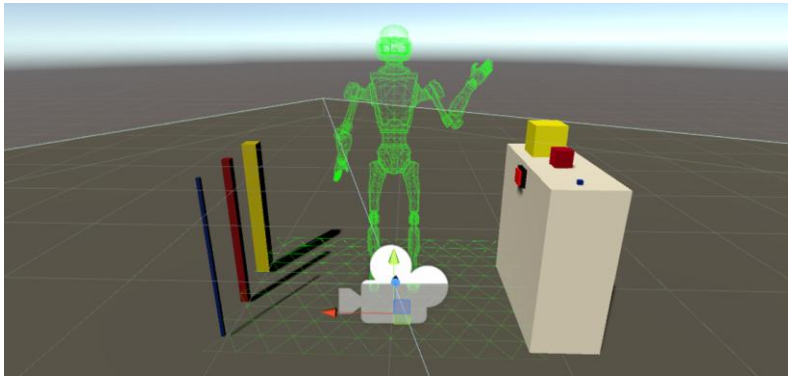
# Study 2 - methodology

- Objective study
  - Evaluation by an administrator
  - Metrics
    - Frame rate
    - Ambiance light
    - Sensor obstruction
- Subjective study
  - Subjective metrics:
    - Quality of Experience,
    - Intuitiveness
    - Ease of use
  - Objective metrics
    - Spatial precision
    - Time to complete a task
  - Users test both systems, one by one, and rate the subjective parameters based on the 7-point Comparison Category Rating (CCR), according to the ITU-T Rec. P.800

# Study 2 – VR application

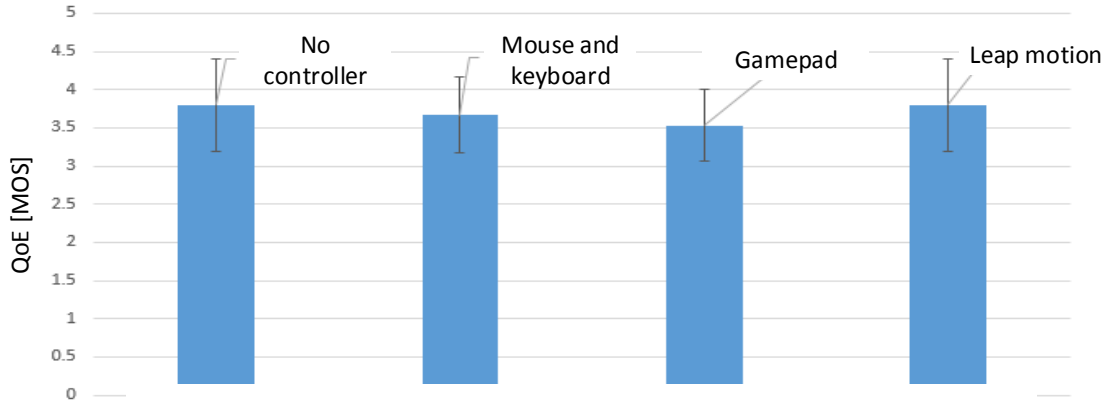
- A simple VR application implementing a pick-and-place task developed by using Unity Game Engine
- Task focused on dexterity – moving of three (small, medium, large) cubes from one position to the other
- In addition to dexterity, tasks were timed to note down the speed and precision of placing the cubes to the final position
- Users were first shortly familiarized with the system with the help of an administrator (e.g., how to grab a cube)

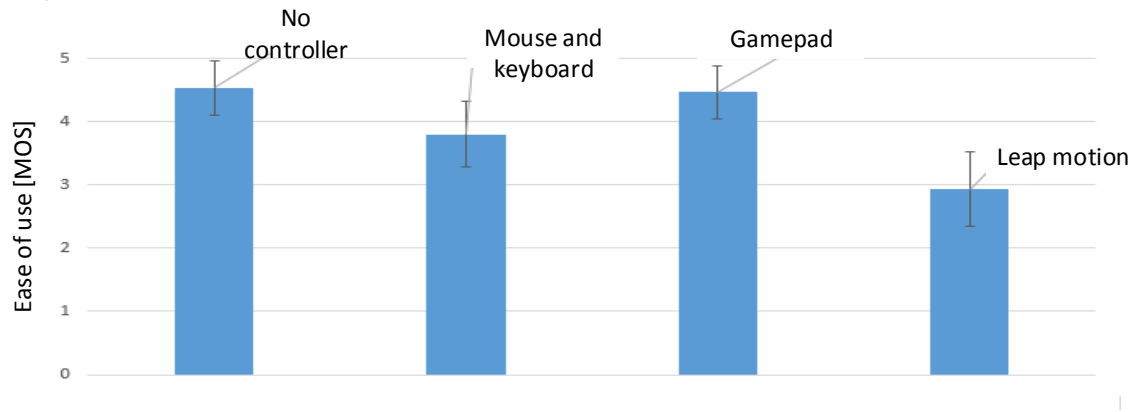


# Results – *QoE* and *Ease of use* for different input devices

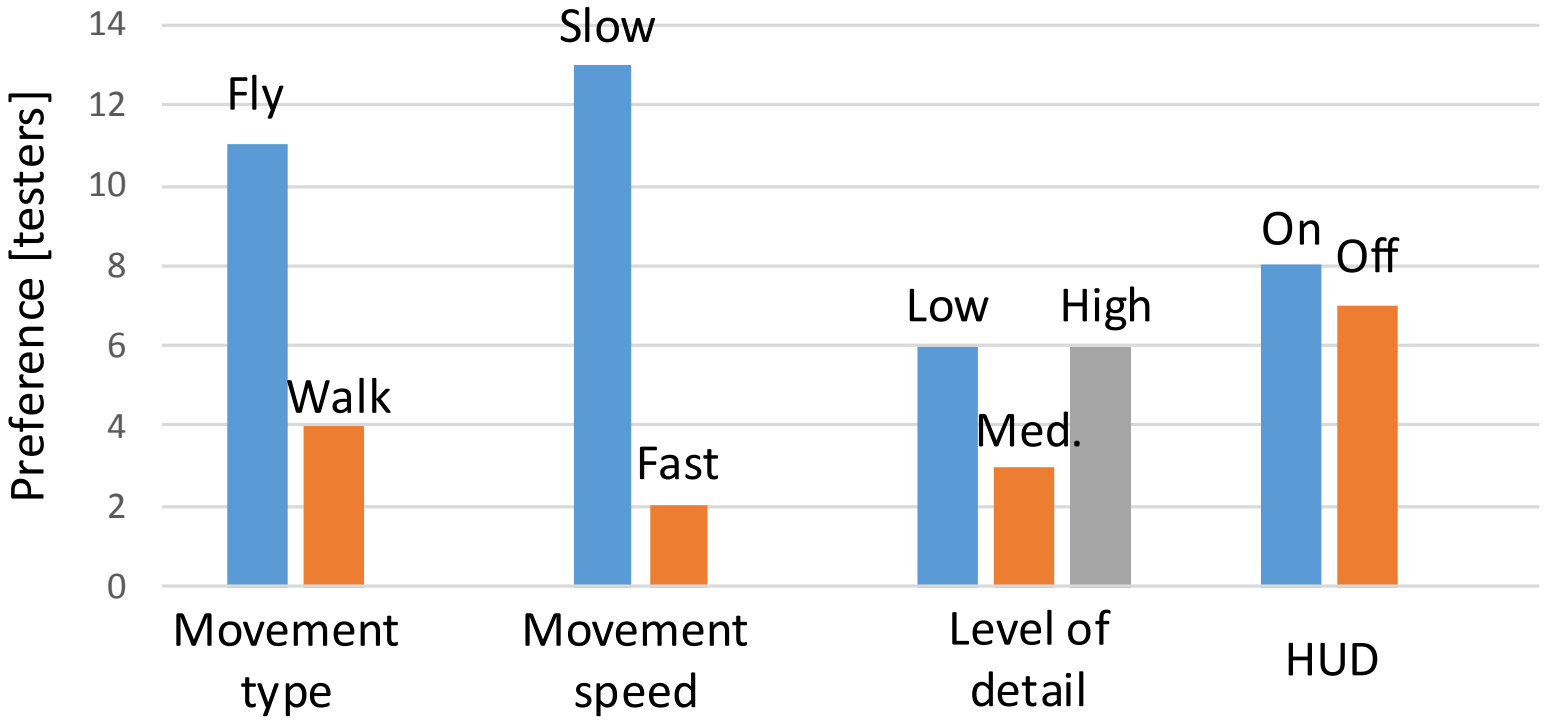
- No distinction between QoE for different input
- Clear distinction for ease of use (leap motion has lowest ease of use due to clumsy functionality



# Results – preferred application settings

- Users prefer flying over walking, and slow movement speed
- There is no agreement regarding level of detail and HUD



# Difference between HTC Vive and Oculus Rift

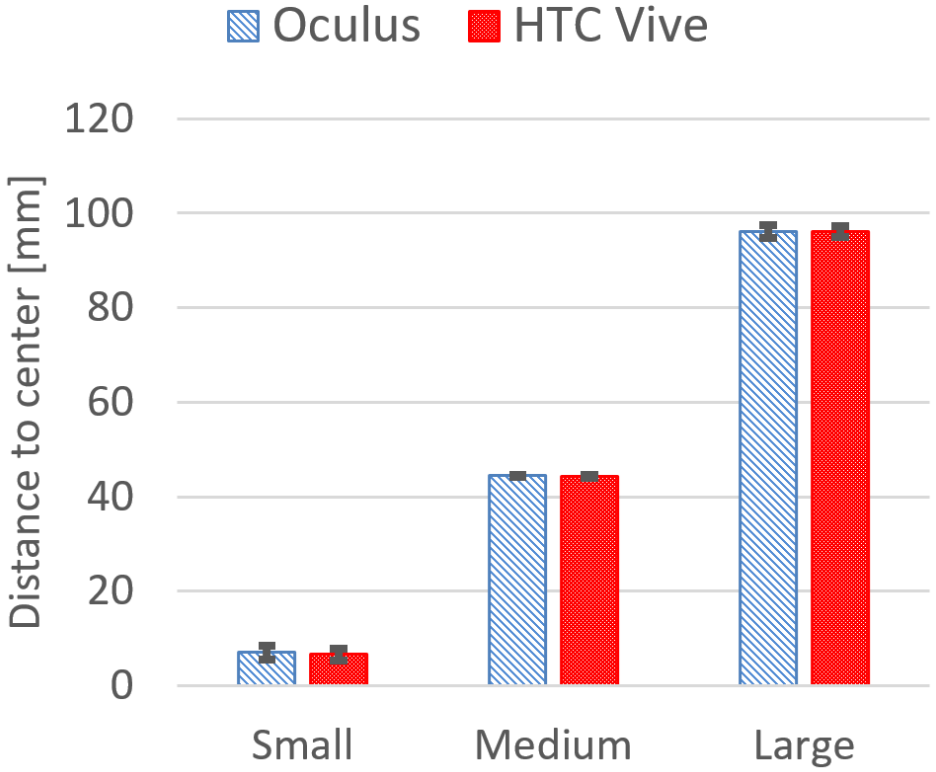
- Both devices have same main characteristics:
  - OLED displays
  - 2180 x 150 resolution
  - Refresh rate of 90Hz
  - Field of view of 110 degrees
- HTC Vive was released with controllers and two sensors which track both controllers and Head Mounted Display (HMD)
- Oculus Rift is released without controllers and with one sensor for tracking HMD – controllers were released as a separate product later with additional sensor tracking only controllers.

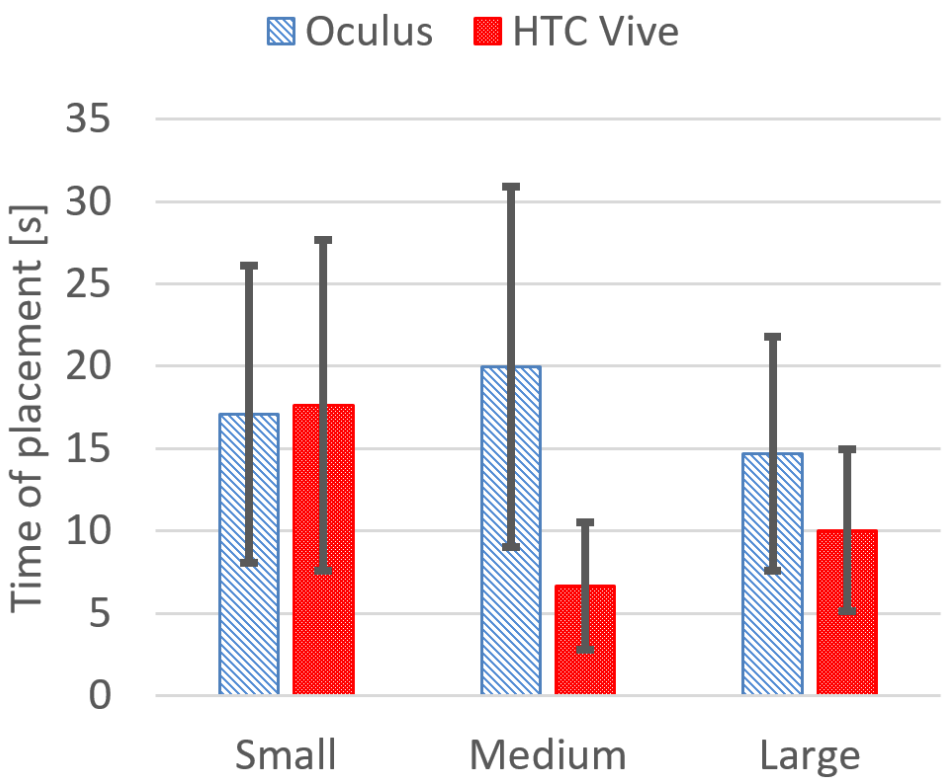
# Results – objective comparison of VR systems

- HTC Vive consistently outperformed the Oculus Rift by 5% in terms of frame rate (both devices have above 90 fps)
- Both devices remain equally unaffected by visible light
- Infrared light causes significant interference for both devices (e.g., Microsoft Kinect camera)
- HTV Vive's sensors simultaneously track both the head-mounted display and controllers, while Oculus Rift has one sensor dedicated for each device
- HTC Vive is more resilient to sensor obstruction due to better initial positioning and tracking technique

# Results – spatial precision and time to complete the task

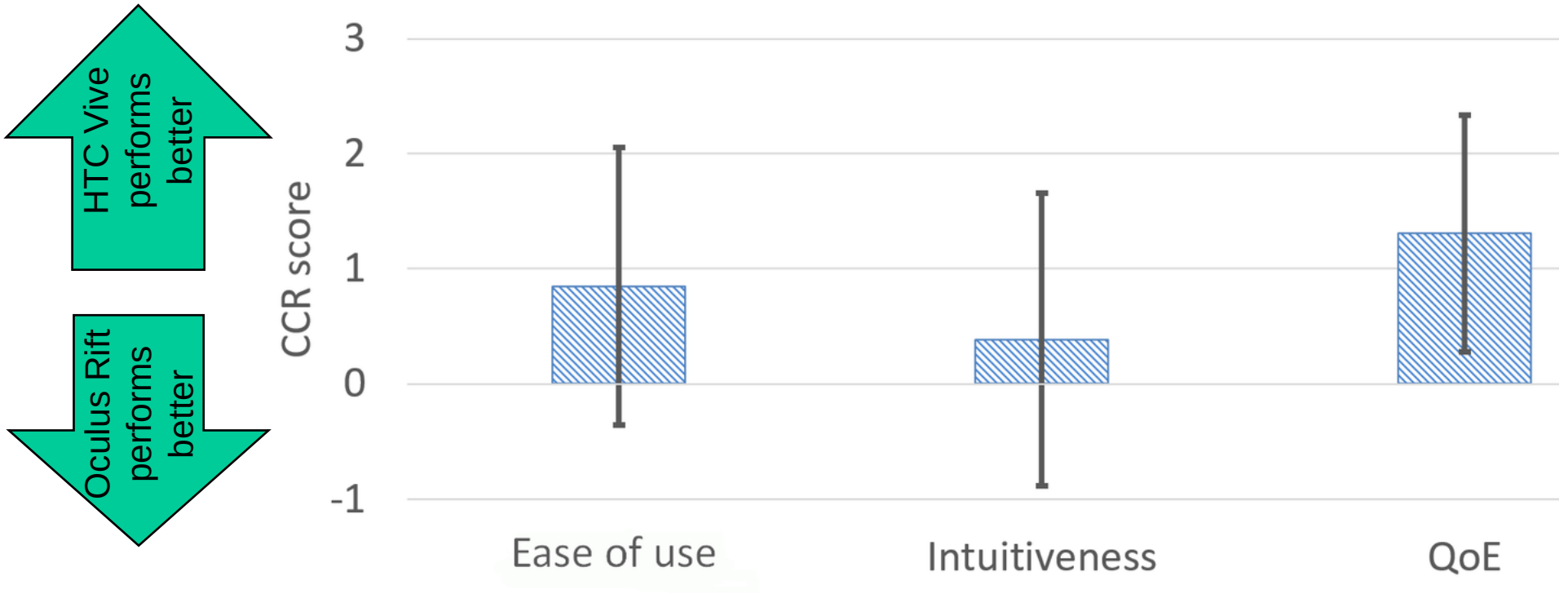
- In terms of spatial precision there is no difference between devices
- In terms of time to complete the task, more time is needed to move the cube with Oculus Rift than with HTC Vive



# Results – subjective metrics

- HTC Vive performed slightly better on evaluated subjective metrics, especially on overall QoE
- The most frequent users' complaint was related to the need to maintain line-of-sight while using Oculus Rift, which limited their natural movement.



# Conclusions

- Our testing group does not have a specific preference between custom input devices if they work properly
- Our testing group preferred flying over walking in VR, as well as slower speed
- The comparison study suggests that HTC Vive was evaluated better by our test group on all subjective metrics, and that it performed better on several objective metrics
- Majority of advantages can be attributed to the HTC Vive sensor system which is more robust to loss of tracking than Oculus Rift
- For future testing the same sensor composition is needed (an additional sensor for Oculus Rift)