

Additional file 1

1. Questionnaire

(1) Visual and ergonomic performance: 8 multiple-choice questions

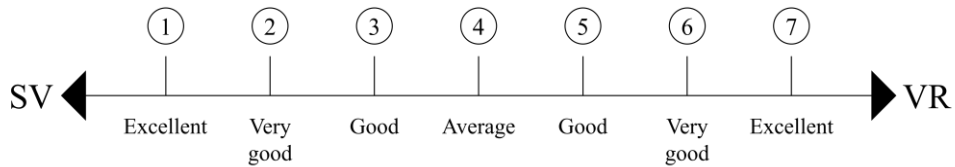
This section comprehends user experience related with visual aspect, physical restriction, and benefits from replacement of stereo viewer.

- 1) How do you feel about overall quality of VR HMD-based image?
① Very good ② Good ③ Fair ④ Poor ⑤ Very Poor
- 2) Is there a time-lag in PSM control on VR HMD image compared to stereo viewer?
① Not at all ② Slightly ③ Moderate ④ Very ⑤ Extremely
- 3) How do you feel about front camera view of VR HMD?
① Very good ② Good ③ Fair ④ Poor ⑤ Very Poor
- 4) How do you think about the impact of visual cut-off from real world due to VR HMD?
① Not at all ② Slightly ③ Moderate ④ Very ⑤ Extremely
- 5) How do you feel the sense of weight about VR HMD?
① Very good ② Good ③ Fair ④ Poor ⑤ Very Poor
- 6) How do you feel the sense of pressure about VR HMD?
① Very good ② Good ③ Fair ④ Poor ⑤ Very Poor
- 7) Do you expect the VR HMD can soothe a pain on neck, shoulder, and back caused from the long-term use of stereo viewer?
① Strongly agree ② Agree ③ Neutral ④ disagree ⑤ Strongly disagree
- 8) Do you expect the workspace expansion of MTM will affect positive during operation when stereo viewer is replaced by VR HMD?
① Strongly agree ② Agree ③ Neutral ④ disagree ⑤ Strongly disagree

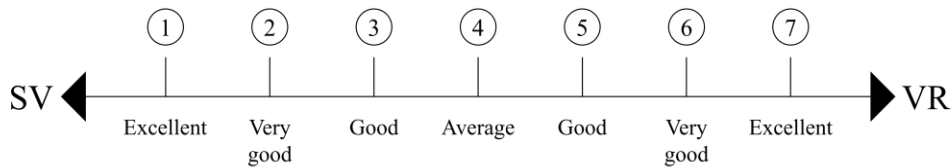
(2) Comparison between the devices: 5 multiple-choice questions

In this section, participants compare stereo viewer to VR HMD from 5 perspectives and grade in 7 levels which device is better or not. The closer the grade is to 7, the better the VR HMD is than the stereo viewer (SV: stereo viewer, VR: VR HMD).

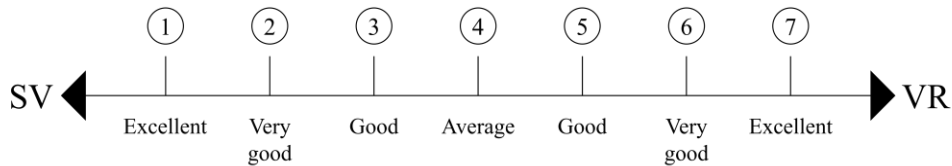
1) A comparison of 3D effect



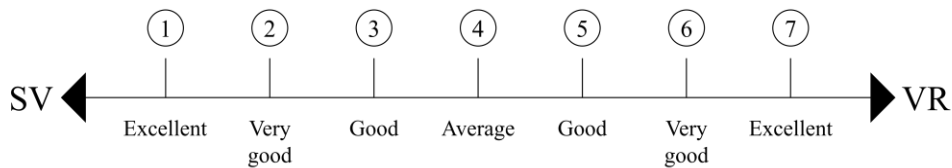
2) A comparison of field-of-view



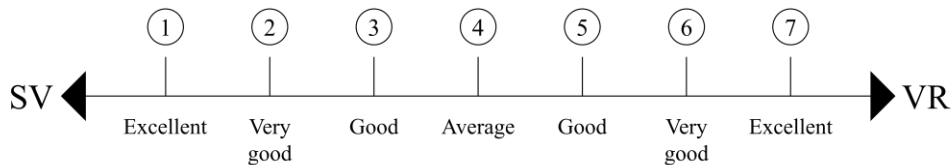
3) A comparison of immersiveness



4) A comparison of concentration retention



5) A comparison of physical fatigue (neck, shoulder, and back)



(3) Comments and Feedbacks: 3 subjective questions

- 1) Promptly write down the opinions need to be enhanced.
- 2) Suggest how to utilize VR HMD for da Vinci surgical robot.
- 3) Freely comment about this evaluation.

2. Modified NASA-TLX

