Cybersickness in Augmented Reality: Gradual changes with the course of prolonged exposure

Zion Park, Jiyoung Oh, Minseong Jin, Seyoon Song, Subin Jeon, Haeji Shin & Chai-Youn Kim
School of Psychology, Korea University

Introduction

Growing interest in virtual reality (VR) and **augmented reality (AR)** emphasizes the need to establish guidelines for proper and healthy usage of such new technical instruments. Compared to the intensive evidence regarding cybersickness in VR, however, symptomatic experiences in AR are not yet thoroughly tackled [1].

This study aims to investigate cybersickness and discomfort during **AR** device usage while manipulating the **exposure duration** to AR content, the user's **familiarity** with the AR device, and AR **content intensity**.

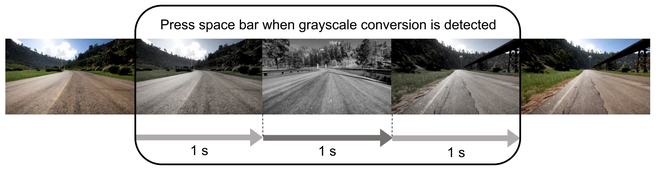
Methods

AR Apparatus

Nreal Light (Xreal Inc.)
- FOV: 52°
- Weight: 106 g
- Size: 146 mm x 175 mm x 44 mm

Stimuli & Task

- First-person racing game videos
- Grayscale conversion detection task at random time points



Independent variables

Exposure duration

10 minutes x 3 viewings
30 minutes cumulatively per session

Familiarity

Participants visited the lab twice in a week interval
- 1st session
- 2nd session

Content intensity - speed

- Slow - average: 110km/h, max: 122km/h
- Fast - average: 290km/h, max: 426km/h

Dependent variables

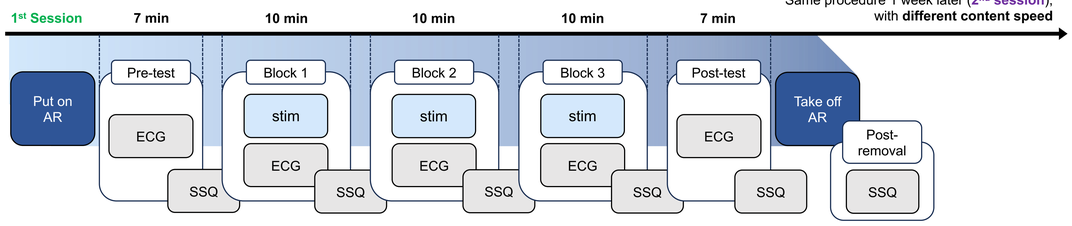
Behavioral measures
- Accuracy
- Response Time (RT)

Questionnaires
- Simulator Sickness Questionnaire (SSQ) [2]
  - SSQ-Nausea (SSQ-N)
  - SSQ-Oculomotor (SSQ-O)
  - SSQ-Disorientation (SSQ-D)

Physiological measures
- Electrocardiogram (ECG)
  - Heart rate (beats per min; BPM)
  - Heart rate variability

Procedures

Group1 (N = 11) 1st session: Slow stimulus / 2nd session: **Fast** stimulus
Group2 (N = 11) 1st session: **Fast** stimulus / 2nd session: Slow stimulus



Results: Behavioral measures

Accuracy

- Accuracy was high overall (mean accuracy: 84.8%)
- Data from blocks in which behavioral accuracy was **below 50%** were excluded from further analyses (Proportion of excluded data: 10.61%)

Response Time (RT)

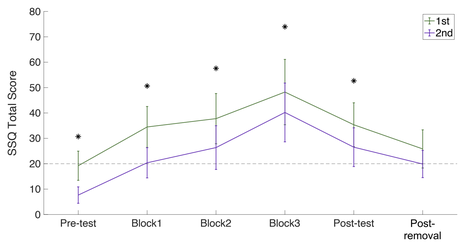
- RT increased with **exposure duration** (F = 12.454, p < .001): Block1 < Block2***, Block3**
- No significant difference in RT between 1st session and 2nd session
  - 1st session : block1 = 1.02s / block2 = 1.27s / block3 = 1.22s
  - 2nd session: block1 = 1.05s / block2 = 1.25s / block3 = 1.21s

* p < .05
** p < .01
*** p < .001

Results: Questionnaires

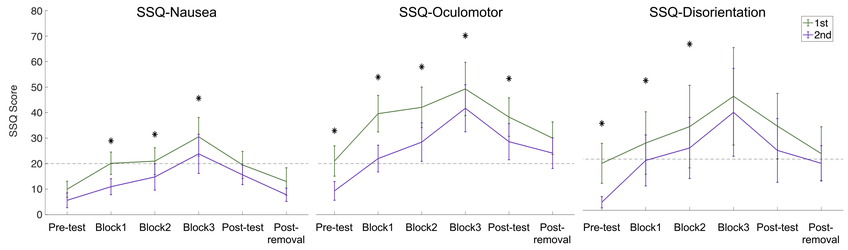
Exposure duration, familiarity, and content intensity have a significant three-way interaction effect on SSQ scores (F = 3.238, p = .041).

SSQ total score



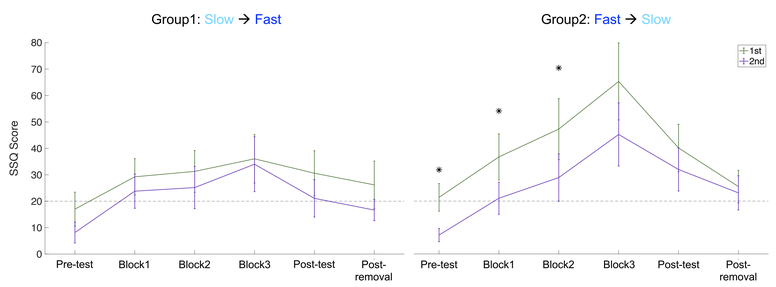
- SSQ score increased with **exposure duration** (F = 14.695, p < .001).
- SSQ score was lower for the 2nd session than the 1st.
  This **familiarity** effect was significant until the removal of AR device.
- Participants reported that cybersickness worsened with continuous exposure to the AR contents, while repeated experience with AR device (**familiarity**) diminished the degree of cybersickness.

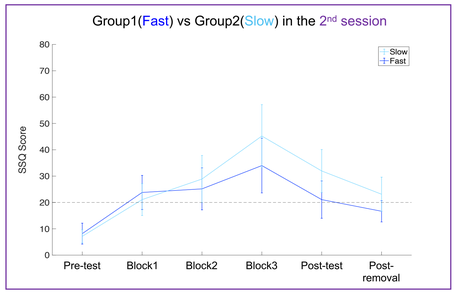
SSQ subscale scores



- There were significant main effects of **exposure duration** on all SSQ subscale scores (F = 13.586, p < .001).
- Overall score for each time point was lower for the 2nd session than the 1st in all SSQ subscales.
- The Oculomotor domain scored highest among the three subscale scores (O ≥ D > N).
  This is in contrast with VR studies, in which the O-subscale score was commonly reported as the lowest.

SSQ total score for optimal AR usage group

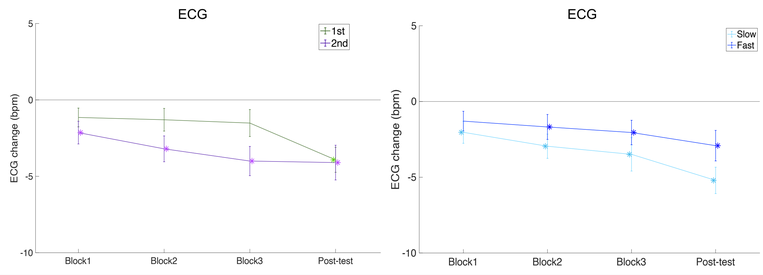




- Those who watched the slow speed (low intensity) video first (group1) showed overall low SSQ scores even in their first experience with the AR device. The scores for the 1st session was not significantly different to the reduced scores in the familiar, 2nd session.
- Those who watched the fast speed (high intensity) video first (group2) showed an increase in SSQ scores due to prolonged exposure. Moreover, the scores in the 2nd session were significantly lower than the 1st session.
- Although the extent of the familiarity effect for group2 was greater than group1, the SSQ score in the 2nd session for group1 tended to be lower than group2 even their contents were more intensive.
- This is worth pointing out, since it implies that one can experience more severe cybersickness even to the lower content intensity, depending on which intensity of stimulus was watched first.

Results: Physiological measures

- Heart rate decreased with **exposure duration** (F=4.638, p=.015).
- Although there is no significant main effect of familiarity and content intensity, heart rate tended to be lower in the 2nd session than 1st ,
  and to be lower in the slow condition than the fast condition.
- Since temporal relationship between physiological measures and cybersickness is not clearly established [3], we are currently examining additional indices such as heart rate variability to probe associations with cybersickness.



Conclusions

In this experiment, we observed that AR content exposure duration and AR equipment familiarity had effects on cybersickness, which was reflected through RT and SSQ scores. Noticeably, the content intensity the user encountered at initial AR device usage seemed to influence the overall degree of discomfort. Guidelines for AR usage should thus recommend low content intensity at initial use, and then proceed to higher content intensity, as the user builds familiarity with the device.

Although temporal relationship between physiological measures and cybersickness is not clearly established [3], decrease of BPM along with exposure duration provides a clue for the possibility of physiological signals serving as cybersickness indices of AR experience.

References

[1] Vovk, A., Wild, F., Guest, W., & Kuula, T. (2018, April). Simulator sickness in augmented reality training using the Microsoft HoloLens. In *Proceedings of the 2018 CHI conference on human factors in computing systems* (pp. 1-9).

[2] Kennedy, R. S., Lane, N. E., Berbaum, K. S., & Lilienthal, M. G. (1993). Simulator sickness questionnaire: An enhanced method for quantifying simulator sickness. *The international journal of aviation psychology*, *3*(3), 203-220.

[3] Chang, E., Seo, D., Kim, H. T., & Yoo, B. (2018). An integrated model of cybersickness: Understanding user's discomfort in virtual reality. *Journal of KIISE*, *45*(3), 251-279.