ICAI 2023
12th International Conference on Applied Informatics
Eger, Hungary, 2023

How Egocentric Distance Estimation Changes in Virtual Environments by using a Desktop Display or the Gear VR

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Abstract

Due to the importance of depth perception in virtual spaces, the effects of display devices on egocentric distance estimation are investigated. We developed a virtual environment that can assess distance estimation skills of users at 10 various distances. Our results show that people are either accurate or overestimate distances on a desktop display, while underestimation occurs with the Gear VR in most cases.

Introduction

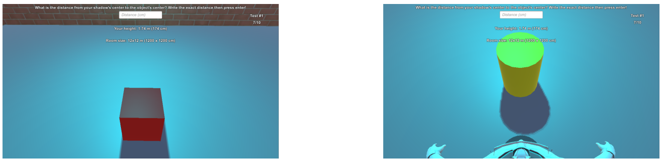
Egocentric distance estimation and depth perception are crucial as they are required for reaching, grasping, and interception tasks [2, 5]. It is possible to improve these skills using virtual reality (VR) technologies and virtual environments (VEs) [1]. Improvement occurs because VR can stimulate cognitive functions [4]. This requires a carefully designed VE, since its composition can affect spatial skills [6]. However, distances are incorrectly estimated in VEs when compared to the real world [3]. To understand this phenomenon better, we have developed a VE in Unity and investigated the effects of immersive and non-immersive display devices.

*Supported by the ÚNKP-22-4 New National Excellence Program of the Ministry for Culture and Innovation from the source of the National Research, Development and Innovation Fund.

Materials and Methods

The aforementioned VE can be used with a desktop display on PC or with the Gear VR on Android. The used desktop display was an LG 20M37A (19.5") device, while the Gear VR had a Samsung Galaxy S6 Edge+ inside it. Overall, the egocentric distance estimation skills of 239 participants were measured. 157 people ($M_{age} = 19.80, SD_{age} = 2.09$) used the desktop display, while 72 ($M_{age} = 22.51, SD_{age} = 6.63$) used the Gear VR. Participants joined the study of their own volition, and no names were gathered. Before the measurements commenced, they had to input some parameters such as the age, gender, height, etc. in the VE's menu.

Participants could not move in the VE. Only the virtual camera could be rotated either with a mouse on PC or with their head on Android. This camera was placed at their actual height. Everyone had to estimate egocentric distances to cubes, spheres, or cylinders between 25 cm and 160 cm at 15 cm intervals. Each of these had to be estimated twice in a randomized order. In the PC version, estimates had to be entered into an input box, while participants had to verbally estimate them in the Android one. In case of the latter, a researcher typed them into the dataset at the same time. Fig. 1 shows a test on the PC version.



(a) A test with a cube. **(b)** A test with a cylinder.

Figure 1. Two tests with different objects.

Results

The distributions of data were assessed with the Shapiro-Wilk test in both versions. Neither the distributions of estimates in the PC version was Gaussian ($W = .88$, $p < .001$), nor in the Android version ($W = .79, p < .001$). Thus, the Wilcoxon rank sum test was used when the estimates were compared between platforms, while its signed rank variant was used for comparing the estimates to the actual distances. An $\alpha = .05$ was chosen for the analyses. The results are shown in Fig. 2.

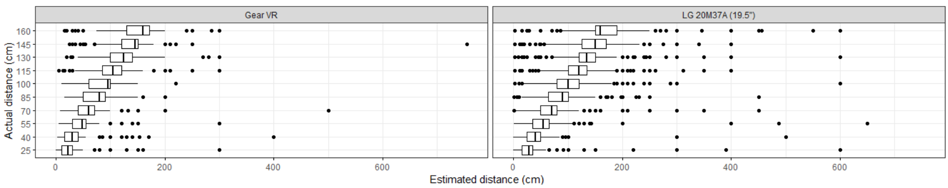


Figure 2. Results on both versions at every investigated distance.

The same distances on both platforms were compared. The two smallest differences are at 145 cm ($W = 25514, p = .026$), and at 160 cm ($W = 25814, p = .014$). The differences are strongly significant for the remaining distances as $p < .001$.

When comparing estimates to actual distances on the PC version, not all of them are significant, however each of them is overestimated. Between 40 cm and 160 cm, these are below 10%. Significant overestimates were found at 130 cm ($V = 20885$, $p = .017$), and at 160 cm ($V = 21559, p = .014$).

Contrarily, when comparing the estimates with actual distances in the Android version, underestimates occurred at all distances except at 25 cm. Therefore, distances were overestimated in case of the latter. The results of the comparisons are the following: 25 cm ($V = 2610, p = .001$), 40 cm ($V = 1426, p < .001$), 55 cm ($V = 1718, p < .001$), 70 cm ($V = 1301, p < .001$), 85 cm ($V = 2224, p < .001$), 100 cm ($V = 976, p < .001$), 115 cm ($V = 2893$, $p < .001$), and 130 cm ($V = 2334$, $p < .001$). The underestimates at 145 cm and 160 cm were not significant.

Conclusions

A VE was developed to assess the egocentric distance estimation skills of users. Besides the components of VEs, display devices are crucial as well. Depending on the level of immersion, either overestimation or underestimation can occur. Users are more likely to overestimate distances to objects at 130 cm and 160 cm with a desktop display. With the Gear VR, it is likely that they underestimate distances to objects that are 40–130 cm away, while overestimation occurs when objects are 25 cm away from them. The designers of future VEs have to keep these in mind.

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