The influence of text rotation, font and distance on legibility in VR

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Abstract

The legibility of text in virtual environments (VE) is especially important for the simulation of user interfaces of real machines and devices. For this purpose a study was conducted to examine the influence of rotation, the distance and the font of text on the legibility in VR. In addition, the minimum readable text size under these conditions was measured using the angular unit dmm. The results of the study show that text rotated 60° or more requires a much larger text size to be legible regardless of the distance of the text to the viewer and font.

Keywords: Virtual Reality, Text Legibility

1 Introduction

The representation of text is necessary and important for many applications of virtual reality. For head mounted displays (HMDs) there are guidelines with recommendations for text parameters if the text is located at a static position in front of the user (e.g. as a virtual Head-Up-Display) [4, 8]. In many real-world environments, however, text is presented in different viewing positions. E.g. most car entertainment systems are located at the center console of a car such that the driver looks from the side onto the display of the system. Thus, when designing VEs (in particular for virtual prototypes) where legibility and readability of text is necessary, it is important to estimate the required text parameters before implementing the system to avoid dissatisfying results and unnecessary costs (cf. [1]).

2 Related Work

Legibility describes how easily or quickly individual letters can be recognized in a text. Readability is associated with the cognitive level and describes how easily a reader can understand written text (cf. [10]). Both properties are interdependent and depend on several factors such as font size, font type, the distance between words, etc. and also depend on display factors like screen size, screen resolution and so on.

Previous work on analyzing the influence of various factors on the legibility of text presented on displays has mostly focused on search for optimal text parameters by measuring user performance, e.g. [2, 5]. *Larson et al.* [6] have observed the influence of text size and left or right rotation on a 3D-display. *Polys et al.* [9] observed that for a bigger field of view displaying text in object space has benefits. *Dingler et al.* [3] created a first guideline for the parameters font, font size, convergence distance, and text box size for UIs in a VE with HMDs.

To our knowledge the influence of rotation, distance to the user and font on the legibility of text presented in a VE using a HMD has not been investigated previously. In addition, reliable minimum text sizes are determined which are required for reading text under the tested conditions.

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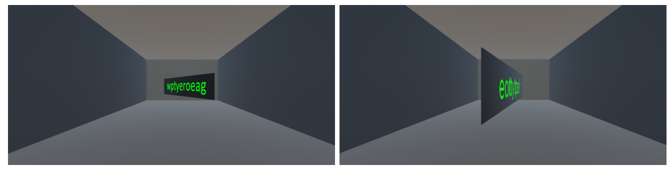

Figure 1: Scenario examples. Left: Font Calibri, Distance 8.0 m, Rotation 60°. Right: Font Metropolis, Distance 4.0 m, Rotation 80°.

3 Experiment

The purpose of the experiment was to investigate how the rotation of text around the vertical axis, the distance of the text from the viewer and text font in a VE influence legibility.

3.1 Experiment Design

For this experiment, a $2 \times 3 \times 5 \times 5$ split-plot-design was used. The between-group factor of the experiment is the rotation direction of the text around the vertical axis (left, right). All other factors were tested per participant as within-group variables. These include font (Arial, Calibri, Metropolis), distance (0.8 m, 1.0 m, 2.0 m, 4.0 m, 8.0 m) and the rotation angle (0°, 20°, 40°, 60°, 80°). Thus every test participant was exposed to 75 different conditions.

Text size, representing the minimal text size that is required to read text under the given condition, was the dependent variable. It is defined here as the height of the lowercase character "x" with the unit dmm (distance-independent-millimeter).

3.2 Technical Setup

Participants were wearing a *HTC Vive Pro* HMD and interacted by pressing a button on a *HTC Vive Controller 2.0*. The experiments were additionally recorded on video. The VE was implemented using *Unity 3D* where signed distance fields fonts were used for the text rendering. It contained a room in which the test participants could orient themselves. The texts were all displayed in green on a black rectangle.

3.3 Test Session

The study was conducted with nineteen volunteers (4 f, 15 m, age 20-54, $MV = 27.6$, $SD = 7.2$). Ten of them were assigned to the left rotation group and the others to the right rotation group. The duration of the task was between 18 and 35 minutes.

After the participants got informed about the procedure, they sat on a chair with a fixed backrest and seat, equipped with the HMD and a controller. The initial head position in the VE was normalized to a height of 1.5 meter. Before testing each condition, they saw a random text with a legible text size. This allowed them to adjust the HMD to ensure that the text can be seen as clearly as possible and to test the interaction for increasing the text size. For all 75 conditions, a text consisting of ten random, alphabetic, lowercase characters weighted by the frequency in the English language (cf. [7]) was displayed with an initial size of 3 dmm. The text parameters were set according to the current condition (Fig.1). The participants increased the text size with the controller in steps of 1 dmm until the characters were just legible. Decreasing the text size was not possible. Next, they read aloud the characters. If one or more characters were

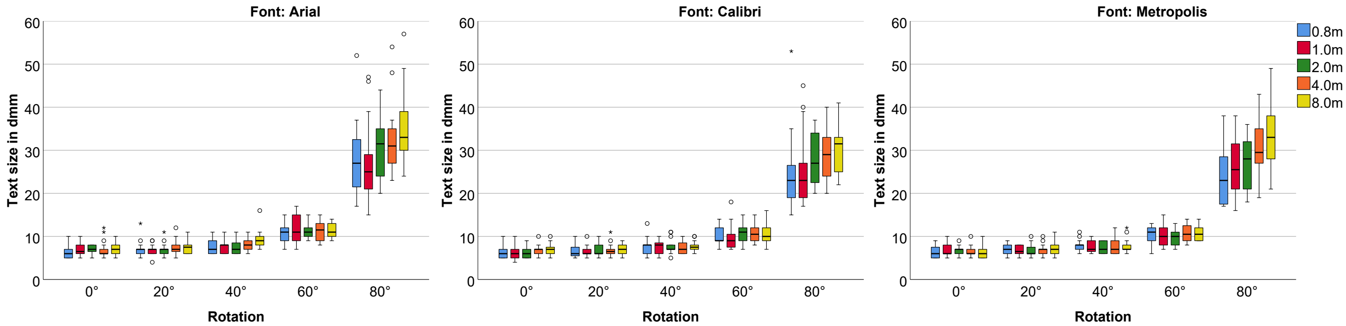

Figure 2: Text size box plots

incorrect, they had to increase the text size and to try again. After all characters were recognized correctly, the participants had to read aloud other ten random characters with the same text parameters and the set text size. This allowed to validate the measured text size.

4 Analysis of the Results

The results are shown in Figure 2. One can see that text sizes are clearly different at a rotation angle of 80° compared to the other rotation angles. Also, the range of values is larger for the biggest angle. When comparing the different fonts, the range of text sizes is similar for the same rotation-distance pairs. This also applies to the text sizes for equal rotation angles and different distances. A Friedman Test has shown that there is a significant difference in the legibility for different rotation angles, $31.148 < X^2(4) < 64.190$, $p < 0.001$. However, this is not true for the influence of the distance on the legibility of the characters. Here, a Friedman Test shows no significant difference for twelve of fifteen cases, $1.812 < X^2(4) < 8.374$, $0.079 < p < 0.770$. Only in three cases, there was a statistical significant difference, $13.386 < X^2(4) < 15.447$, $0.004 < p < 0.010$. Similarly, a significant impact of the different fonts could not be observed. In nineteen of twenty five cases, a Friedman Test shows no significant difference, $0.259 < X^2(2) < 6.000$, $0.052 < p < 0.910$, while there was a significant different in six cases, $6.043 < X^2(2) < 8.943$, $0.010 < p < 0.047$. Finally, a Kruskal-Wallis Test has shown that there was no significant difference in the rotation direction, $X^2(1) < 3.403$, $p > 0.064$.

5 Discussion

The experimental results give a first impression of the extent to which the factors rotation, distance and font affect the legibility of text. However, not all factors have been considered that might additionally influence the minimal required text size, e.g. human factors (age, vision). In the experiment only the text color green was used, providing the best quality for the given hardware. Other colors might require bigger text sizes due to rendering artifacts. The impact of the different variables might differ for other displays and resolutions. Furthermore the light setup in the experiment has led to unexpected Fresnel artifacts. The reflections might have made it more difficult to recognize rotated text. Thus further experiments are required to determine the correlation between all involved factors as well as reliable text size recommendations.

One could argue that most of the texts people read are not or only slightly rotated. However, there are conceivable cases, such as entertainment systems in cars, where the text is actually rotated relative to the user. If a VR simulator is to be effective for these applications, the text labels on the buttons should be as legible as in reality.

6 Conclusion And Outlook

In this paper, a study was reported which intended to find the minimal required text size for reading text in a VE. In addition, it was tested whether these text sizes vary significantly with different rotation angles, distances and fonts. The results show that rotation has a statistically significant influence, especially for a rotation angle of 60° or above. The tested distances and fonts did not show a measurable influence. Testing the legibility of text is quite a complex task as it depends on many factors. For that reason, more research and experiments are required to give appropriate guidelines for developers and designers. We recommend to reproduce the experiment with different hardware, text and colors and with more test subjects.

References

[1] A. Bolder, S. M. Grünvogel, and E. Angelescu. Comparison of the usability of a car infotainment system in a mixed reality environment and in a real car. In *Proceedings of the 24th ACM Symposium on Virtual Reality Software and Technology*, VRST '18, pp. 8:1–8:10. ACM, New York, NY, USA, 2018. doi: 10.1145/3281505.3281512

[2] I. Burmistrov, T. Zlokazova, I. Ishmuratova, and M. Semenova. Legibility of Light and Ultra-Light Fonts: Eyetracking Study. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction - NordiCHI '16*, pp. 1–6. ACM Press, Gothenburg, Sweden, 2016. doi: 10.1145/2971485.2996745

[3] T. Dingler, K. Kunze, and B. Outram. VR Reading UIs: Assessing Text Parameters for Reading in VR. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems - CHI '18*, pp. 1–6. ACM Press, Montreal QC, Canada, 2018. doi: 10.1145/3170427.3188695

[4] Facebook Technologies, LLC. Introduction to Best Practices. https://developer.oculus.com/design/latest/concepts/book-bp/. Accessed: 20 November 2019.

[5] J. Jankowski, K. Samp, I. Irzynska, M. Jozwowicz, and S. Decker. Integrating text with video and 3d graphics: The effects of text drawing styles on text readability. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pp. 1321–1330. ACM, 2010.

[6] K. Larson, M. van Dantzich, M. Czerwinski, and G. Robertson. Text in 3d: some legibility results. In *CHI'00 extended abstracts on Human factors in computing systems*, pp. 145–146. ACM, 2000.

[7] R. E. Lewand. *Cryptological Mathematics*. Mathematical Association of America, Washington, DC, USA, 1st ed., 2000.

[8] C. McKenzie and A. Glazier. Designing screen interfaces for VR. https://events.google.com/io2017/schedule/?section=may-19&sid=3a7c6766-0d0d-4778-bc22-b8f3094aa451. Accessed: 21 November 2019.

[9] N. F. Polys, S. Kim, and D. A. Bowman. Effects of information layout, screen size, and field of view on user performance in information-rich virtual environments. *Computer Animation and Virtual Worlds*, 18(1):19–38, 2007.

[10] A. Sears and J. A. Jacko. *Human-Computer Interaction: Designing for Diverse Users and Domains*. Taylor & Francis Inc, New York, 2 ed., 2008.