VR Reading UIs: Assessing Text Parameters for Reading in VR

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CHI'18 Extended Abstracts, April 21–26, 2018, Montreal, QC, Canada
ACM 978-1-4503-5621-3/18/04.
https://doi.org/10.1145/3170427.3188695

Abstract

Virtual Reality (VR) devices have increasingly sparked both commercial and academic interest. While applications range from immersive games to real-world simulations, little attention has been given to the display of text in virtual environments. Since reading remains to be a crucial activity to consume information in the real and digital world, we set out to investigate user interfaces for reading in VR. To explore comfortable reading settings, we conducted a user study with 18 participants focusing on parameters, such as text size, convergence, as well as view box dimensions and positioning. This paper presents the first step in our work towards guidelines for effectively displaying text in VR.

Author Keywords

Reading; Virtual Reality; Text Parameters; Reading Comfort

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

Motivation and Background

As more and more VR systems enter the consumer market, developers and designers create an increasing set of games, applications, and utilities. Slowly, those creators lay the foundations for User Interface (UI) design patterns in VR. While the big advantage of VR lies in the immersive-

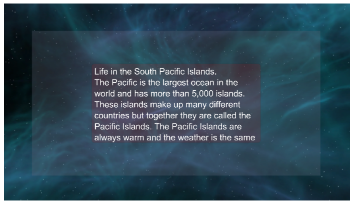

Figure 1: Screenshot of the reading UI for setting preferred parameters.

ness through a multimodal presentation, text remains an important modality to convey information [7] as it is one of the most common and prominent ways to acquire knowledge. There are text layout, legibility, font and other guidelines for most major display and device types, from regular monitors to non-rectangular displays, desktops, smartphones, and watches [3].

Early work by Duchnicky and Kolers [5], for example, focused on the effect of window height and line width on reading performance. Especially for smaller window sizes, they concluded four lines of text to be optimal, whereas only two lines had a negative effect on readers. Bernard *et al.* [1, 2] also explored a number of parameters to support legibility, such as font size and font family. Rello *et al.* [8] investigated different font sizes for the body of websites. Using an eye tracker and comprehension tests, they found that readability and text comprehension significantly improves when online text is displayed with larger font sizes, namely 18, 22, and 26.

Reading in VR, however, has so far only been sparsely researched [6]. Sousa *et al.* [10] investigated ambient lighting conditions for when radiologists analyzed and interpreted images. Using VR headsets they report diminishes the effects of unsuitable ambient conditions. Grout *et al.* [6] focused specifically on reading tasks with Head-Mounted Displays (HMDs) examining different aspect ratios and comparing plane *vs.* curved displays. Studies with extensive reading parameter variations in VR, however, seem to be lacking. For designers to create immersive, yet comfortable and effective reading experiences, we need to assess some basic text and UI parameters first.

At the 2017 Google IO, Google engineers introduced a new unit for perceived size in VR, which they called '*dmm*' (distance-independent millimeter). It allows for a consistent screen layout system that can be applied to any screen at any distance. The human eye can comfortably cover a viewing angle of about 60° both horizontally and vertically, so primary UI elements should be kept in this area when head rotation is to be avoided [4]. Neck rotations, on the other hand, can increase this viewing angle to about 120°. Companies, such as Google or Unity, informally release their best practices with regard to text presentation online, but a set of comprehensive guidelines for displaying text in VR is yet missing. In our current work, we conduct a series of studies to elicit reading guidelines in VR. In this paper, we present a first user study focusing on comfort levels of different text parameters, such as text size, vergence settings, and text box dimensions.

Method

To define reading parameters for maximizing reading comfort, we conducted a first lab experiment with a focus on the font, vergence, and view box adjustments. We, therefore, allowed participants to adjust their preferred text parameter settings and asked them to state their preferences with regard to text display in a semi-structured interview.

Through University mailing lists and social networks, we recruited 18 participants (8 female) with backgrounds in computer science, design, linguistic, and psychology. Five participants wore contact lenses, five wore glasses, while eight did not require any vision correction. Most of them indicated to regularly read on their phone (15), on printed media (14), on a PC (12), e-reader (4), or tablet (3). While seven participants said they frequently used a VR headset, ten had used one once or twice before, and one participant even owned one.

Figure 2: Study participant setting her preferred text parameters.

Apparatus
We used an Oculus Rift CV1 HMD, with 6 degrees-of-freedom (DOF) tracking (3 rotational, 3 spatial). According to the Oculus developer documentation [1], the Oculus Rift CV1 has optics equivalent to looking at a screen approximately $1.3m$ away. We simulated the Virtual Environment (VE) using a Windows 10 PC with an Intel CORE i7 and GeForce GTX 1060 graphics card. For user input, we used an Xbox controller. The VE was developed in Unity 3D and the Oculus SDK. It showed a soft dark background consisting of a space scene (see Figure 1). We used the sans-serif Ariel font throughout the experiment. Our custom-built program recorded participant's preference data including text size, distance, text box size, and explicit preferences.

Procedure
We invited participants to our lab and instructed them on the purpose of the study. After signing a consent form, we handed out a short demographic survey and introduced the study contents. Participants then put on the Oculus headset, made sure that the device was placed comfortably, and modified the focus using the adjustment slider until a shown text was displayed sharply. The headset provided enough space for users to wear their eyeglasses inside. We started the study by presenting a standard text with either a fixed font size or a fixed distance. We were interested in the three variables font size, vergence distance, and angular size, which are all related to each other. We, therefore, studied participants' preferences for each variable by keeping one variable fixed and allowing participants to control another. The size and distance to the text were set randomly within ranges (distance between $0.2m$ and $90m$, and $0.09m$ and $1.8m$ in absolute text height). From this starting point, participants used an XBox controller to adjust one of either the text size or the distance to the text, until the angular size of the text was deemed optimally comfortable for reading. This task was repeated 5 times. Next, we wanted to determine the most comfortable convergence distance to the text, given a fixed angular size of the text. The angular text size determined from the mean size-distance ratio of the size-distance pairs of data taken in the previous part of the experiment. While keeping the angular text size fixed, the convergence distance was set randomly within the same distance ranges ($0.2m$ and $90m$). Participants could then adjust the convergence to the most comfortable distance. We also asked them to select convergence distances representing the closest comfortable distance, and the farthest comfortable distance. Having determined participants' preference for angular size and convergence distance, we fixed those parameters and allowed the user to adjust the text box width and the number of lines of the visible text, *i.e.*, the view box. Finally, we asked participants to record their preference according to three UI parameters: dark *vs.* light background color, serif *vs.* sans-serif font, and the vertical position of the view box.

[1] https://developer.oculus.com/

Results
In the following, we present the results of the user-defined settings grouped into angular height, vergence, view box dimensions, its positioning, as well as the UI parameters.

Angular Height
Angular size is generally given in degrees, but we refer to it in Google's unit of angular size—dmm: distance-independent millimeter—where $1dmm = 1mm$ height at $1m$ viewing distance. The preferred height was $32 + / - 11dmm$.

Vergence Distance to Text
With height set fixed, user's selection of most comfortable vergence distance are shown in Figure 3. From this, we derived equations 1 and 2.

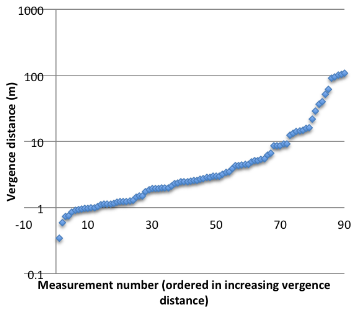

Figure 3: All preferred vergence distance measurements shown in order of increasing vergence distance. Note the logarithmic scale on the vertical axis.

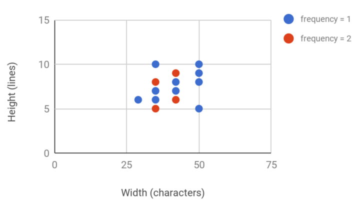

Figure 4: Preferred width and height of the text box viewed in the virtual environment by participants.

Text Feature	Preference
dark vs. light background	13 of 18
sans-serif vs. serif font	14 of 18
vertical text box position	-1.0 +/- 2.6 deg

Table 1: Summary of text features and participants' UI parameter preferences.

View Box Parameters

Preferences of text box width and height are shown in Figure 4. The preferred height of the text box was 7.3 ± 1.7 lines and the preferred width was 40 ± 6.5 characters. The preferred vertical position was -1.0 ± 2.6 degrees from the horizontal, corresponding a small movement down of the center of the text box.

Text Font and Background

A majority of 13 out of 18 participants (72.2%) preferred white text on a black background as opposed to black text on a white background (see Table 1). 14 of the 18 participants (77.8%) preferred sans-serif Arial text compared to serif Times New Roman fonts.

Implications and Discussion

In our study, we explored font size, vergence, and view box dimension for comfortable reading in VR. While it is worthwhile investigating the effects of these parameters when reading for an extended amount of time, this study is a first step in form of a user-defined exploration of text parameters in VR. Table 2 summarizes our results giving the corresponding sizes based on the different measures of text size.

The Oculus Rift CV1 HMD used in the study has a fixed focus distance, equivalent to viewing a screen at approximately 1.3 meters. A mismatch between the vergence

Height parameter	Preferred size (dmm)	Preferred size (degrees)
x-size	23 ± 7.8	1.3 ± 0.44
capital height	32 ± 11	1.8 ± 0.61
body height	41 ± 14	2.3 ± 0.77

Table 2: Summary of preferred text angular height parameters for Ariel font. Angular size is given in degrees and Google's unit of angular size where $1dmm = 1mm$ height at $1m$ viewing distance.

distance and the focus distance commonly referred to as vergence-accomodation mismatch, is known to lead to discomfort and fatigue [9]. We, therefore, expected users' preferences for vergence distance not to stray too far from the HMD's focus of $1.3m$. Shibata *et al.* [9] investigated acceptable ranges of vergence-accommodation mismatch to avoid such discomfort. From their original heuristic relations we can derive appropriate vergence distances:

$$d_v \mathrm{min} = \frac{d_f m_{\mathrm{near}}}{1 - T_{\mathrm{near}} d_f} \quad (1)$$

$$d_v \mathrm{max} = \frac{d_f m_{\mathrm{far}}}{1 - T_{\mathrm{far}} d_f} \quad (2)$$

Here, d_v is the vergence distance, d_f is the effective distance to the display (the focus distance), and $m_{\mathrm{near}} = 1.035$, $T_{\mathrm{near}} = -0.626$, $m_{\mathrm{far}} = 1.129$ and $T_{\mathrm{far}} = 0.442$ are the slopes and intercepts of the upper and lower bounds of vergence-accommodation comfort when considering vergence and focus in diopters (inverse units), which were determined empirically [9]. These relations give the maximum and minimum comfortable vergence distances for a given focus distance. In the case of the Oculus cV1, $d_f = 1.3m$,

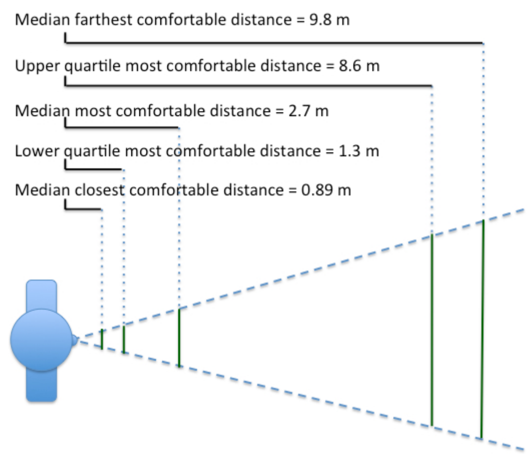

Figure 5: Vergence distances elicited throughout our study as a guideline for text display in VR. Distances are to scale.

which yields maximum and minimum convergence distances of $d_v(max) = 3.45m$ and $d_v(min) = 0.74m$. This corresponds also to Oculus' guidelines for developers, who derived them from the same source. We find that the closest comfortable distance derived from the guidelines or $3.45m$ shows agreement with what was indicated by participants in our study shown in Table 3. We find, however, that 59% of the time, participants selected a convergence greater than $3.45m$ as their "most comfortable vergence distance for reading". In addition, 67% of participants indicated vergence distances greater than $3.45m$ when asked to select the "farthest comfortable distance". This indicates that our participants tended to opt for a vergence distance not only farther than the focal distance, but farther than what is considered comfortable limits for the vergence-accommodation mismatch. This may show a tendency towards a preference for viewing large displays at a distance, and with a corrected accommodation, the tendency towards

	Closest distance	Most comfortable	Farthest distance
lower quartile	0.61	1.3	2.6
median	0.89	2.7	9.8
upper quartile	1.5	8.6	64

Table 3: Summary of convergence distance (meters) chosen by participants.

larger displays placed farther away from the user may be more pronounced.

There was quite a variation in preferences within the participant sample and a large range of allowed comfortable convergence distance for displayed text. Figure 5 summarizes the initial guidelines we derived for those designing information displays and reading platforms in virtual reality with HMDs having fixed focus lenses of similar properties to the Oculus CV1, which has a focal distance of $1.3m$. A rough guideline is to place text with an appropriately selected angular size as discussed above at a distance of between 1 and 10 meters from the user, but ideally at around $3m$.

Conclusion

This paper presents first results of our assessment of basic text parameters for reading in VR. While we conducted a user study to explore comfort levels of parameters, such as text size, vergence, and view box dimensions, in follow-up studies we are planning to apply our initial results to text interfaces and measure their effect on reading comfort, text comprehension, motion sickness, and visual fatigue. The current set of recommendations presented acts as a reference point for our research and can be used by other researchers and application developers with the goal of providing effective reading experiences in VR systems.

Acknowledgements

We thank the participants of our study and acknowledge the financial support by JST CREST under Grant No: JP-MJCR16E1.

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