International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:8, No:12, 2014

Preferred Character Size for Oblique Angles

Photjanat Phimnom, Haruetai Lohasiriwat

***Abstract*—**In today's world, the LED display has been used for presenting visual information under various circumstances. Such information is an important intermediary in the human information processing. Researchers have been investigated diverse factors that influence this process effectiveness. The letter size is undoubtedly one major factor that has been tested and recommended by many standards and guidelines. However, viewing information on the display from direct perpendicular position is a typical assumption whereas many actual events are required viewing from the angles. This current research aims to study the effect of oblique viewing angle and viewing distance on ability to recognize alphabet, number, and English word. The total of ten participants was volunteered to our 3 x 4 x 4 within subject study. Independent variables include three distance levels (2, 6, and 12 m), four oblique angles (0, 45, 60, 75 degree), and four target types (alphabet, number, short word, and long word). Following the method of constant stimuli our study suggests that the larger oblique angle, ranging from 0 to 75 degree from the line of sight, results in significant higher legibility threshold or larger font size required (p-value < 0.05). Viewing distance factor also shows to have significant effect on the threshold (p-value < 0.05). However, the effect from distance factor is expected to be confounded by the quality of the screen used in our experiment. Lastly, our results show that single alphabet as well as single number are recognized at significant lower threshold (smaller font size) as compared to both short and long words (p-value < 0.05). Therefore, it is recommended that when designs information to be presented on LED display, understanding of all possible ranges of oblique angle should be taken into account in order to specify the preferred letter size. Additionally, the recommendation of letter size for 100% legibility in our tested conditions is provided in the paper.

***Keywords*—**Letter Size, Oblique Angle, Viewing Distance, Legibility Threshold.

I. INTRODUCTION

NOWADAYS, the cost of LED display manufacturing has been much reduced whereas its quality has shown to improve over time. As a result, this type of display becomes more accepted and has taken over the old LCD technology. The use of LED screen can be found in a wide variety of places including both indoor and outdoor areas (e.g., advertising menu in front of the restaurants, presenting queuing number at the hospital, screens for training or conference room, outdoor advertising using digital video). In such circumstances, presenting information in text and number format is typical. According to many studies regarding reading from VDT screens, various factors have been found to affect reader's performance.

Photjanat Phimnom is with Ergonomics Laboratory, Industrial Engineering Department, Chulalongkorn University, Bangkok, Thailand (Phone: +6628104341; e-mail: photjanat@gmail.com).

Haruetai Lohasiriwat is with Ergonomics Laboratory, Industrial Engineering Department, Chulalongkorn University, Bangkok, Thailand (Phone: +6622186814; e-mail: haruetai.l@chula.ac.th).

Character quality is one well-known variable claimed to affect poorer reading performance in VDT condition when compared to paper-based format [1]. A critical review by [2] is a good example of discussion on reading from VDT against from hardcopy. The paper concludes wider range of issues beyond only character quality on reading performances (i.e., speed, accuracy, fatigue, comprehension). Character height also has been received numerous attentions over times (e.g., [3]-[6]). Generally, the suggested heights are in agreement to be within the range of 16-24 MOA (definition of measured font size in MOA or minute of arc will be discussed in more detail afterward). Some well-known standards also support this range of character height [7]-[10]. The maximum size is recommended to avoid high number of fixations during reading task. In application, designers have to consider limited space on screen along with amount of information needed to present before coming up with the letter height decision. The largest size possible is usually applied to encourage comfortable reading. On the contrary, the minimum size is applied for accurate legibility of a single character (or legibility threshold). Other attributes related with the character were also examined. A good summary on typography has been given in [11]. In shorts, besides character height, one has to take into account other factors such as stroke width, width-to-height ratio (similar to dot-matrix in VDT), and styles or font types. Hardware considerations also play crucial role even though conclusions are mixed or indecisive occasionally. For instance, though favor toward dark characters on a lighter background is given by many studies (e.g., [12], [13]), the visual acuity found not to be affected by this factor [14]. Some issues however receive more concrete conclusions. Luminance contrast ratio is repeatedly found to affect reading performance whereas color contrast or differences in chromaticity seems to have no influence (e.g., [15], [16]). Other researchers have explored features more related to the readers rather than concerning characteristics of the target or display. Standard relationship between vehicle speed (the reader's moving velocity) and legibility distance [17] gives a good illustration of importance to consider realistic reading condition. Viewing under oblique condition has also been earlier discussed. Narrower than 45 degree to either left or right of the normal-line-of-sight perpendicular to the screen is recommended [18]. Unfortunately, many actual situations cannot follow. A good example is standing or sitting in a conference or classroom. These situations are unavoidable to have someone stay to the side of the screen. According to our estimation, the angles can easily reach 45 degree limit in those conditions. Possible viewing from oblique angle up to 57.1 degree is also reported when reading from medical device display [19]. This large angle results from the position of display which mounted from high location.

To sum up, though many affected factors on reader's performance have been examined thoroughly and many standards are readily available, the real life circumstances may not possible to follow (such as oblique angle mentioned). At the same time, interaction effect among some variables still gives possible research issue. It thus comes to our interest to examine that when viewing from oblique angles, will there be any significant effects on legibility and if so, to what extent. Consequently, should there be any adjustment to the current recommendation (which usually refer to typical straight and direct looking) of character size where extreme oblique angle is unavoidable?

II. Method

A. Subject

The total of ten, eight women and two men, participants was volunteered to the study. Their age range is between 20 - 29 years. Highest education for all participants is either undergraduate or master's degree level. All participants were tested for their visual acuity using Snellen chart to ensure normal vision. Corrected glasses were allowed for those with existing eyesight problem. Typical procedure for Snellen test was followed. Ambient light in our experiment room was controlled to be within the suggested range of 300-750 lux suggested for normal office settings [20], [21].

B. Variables

Three independent variables hypothesized to affect legibility threshold were tested. Our experimental Design is 3x4x4 within subject design. These factors include viewing distance, oblique screen angle measured from the participant's line-of-sight, and target types. Three levels of viewing distance were selected based of 6 m cutoff point between near and far vision [22]. Hence, our study used 2 m and 12 m conditions to represent near and far points accordingly. Note that two meter is also the nearest viewing distance recommended for 40-60 inch LED screen [19]. For 12 m condition, it is the maximum possible distance which can be set up in our laboratory. Note that according to [23], the maximum viewing distance of a lecture hall with a capacity ranging from 25-300 people is as far as 16 m. For oblique angle factor, four levels were tested which are 0, 45, 60, and 75 degrees. The first two levels were selected based on recommended range by [18]. Then, since the pilot test showed that oblique screen beyond seventy five degree results in inability to recognize the letter correctly, therefore testing condition was limited to this particular angle. The 60 degree level was later included as the middle point between 45 and 75 degrees. Lastly, target type is used as the third independent variable. The total of four categories in this factor was carried out including single alphabet, single number, short word and long word. Our major reason for setting up these groups was due to application objective. In real circumstances, there are more likely to have information presented in word format rather than single character. For word group, the levels were classified based on language education level in Thailand [24]-[26]. Short word is vocabulary for primary education consisting of four character and single syllable. Then, vocabulary of Senior high schools including 7-8 character and 2-3 syllables is defined as a long word group.

For dependent measure, the average percentage of correction response (to be called as "%correction") under each condition was the primary data acquired from our study. The calculation used is shown in (1).

$$\%correction = \frac{Number\ of\ correct\ responses}{Total\ number\ of\ trials} \times 100 \quad (1)$$

Once %correction was calculated for every condition, related psychometric chart (%correction against font size) was drawn. The minimum font size required for legibility was then found utilizing similar method for psychophysics absolute threshold. In other words, the related physical unit for font size (measured in MOA) which results in fifty percent correction was the legibility threshold reported. This threshold is defined as our dependent measure. Note also that font size described in minute of arc (MOA) unit was calculated based on the character's height in relation with viewing distance [27] using (2).

$$V = \arctan\left(\frac{S}{2D}\right) \quad (2)$$

when V is Visual angle (degree)
S is Character's height on screen (mm)
D is Viewing distance (mm)

Table I shows actual character height use to represent each of the seven MOAs in three tested viewing distances.

TABLE I
CHARACTER HEIGHT FOR EACH MOA AND VIEWING DISTANCE

Distance (m)	Font Size (MOA)	Character's height (mm)
2	2	1.2
	4	2.3
	6	3.5
	8	4.7
	10	5.9
	16	9.3
	22	12.8
6	2	3.5
	4	7.0
	6	10.5
	8	14.0
	10	17.5
	16	27.9
	22	38.4
12	2	7.0
	4	14.0
	6	20.9
	8	27.9
	10	34.9
	16	55.9
	22	76.8

C. Equipment and Setting

A 60 inch LED screen with 1360x768 resolutions was used to present targets to the participant who sat directly in front of the display. Oblique angle and viewing distance positions were designated on the floor using color tape. Participant's head position was ensured fixation throughout the data collection process using a custom made chinrest. Participant's line of sight was set to be at the same horizontal level and direct toward screen center in order to encourage foveal vision. Participants were allowed to correct the height of an adjustable chair for their individual comfort. A video recorder was also used to continually record participant's responses. Fig. 1 illustrates our experimental setting.

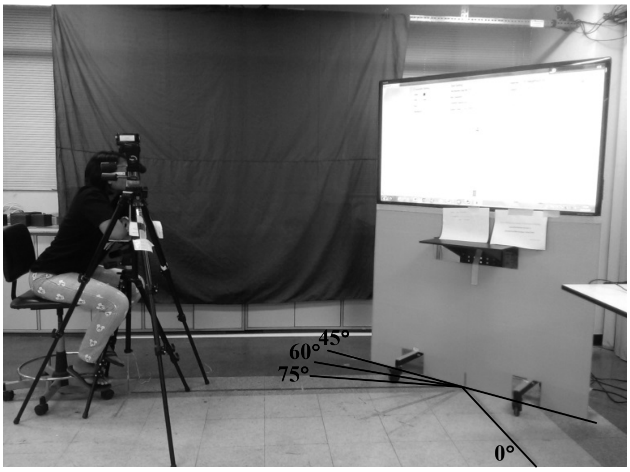

Fig. 1 Experimental Setting in Ergonomics Laboratory

At the center of LED display was the target in which participants were required to recognize. All characters were in Arial style and presented in black color against white background. Character height was adjustable using computer program created by the research group. Display brightness was controlled to be the same for all conditions and subjects. Additionally, a Snellen chart was used to test for normal vision prior to the actual experiment section.

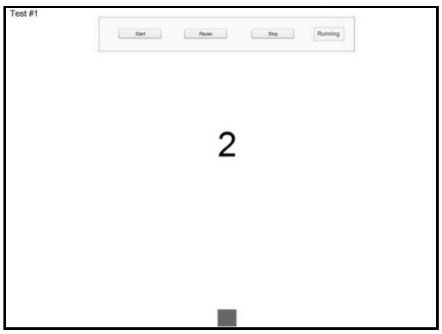

Fig. 2 Screen from Testing Program (Fonts Style in Arial)

D. Experimental Procedure

To find legibility threshold for each condition, a classical psychophysics approach known as Method of Constant Stimuli was utilized. Prior to actual experiment, a pilot test was performed on two volunteers. Results suggested that the threshold is concentrated around 6-10 MOA. Therefore, font size was tested in a range of 2 to 10 MOA with 2 MOA increasing level in between. Additionally, font size of 16 and 22 MOA were also included to cover the size recommended in many standards. In conclusion, there are seven font sizes available for tested. Due to difficulty in setting up screen oblique angle, this factor was presented in order from 0 degree (perpendicular to participant's line-of-sight) and gradually increased to cover all levels. Distance and target type factors were presented randomly. Font size levels were also randomly presented according to Method of Stimuli protocol. The only task participant has to perform was reporting what they recognize on the display. During instruction regarding our methodology, participants were informed about four types of target. For word conditions, participants were asked to pronounce the word rather than spelling out all alphabets. However, if participant may unable to recognize the presented word, that particular trial will be excluded from the study. Videotape recording was utilized throughout the entire experimental period.

III. Results

To draw psychometric chart, %correction responses were plotted against font size for every tested conditions. The typical S-shaped curve was found. Then, linear regression method was used to estimate data along the dramatic change portion of the curves (data where there is abrupt change from very low to very high %correction). For example, in the condition of 45 degree oblique screen angle, 6 m viewing distance, and having number as target type, the psychometric plot is as shown in Fig. 3. Linear regression used to estimate data between 0 to 100 % correction can account for 94.94% of variance. Note that R-squared for all linear regression results in this study is at the average of 0.97.

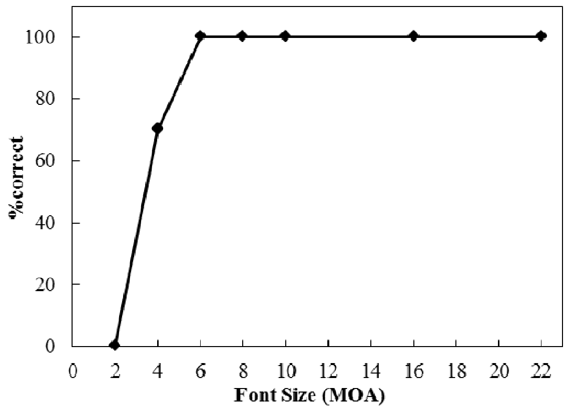

Fig. 3 Example of Psychometric Chart (45^{o} oblique angle, 6 m distance, number target type)

Next, the acquired regression formulas were used to estimate minimum font size that expected to result in 50%

corrections or the legibility thresholds. It is these thresholds which later used as dependent variable. ANOVA full factor design shows that there are significant differences of legibility thresholds on all three tested factors (p-value < 0.05). Pairwise comparison utilizing Bonferroni method was also performed to give information on different grouping at 0.95 confidence level.

In summary, the 2 m viewing distance requires significant larger font than the farther points as illustrated in Fig. 4. All oblique angle levels are significant differences from each other. Generally, the more screen tilted, the larger font size required as shown in Fig 5. For target type factor, there is no difference between single characters (i.e., alphabet and number) whereas short and long words are main reasons for significant difference found. Fig. 6 shows that in order to read the words correctly, participants required larger font size than single character conditions.

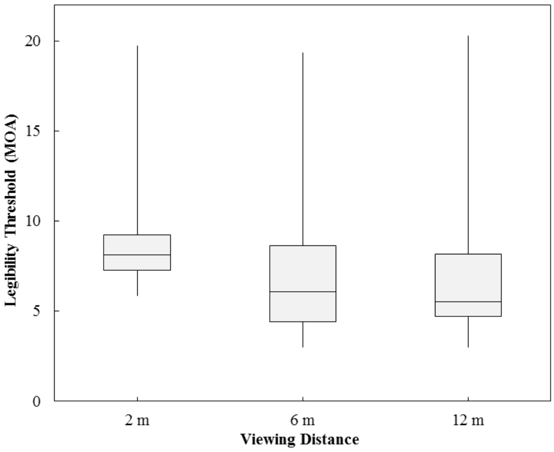

Fig. 4 Viewing Distance Main Effect Plot

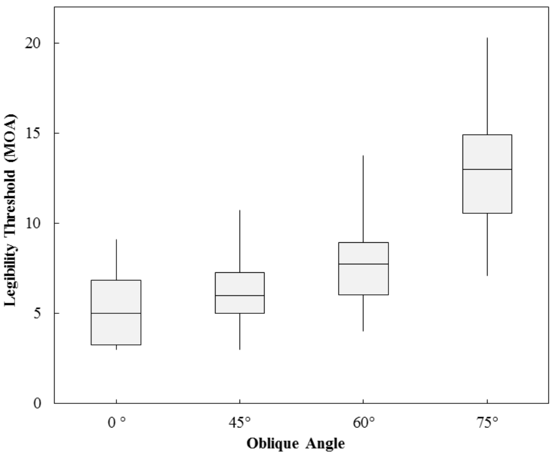

Fig. 5 Oblique Angle Main Effect Plot

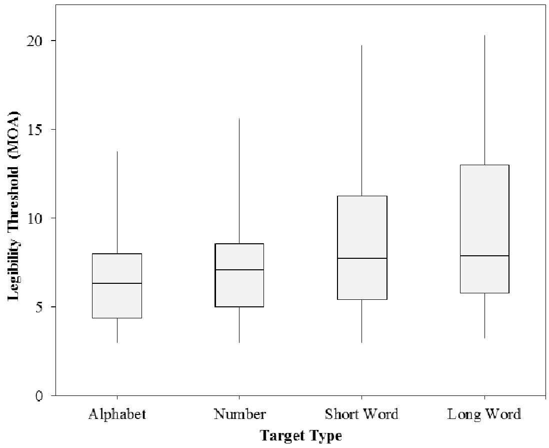

Fig. 6 Target Type Main Effect Plot

Additionally, among all three tested factors, oblique angle is likely to be the major determinant for significant interaction effect. Both interactions of "oblique angle x target type" as well as "oblique angle x viewing distance" are found to be significant at p-value < 0.05. Figs. 7 and 8 suggest that the oblique angle of 75 degree possibly be the key underlying reason.

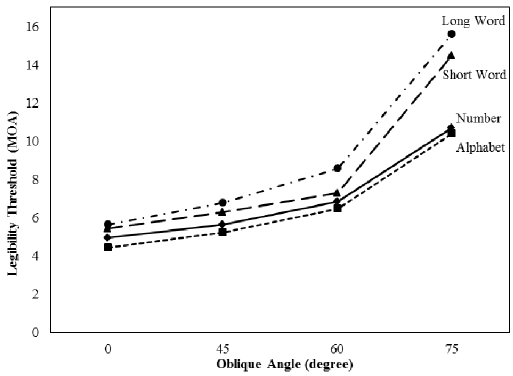

Fig. 7 Oblique Angle and Target Type Interaction Plot

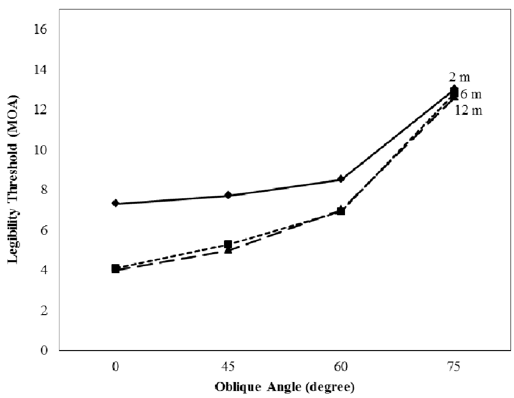

Fig. 8 Oblique Angle and Viewing Distance Interaction Plot

IV. Conclusion & Discussion

Main effect findings from the experimental data consent to our expectation. Conditions with more difficulty in readability result in larger legibility thresholds. These conditions include closer viewing distance, larger oblique angles, and recognizing words as compared to single characters. Rationale behind these main effects is believed to differ from one to another.

For viewing distance, quality of the screen actually used for our study could play a crucial role. Though suggested to be viewable from 2 m onward, participants in our study subjectively report that picture in near point condition (2 m) is much worse quality than farther away. The reason can be the fact that at the near point, character height is smaller for the same MOA as compared to the far settings. Therefore, the number of pixel per character height in 2 m condition is much less and hence worse the resolution. As an example, the 8 MOA condition results in a character using 5 pixels in 2 m viewing distance compared to 14 and 29 pixels in the 6 and 12 m settings respectively. Meanwhile, legibility threshold changes among oblique angle conditions are expected to be the result of target's spatial resolution. In the other words, the same font size when viewed from more oblique angles will be perceived as more density (i.e., thinner character combined with smaller gap within and between characters). This possibility supports the use of stroke-width to height, rather than merely character height, as a guideline on appropriate font size for visual information display. However, the actual *perceived* stroke-width viewing from oblique angles should be taken into consideration. Then, since word is simply a series of characters, this similar effect of spatial quality can further give consequence in lower performance under the word conditions. It is important to point out that all target types used in our study required bottom-up information processing approach. Therefore, ability to recognize each character separately is required for our task successfulness. To test whether this possible explanation is valid or not, an experiment based on finding legibility threshold for words in different length (defined by number of characters) can be carried out. It also might be interested to investigate on targets which required top-down processing in future study. Our speculation is that the threshold could be reduced for those conditions in the same way skilled readers could comprehend poor print-text quality [28].

The results found in this present study suggest few design application points of view. First, we recommend that when designs information to be presented on LED display, understanding of all possible ranges of oblique viewing angle in real setting should be taken into account. The decision on font or character height should be made only after this awareness. As a precaution against LED display viewing angle provided by manufacturer, such angle is the maximum angle at which a display can be viewed with the halved brightness as at directly forward. However, it does not infer that reading performance will be the same throughout this range. Secondly, using the linear regression formulas acquired to make psychometric charts, character size for 100% correction can be estimated.

TABLE II
Averaged Minimum Font Size in MOA Required for the 100% Correction

Target Type	Oblique Angle (degree)	Font Size in MOA[a]	
		Distance 2 m[b]	Distance 6-12 m[b]
Number	0	9	5
	45	9	6
	60	10	8
	75	15	13
Alphabet	0	9	5
	45	9	6
	60	10	8
	75	14	13
Short Word	0	9	6
	45	10	7
	60	10	10
	75	*18*	13
Long Word	0	9	6
	45	11	7
	60	11	11
	75	*20*	*20*

[a] Decimal rounded and presented only whole number.
[b] There is no difference between 6 and 12 m viewing distance.
[c] Italics show conditions with larger than 16 MOA is required.

Table II gives the summary of our calculation. Compared the figures to font size standard, minimum size of 16 MOA is still practical for recognizing single character under all tested conditions. Nonetheless, this recommended size cannot be applied to guarantee readability for words especially at the large oblique viewing angle. Therefore, it is our recommendation to design for font size toward maximum guidelines of 20-24 MOA for any circumstances which oblique viewing is unavoidable.

Acknowledgment

The author would like to thank Dr. Phairoat Ladavichitkul, Faculty members of the Ergonomics Laboratory, Industrial Engineering Department, Faculty of Engineering, Chulalongkorn University, Bangkok, Thailand for the full support in this research.

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