Effect of Ambient Illumination, Brightness and Tilt Angle on Typing Performance

K.Srestthaporn and H.Lohasiriwat

Abstract—**Nowadays, computers are electronic devices that play an important role in almost everyone daily life. We use computers for various purposes and under a wide range of ambient illumination. High illumination level usually results in glare issues. Adjusting screen brightness and tilting screen to some angles are common quick solutions against problems with visibility due to glare. This present research aims to investigate effect of the three factors simultaneously and quantitatively on visual-related task performance. The task used in this study is simple typing task. Speed of typing each character is defined as the task performance. Testing conditions were set within ranges that simulate actual working conditions for computer or any visual display terminals. Ambient illuminations were tested in range of 200 to 1600 lx. Screen brightness levels were varied to cover all range of adjust ability allowed by characteristics of the display used; approximately from 67 to 200 cd/m^2. Tilting angle was tested from vertical position to backward tilting at 70 degree (measured from the vertical line) to simulate actual use of touch screen devices. The result of this study found that brightness and tilt angle significantly affect average typing time (both at p-value = 0.000). Interaction between tilt angle and the other two factors (ambient illumination and brightness) were also found significant at p-value = 0.037 and 0.000 respectively. Interaction effect results suggest that tilting angle is the major factor affecting typing time, especially ones over fifty degree. Discussion regarding underlying reason is given in the paper along with possible future studies.**

***Index Terms*— Ambient illumination, brightness, tilt angle, typing performance, visual display terminal, light setting.**

I. Introduction

FROM past to present, computer has been playing an important role for many activities in our daily lives. There is a widespread of computer usage in both household and office settings. With this intensive usage, computer is found to be operated under a wide range of ambient illumination levels. For example, precision work such as product checking in warehouse requires approximately 200 lx light setting. Precision work such as routine working in the office requires around 400 lx. The more precision is required in performing activities, the higher ambient illumination will be needed. The maximum recommendation by Thai National Regulation [1] is 1600 lx for the highest precision task level such as one involving measurement of some small parts.

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Note that suggested illumination standard for typical office activities is in the range of 200-750 lx [2]. The major reason for giving guidelines toward ambient illumination is due to the fact that this factor is found to affect working performance as well as worker's health related issues (e.g., headache, eye pain, and blur vision [3]). Research in the past showed that both intensity and color of the light bulbs affect percentage of correct response in character identification [4]. This particular test was conducted at 250, 500, 1000 and 2000 lx. Note that although 2000 lx is considered beyond illumination guideline, it can be commonly found in diverse areas such as steel and copper engraving task in which computer or other types of visual displays are still in use [2]. This high level of ambient illumination leads to another visual problem, decreasing in contrast between target and its background.

When working under high illumination level, problem with glare is rather common. For example, using computer outdoor on a sunny day, the sunlight could directly shine down on the screen. This situation results in direct glare within observer's visual field. At other times, light may get reflected from objects (e.g. windows, walls, partitions, side mirror of the car) and eventually enhance the total illumination level leading to glare in the similar way. The latter case is known as reflected glare situation. When working with visual display terminal, issues with glare may also come in reflection form. Computer users can easily experience light striking onto the display and eventually leads to sharp reflections of the surroundings superimpose on the to-be-seen data. These reflections can distract the observer's eyes due to its high brightness and also reduce contrast between the data and its background [5]. One way to cope with glare issues from high luminance surrounding is to adjust screen brightness to match with the surrounding luminance level (also known as luminance ratio) [5].

Nonetheless, screen brightness is also altered according to viewing angle. In other words, screen luminance level is also a function of how much the screen gets tilted. Using luminance meter, it was found that the farther the screen get tilted away from the vertical line, the lower the display luminance [6]. The underlying reason is characteristics of LED display in which the highest brightness occurs only when looking directly in front of screen whereas lowering brightness will be found when viewing from some oblique angles. Therefore, it is unavoidable to take into account of display tilting factor when concerned with display brightness. More advanced in touch screen technology, many displays nowadays are also simultaneously used as input device (e.g. tablet, smart phone). Working with the display tilted toward lay flat position is thus highly common. This position is a great change compared to 5 - 20° in traditional computer desktop screen [7].

In conclusion, the three factors mentioned (i.e. ambient illumination, brightness, and display tilt angle) are

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hypothesized to affect visual-related task performance. The current research aims to investigate these three factors quantitatively and simultaneously. Task performance used in this present study is typing speed per character similar to another prior study [8]. In addition to typing speed, a wide range of studies have used various kinds of task to measure visual-related task performance (i.e. character identification and reading comprehension [2], reading time [9]).

II. Methodology

A. Subjects

The total of ten participants volunteered to the study. Participants consisted of nine female and only one male. Their age ranges are between 20 - 46 years old. All participants had no injury in the arms, wrists, and hands on either side. Participants with eyesight problem were allowed to use their normal glasses during the study. Moreover, participants must have experience in using computer on a daily basis.

B. Experimental Setting

Equipment used in the study included table. The table dimensions were 74 cm height, 80 cm width, and 160 cm length. The black feather board with the height of 45 cm was used as the workstation partition. This partition was installed in order to reduce any possible additional light factors from other light settings inside the laboratory. The other light settings referred here were normal office fluorescents mounted on the ceiling as shown in Figure 1(left).

Display used in the study was a 19.5-in, FT200HQLbmj touch screen LED. Screen dimensions were 18.6 inch horizontally and 13.9 inch vertically. Maximum luminance of the screen was limited to 200cd/m^2. Spyder 4Elite was used to calibrate display characteristics. Display was located on the table surface at 70 cm distance measured from the participant's eye to screen center. Keyboard was placed on the table. Usually, keyboard set up resulted in slightly higher than the participant's sitting-elbow-height as shown in Fig. 1 (right). Fig. 2 shows the customized compact fluorescent dimmerable lighting panel used to adjust ambient illumination level. All fluorescent were 6400K in color temperature.

Fig. 1 (Left) Adjustable ambient illumination panelinstalled on the ceiling and (Right) Computer workstation setting

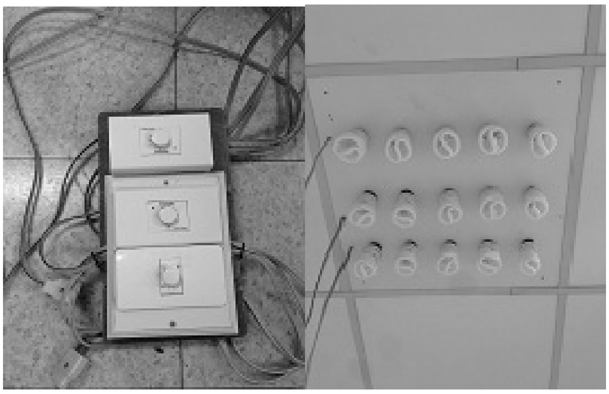

Fig. 2. (Left) Dimmer able switches and (Right) and Fluorescent lamps

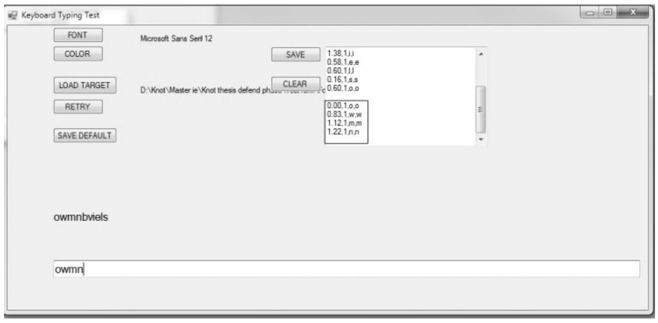

Fig. 3. Screen Shot of Key TestingProgram

A key testing program was created to use in the study. Basically, targets (random characters) were shown on screen and participants were asked to type accordingly in the space provided. Typing time in milliseconds measured from the beginning of target shown to the finishing of input typing by participant was collected automatically by the program. A screen shot from the program was shown in Fig. 3.

C. Experimental Design

Independent variables in this research include three major factors. First, there were five ambient illumination levels; 200,400,600, 1000 and 1600 lx. Illumination level was measured by lux meter at the computer table surface. Secondly, three brightness levels were tested; 0%, 50%, and 100%, which is equivalent to luminance level of 66.7, 144.6, and 200.2cd/m^2 respectively. Last of all, six screen tilt angles were manipulated; 0°, 10°, and 20°, to simulate normal computer desktop range and 30°, 50°, and 70° to cover larger tilting range found with touch screen device. Hence, the design of experiment is 5×3×6 (90 conditions) within subject design.

Meanwhile, since some characters could require less time to type than others, all target characters in the test were grouped into four categories, according to index of difficulty (ID) defined by [10]. The first ID group (ID1) is characters known to require least amount of typing time. The later ID groups (i.e., ID2, ID3, and ID4) were related to gradual increase in typing time. The number of letters in ID 1 to 4 was 10, 14, 11 and 11 respectively. The list of characters for each ID used in the study is shown in Table I. Within each ID category, letters were presented to the participant randomly.

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TABLE I
LIST OF CHARACTERS FOR EACH INDEX OF DIFFICULTY (ID)

ID	Characters
1	e i vbnmwosl
2	d krtyufghj
3	a ;'3810-=z/
4	q p[]\456729

In addition to ID, there were also few additional control variables. The spyder4 Elite was used to adjust the color temperature to 6500K and gamma to 2.2. The screen contrast was adjusted to 100% for all conditions. The font type used was Times New Roman with approximate 5 mm in height (12 point). Dependent variable was the average typing time per character measured in milliseconds (ms) unit.

D. *Experimental Procedure*

The first step of the experiment was to calibrate screen to ensure all control variables. Then participant had to practice typing approximately 230 characters for the trial test. After finishing this trail period, participant took a test on each condition with one minute break in between until completing the ninety conditions. The task to be performed is typing characters according to targets shown on screen. Similar to the trial test, each condition consisted of 230 targets to be typed. The order of experimental conditions was randomized using lot draw. Any incorrect response would later be removed from the data collection during analysis process.

III. RESULTS

To analyze the collected data, the ANOVA test at 0.05 significant levels was applied. In addition, since some individual differences (e.g. typing skill, visual ability, attention level) can be nuisance factors influencing typing time, ANOVA analysis was tested using randomized block design. Participant factor was blocked. Statistical analysis suggested that there was no significant main effect on ambient illumination factor (p-value = 0.134) whereas brightness and tilt angle factors were significant (p-value =0.000 and 0.000). Fig. 4 to 6 illustrate main effect plots on the three independent factors.

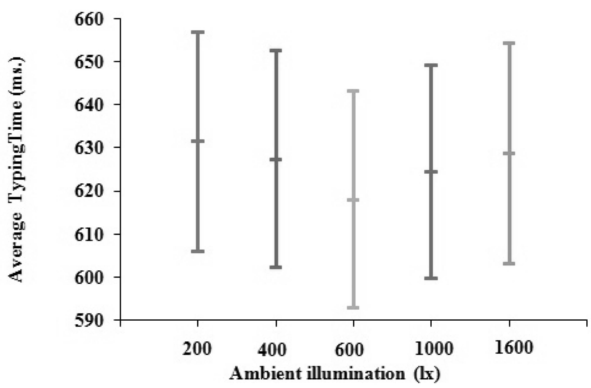

Fig.4. Main effect of Ambient Illumination on Average Typing Time

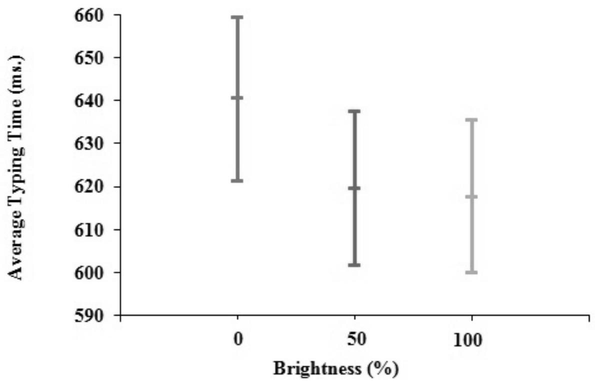

Fig.5. Main effect of Brightness on Average Typing Time

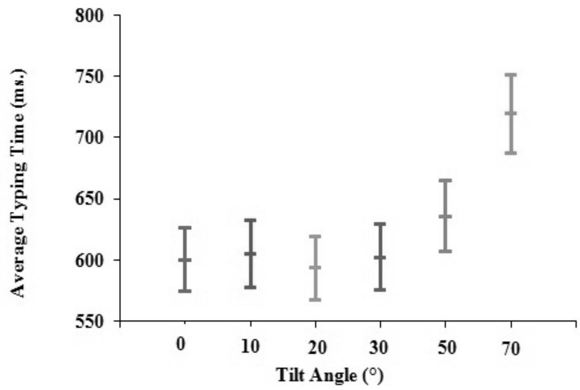

Fig.6. Main effect of Tilt Angle on Average Typing Time

There was the tendency to perform better (or faster typing) under more brightness conditions (Fig. 5). The average typing time for 0%, 50%, and 100% brightness were 641ms, 620ms (3% increased), and 618ms (3.6% increased) respectively. For tilt angle, the best performance is found to be at 20° setting. Other tilting angles (both more forward and backward) result in slower typing (Figure 6). Specifically, average typing time for 0°, 10°, 20°, 30°, 50°, and 70° were 600ms, 605ms, 593ms, 602ms, 636ms, and 719ms, compared to the minimum time found with 20°, average typing time from 0° to 70° are 1.2%, 2%, 0%, 1.5%, 7.3%, and 21.3% respectively.

The interaction analysis suggested that tilt angle is a major factor related to significant interaction with the other two variables. Statistically, tilt angle interaction with ambient illumination and with brightness were found significant at p-value = 0.037 and 0.000 respectively. Fig.7 and 8 illustrated significant interaction plots. Brightness and ambient illumination (though no significant interaction effect) were shown in Fig. 9.

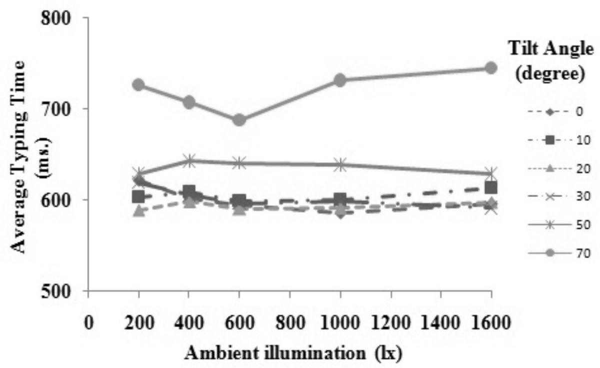

Fig.7. Interaction Plot between Tilt Angle and Ambient Illumination

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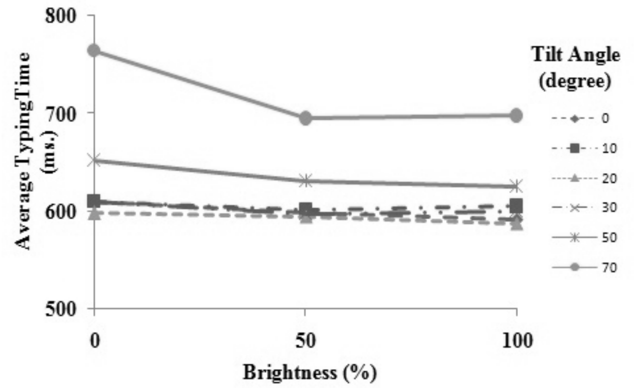

Fig.8. Interaction Plot between Tilt Angle and Brightness

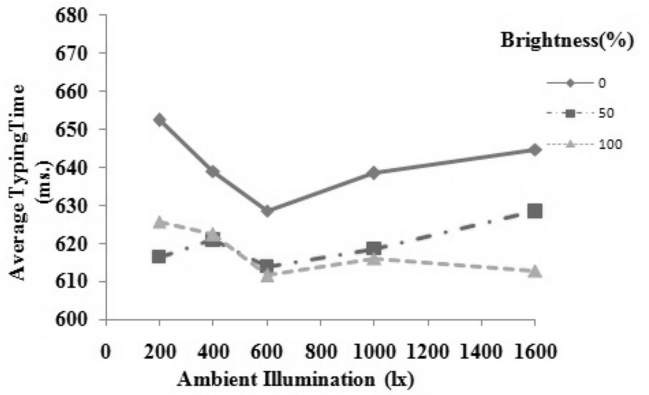

Fig. 9. Interaction Plot between Brightness and Ambient Illumination

IV. Conclusion and Discussion

Although there are significant main effects on both tilt angle and brightness factors, looking at interaction plots (Fig. 7 and 8) suggest that the underlying reason for such effects is the large increase in typing time under 50^o and 70^o conditions. A clear evidence is that once data collected from the 50^o and 70^o tilting conditions were removed, there would be no significant found (both main effect and interaction).

Three major consequences on tilt angle factor can be used to explain its lower performance. First of all, tilting display is automatically related with the increase of viewing oblique angle. When display get tilted backward, participant's line-of-sight is altered away from perpendicular to the screen toward larger oblique angle. Viewing from these oblique angles is eventually the first explanation for reduction in readability [11]. Secondly, as screen gets tilted, contrast between target shown on the display and its background is further reduced. This contrast reduction is due to the present of veiling glare (reflection of the ceiling lights into the screen). Veiling glare has been repeatedly found as a major disadvantage for visibility [12]. Last but not least, visual display usually has limited viewing angle. This angle is normally specified by manufacturer to be the maximum angle at which a display can be viewed with the halved brightness as at directly forward. In other words, when looking at monitor from different angles, either from the sides, top, or below, there will be colors shift and/or screen darkening [8]. For the display used in this study, its viewing angle is specified to be 160 degree vertically. Therefore, the 70^o tilt angle condition is at its limit where brightness is expected to be reduced in half. According to these three consequences found with tilting display, it is understandable for significant lower performance in the testing conditions.

In terms of brightness factor, the lower brightness has significantly increased typing time particularly at 50^o and 70^o tilt angle as shown in Fig. 8. This could be the result of the already lower brightness found with tilted screen mentioned earlier. Therefore, when accompanying with additional decrease in adjusted brightness, the screen will be perceived as darkened and eventually affect readability to a larger extent. For ambient illumination factor, enhancing veiling glare is expected to be major cause of increased typing time at 50^o and 70^o tilt angle as illustrated in Fig 7. In other words, changing ambient illumination from 200-1600 lx seems not to affect typing performance except when the light source becomes source of veiling glare. Note that the variations of typing performance within 70^o tilting conditions (slight increase in typing times at low and high illumination levels) are relatively small and found not to be significant using One-way Anova test.

The results from this research have some points in application and future study. First of all, considering the three factors that could be manually adjusted or designed; ambient illumination, brightness, and tilting angle of the display, the current study suggests that tilting angle is the most crucial factor. Our study agrees with many standards [7] that tilting angle should stay within 0-20^o or the maximum acceptable angle can be toward 30^o. This conclusion is based on the finding that when setting the screen tilting in this range, typing performance is in a significant better range and change in the other two independent factors cannot affect the typing performance. Furthermore, we suggest that future research aims to study that effect of screen tilting angle should control for oblique angle to be perpendicular to the screen. Bringing the monitor closer to participant's body can ensure direct looking toward screen center rather than viewing from oblique view. Also, trying other types of visual-related task can be used (e.g., tracking task). Lastly, though interaction between brightness and ambient illumination was found to be not significant, it is interesting to point out the crossed lines found in Fig. 9 (lines of 50% and 100% brightness levels). In the low illumination range (200-400 lx), lower brightness (but not as low as 0%) seems to result in better performance. Likewise, in the high illumination range (600 – 1600 lx), higher brightness seems to relate with better typing performance. The luminance ratio is expected to be one possible explanation on these results. Guidelines usually suggest the user to adjust screen brightness to match with the surrounding luminance level so that the luminance between two adjacent areas will not be too different. Hence, more coincide between brightness setting and illumination (high-high and low-low) is a better match than the vice versa. Meanwhile, the lowest brightness of 0% should be avoided since the performance is found to be worst across all illumination levels.

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