Research Project for Utilization of Human Color Information in Information Systems
(Report for 2005 academic year)

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要約：情報システムを人間が利用する際に，情報呈示の形式として視覚情報を最もよく利用する。その中でも，色情報は重要な役割を果たしている。しかし，情報システムにおける視覚情報の利用について，学術的面だけではなく応用面においても，まだよく調べられていない。我々のグループでは，視覚情報とりわけ色情報の利用を促進する目的で，研究プロジェクトを実施した。

2005年度の研究プロジェクトは，広い面積に色を呈示したときに色の見えが鮮やかに変化する面積効果と，ペンやマウスを使ったポインティング課題においてターゲットに色を用いた場合の効果について重点を置いた。本報告書ではこれら研究成果を紹介する。

Abstract：Visual information is mostly used as a form of information presentation in information systems when humans use them in any process. Especially, color is important in the presentation. However, utilization of visual information in information systems has not been well investigated, neither in scientific aspects nor in applicable aspects. Thus, our group is conducting research projects in order to enhance the utilization of visual information, especially color.

In 2005 academic year, we concentrated two research themes. The first theme is the area effect by which an appearance of color in a large chromatic field can be more saturated than the one in a small chromatic field. The second theme is about the effect of color in targets for pointing tasks with mouse and pen. In this report, we show some results of these themes in our project.

1. Structure of the project

1.1. Purpose

Visual information plays the most important role as a source of information processing related to humans. Thus, visual information is the most used form of information presentation in information systems concerning humans in any process.

Especially, color is extensively used in information systems and technologies. However, utilization of visual information in such systems has not been investigated well, neither in scientific aspects nor in applicable aspects.

Our group conducts research projects in order to enhance the utilization of visual information, especially color, in information systems in collaboration with the Graduate School, Department of Information Systems Engineering and Research Institute of KUT.

We also expect that Ph.D. students and masters students in the graduate school will join our research projects and will acquire high ability as specialists in color science and engineering.

1.2. Outline in 2005

The term of this project is four years and 2005 academic year is the second year, although this is the first year after our project has been supported by the grant for KUT.

Research projects fall within the three research regions below. Each region had sub research theme(s) at the beginning.;

(1) Perception region :

Color appearance change with the effect of larger size of chromatic area. (Keizo SHINOMORI and Mamoru OKADA)

(2) Operation region :

Effect of color on human performance in Human-Computer-Interfaces. (Xiangshi REN and Keizo SHINOMORI)

(3) Communication region:

Selection of color inks in color printing adjusted to each print with approximate calculation (the Genetic algorithm (GA)). (Leader: Akio SAKAMOTO)

&

Color control and calibration systems for network communication of color information. (Leader: Yutaka KIKUCHI)

Through collaborative work in these three core regions, we expected to establish an easy and accurate means of utilization of color in information systems and technologies.

(4) Modeling region:

Construct a model(s) of human visual information processing for computer simulation.

As the progress in 2005 academic year, although we expected to continue research themes for communication region, these themes are paused by a lack of staff to perform experiments. Thus, we will introduce doctoral students from 2006 academic year.

Nevertheless, we have made great success to perform research projects in (1) Perception region and (2) Operation region. These results were presented in international meeting and will be published soon as shown in the next section. Because these results are obtained as a part of thesis of one undergraduate student and one Ph.D. student, we can say that one of our purposes in this project is highly achieved.

1.3. Achievement in 2005 academic year

Because the 2005 academic year is the second year in our joint project, we have some achievements directly concerning to the project.

International conference publishing reviewed proceedings;

1. Keizo Shinomori, Mina Hashimoto and Mamoru Okada : "Color appearance change with the effect of larger size of chromatic area.", Proceedings of NEINE' 05 (the International Conference on Next Era Information Networking, Shanghai, China, 4-5 September 2005), pp.438-441, 2005.

2. Keizo Shinomori : "Ageing effects on colour vision ~Changed and unchanged perceptions~." AIC Colour 05 -the 10th Congress of the International Colour Association in Granada, Spain (May 8-13, 2005) [Proceedings book of AIC Colour 05, Eds. Juan L. Nieves and Javier Hernandez-Andres, pp. 7-12.] [Invited talk]

3. Kong, J., Ren, X., Shinomori, K. (2005). Influence of colors on pointing tasks in human computer interfaces, Proceedings of The IASTED International Conference on Human-Computer Interaction, November 14-16, 2005 Phoenix, USA, pp 7-12.

Domestic conference;

Two oral presentations in Japanese.

Journal papers;

1. Kong, J., Ren, X. and Shinomori K. (2006). Influence of Colors on Pointing Tasks in Human Computer Interfaces, IEICE Journal (English) **[Conditionally accepted]**

Our group also has other achievements concerning to this projects as listed below (achievements shown above are not included).

- Journal papers : 6 papers (including one article in reviewing).
- International conference publishing reviewed proceedings : 7 papers.
- International conference : 6 presentations.
- Domestic conference : 6 presentations.

In following chapters, we introduce important achievements in original shape with the authorization of publishers. These are No.1 and No. 3 articles in the list of international conference proceedings shown above.

2. Research achievement in perception region

We summarize the research achievement in perception region by one paper that are published by Keizo Shinomori, Mina Hashimoto (Undergraduate student in Shinomori lab.) and Mamoru Okada (NEINE ' 05). This chapter shows this paper as shown below.

Color appearance change with the effect of larger size of chromatic area.

Keizo SHINOMORI, Mina HASHIMOTO and Mamoru OKADA

Abstract

In applicable use of color in human interface,

we have to take care of one famous effect, called as "area effect". The area effect causes shifts of brightness and chromaticness when the area size of a color object becomes larger.

This area effect has been known well but neither numeric model nor the mechanism has been cleared. Thus, we started this research to obtain both of them as the final goal.

We tried the paper-matching test, in which observers adjusted a small test field until they considered the small one was the same with a large reference field in color appearance. One of 162 colors was chosen as the reference stimulus and it was displayed as the large test field on a CRT display. The small test field was displayed to another CRT display. Observers controlled all parameters of hue, saturation and brightness until they considered the small test field was the same with the large reference field in color appearance.

When the hue of the reference field was red, observers perceived more saturated color in the large reference field. On the other hand, when the hue was blue, they perceived less saturated in the large reference field. The brightness tended to increase in all hue. Although averages on chroma and brightness also tended to go up in all hue, the changes of chroma and brightness on blue became less than those of red.

As the result, we concluded that at a large view field, human being perceives more saturated and brighter color than the color at the small view field.

2.1 Introduction

Visual information plays the most important role as a source of information processing related to humans. Thus, visual information is the mostly used form of presentation of information in information systems concerning humans in any process. Especially, color is extensively used in information systems and technologies. However, utilization of visual information in such systems has not been investigated, neither in scientific aspects nor in applicable aspects. We conducted the research projects in order to enhance the utilization of visual information, especially color, in information systems.

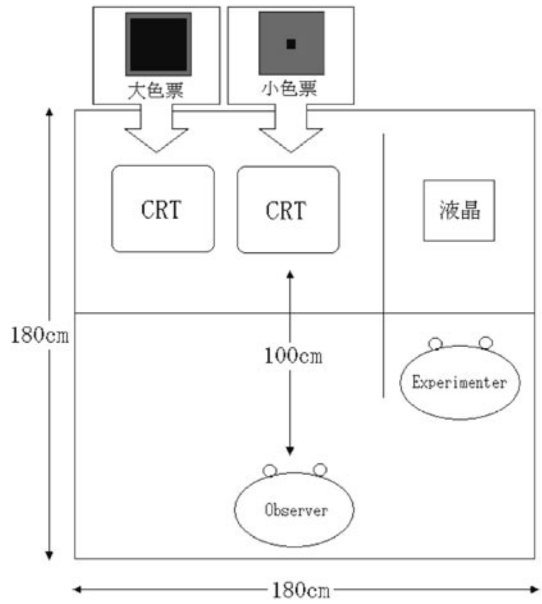

Figure.1: Scheme of the apparatus and stimuli used for this experiment.

In applicable use of color in human interface, we have to take care of one famous effect, called as "area effect". The area effect causes shifts of brightness and chromaticness when the area size of a color object becomes larger. This area effect has been known well but neither numeric model nor the mechanism has been cleared. Thus, we started this research to obtain both of them as the final goal. As the first step, in order to verify

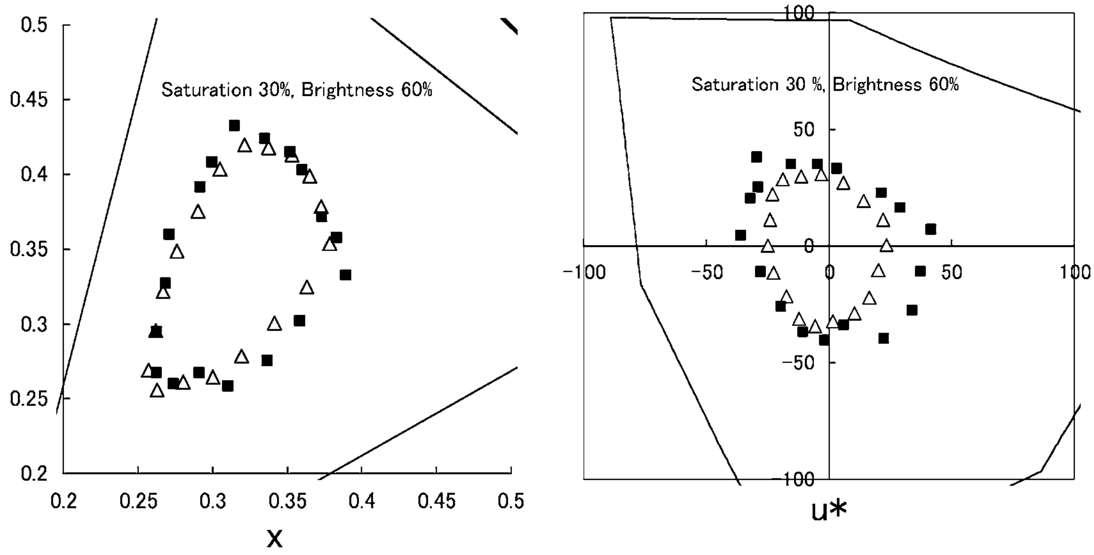

Figure.2: Left panel : xy chromatic coordinates of unchanged large test field (denoted by open triangles) and matched small test field (denoted by filled squares) on observer T.T when saturation and brightness were set to 30 % and 60 %, respectively. Right Panel : as is in the left panel except plotted on u*v* chromatic coordinates.

luminous and chromatic shifts of matching color caused by area effect, we tried the paper-matching test, in which observers adjusted a small test field until they considered the small one was the same with a large reference field in color appearance.

2.2 Methods

In our experiments, two CRT displays were used as shown in Figure 1. They were set to a color temperature at 6500K. One of 162 colors was chosen as the reference stimulus and it was displayed as the large test field on a CRT display. The small test field was displayed to another CRT display. Observers controlled all parameters of hue, saturation and brightness until they considered the small test field was the same with the large reference field in color appearance.

2.3 Results

At first, we plotted our data on xy chromaticity coordinates. The left panel of Figure 2 shows the results of the color matching in the smaller test field (denoted by filled squares) when the color of the large field is stable (denoted by open triangles) on one observer (observer T.T) at one condition (saturation=30% and brightness =60%). When the hue of the reference field was red, observers perceived more saturated color in the large reference field because the matched color in the small test field has to be more saturated. On the other hand, when the hue was blue, they perceived less saturated in the large reference field.

However, when we plotted our data on u^*v^* chromaticity coordinates as shown in the right panel of Figure 2, the value of chroma did not become lower in all hue. In addition, the brightness tended to increase in all hue. For the reason that a luminous value relates to the chromaticity on u^*v^* chromaticity

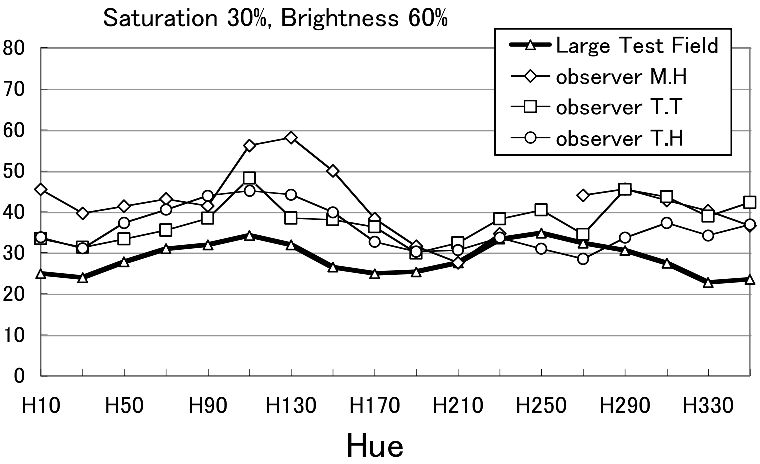

Figure.3: Chroma of the adjusted small test field for three observers (denoted diamonds for observer M.H., squares for observer T.T. and circles for observer T.H.) and unchanged large test field (denoted triangles) calculated as C*uv in u*v* chromatic coordinates.

coordinates, the value of chroma also becomes larger. So, we assumed that the value of chroma did not actually become lower on blue.

2.4 Discussion

To clarify the relative amount of change of the saturation and the brightness in different hues, we plotted the chroma (as the index of saturation) as a function of hue of the large test field in Figure 3 for all three observers. Chroma was calculated as C * uv (metric chroma)[1].

As shown in the figure, although averages on chroma also tended to go up in all hue, the changes of chroma on blue (around H220) became less than those of red (around H30), green (around H130) and red-purple (around H310). This suggests that blue did not change so much compared to those colors. This fact mentions us that we have to be careful when we think about the area effect in different colors.

2.5 Conclusion

We indicated from our experiments that luminous and chromatic shifts of matching color by area effect are both in saturation and brightness of the color. As the result, we concluded that at a large view field, human being perceives more saturated and brighter color than the color at the small view field.

Acknowledgement

This research is mainly supported by Grant-in-Aid for Scientific Research (C)(C-2, 16500145) from the Japan Society for the Promotion of Science. It is also partially supported by Hi-Tech Research Center Support to KUT and Graduate School Sophistication Special Promotion Support from the Ministry of Education, Culture, Sports, Science and Technology.

References

1. Handbook of Color Science [second edition], ed. the Color Science Association of Japan (Tokyo University Publication Inc., Tokyo : Japan), 1998.

3. Research achievement in operation region

We summarize the research achievement in operation region by the papers that are published by Jing Kong, Xiangshi Ren and Keizo Shinomori (The IASTED International Conference on Human- Computer Interaction) in this chapter.

INFLUENCE OF COLORS ON POINTING TASKS IN HUMAN COMPUTER INTERFACES.

Jing Kong, Xiangshi Ren and Keizo Shinomori

Abstract

Fitts' law has been applied to evaluate the pointing task widely. However, the effect of using color in the interfaces has not been discussed by literature. This paper introduces the research on the color effects in pointing task by using Fitts' law as the evaluation method. Different colors and color demonstrating styles are applied in the experiments with similar design of the paradigm Fitts' law pointing task. The experimental results show that when the subjects use mouse as the input device, there is no significant difference among the mean time of performance with the interface with colourful target and white target. The results also reveal that the color demonstrating styles will bring no significant difference to pointing task when the mouse is applied, either. However, when tablet personal computer and pen are applied, the subjects without much experience in tablet personal computer usage need more time to perform the task with colourful target than with the white target. When the colors are changed randomly during the subjects tapping on the target, the difference is even more obvious.

3.1 Introduction

Human computer interaction (HCI) is an important area including the knowledge and techniques of a great number of scientific branches such as computer science, physiology, psychology, motor control, philosophy, etc. With the tremendous developing speed of technology, numerous new interfaces and devices appear to the market. Even for the pointing task alone, there has been mouse, tablet pen, trackball and so on as the input devices. Each of these devices has its own features and may be better in some aspect than the others. Therefore, we use models to give clear evaluation of different devices or interfaces. For pointing task, the most famous model for evaluation and prediction is Fitts' law, which was proposed in 1954 by Paul Fitts [1], and has been widely used to predict and evaluate the performance of rapid and aimed movements. After the descendent modifications of Fitts' original formulation, now the most popular format of Fitts' law is as follows [2]:

$$MT = a + b\log_2(A/W+1) \qquad (1)$$

where a and b are constants, A is pointing distance, W is the target width that limits the pointing accuracy tolerance demanded by the task and MT is the expected average movement time of task completion. We call this as the *ID* model.

The second term of Fitts' law is called as the index of difficulty (*ID*) [2] [3] [4]:

$$ID = \log_2(\frac{A+W}{W}) \quad (2)$$

Fitts' law has been applied widely in human computer interaction notwithstanding the lack of theoretic supports since 1978 [5]. It can help to compare the different input devices or interface design [5] [6]. However, although the circumstances of human computer interaction are mostly colorful, all the existing researches of the pointing task related with Fitts law, either theoretic or applications, are based on black and white interfaces. The effects of color have not been considered into the motor tasks related with Fitts' law researches. Therefore, the purpose of this paper is to evaluate the pointing task with colorful interfaces. Fitts' law model will be used as the evaluation tool for the interfaces with different colors and different color presenting styles. This will be a new horizon for Fitts' law theory analysis.

3.2 Experiment 1: on interface with fixed colors

3.2.1 Subject

Eleven volunteers, of different genders and ages (20 to 29 years, nine males and two females, average 22.3 years old) participated in a target pointing experiment. All the other subjects' dominating hands were the right hands. All the subjects have normal color vision.

3.2.2 Apparatus

We used two groups of apparatus to test the influence of color on human performance in HCI interfaces. The first group of apparatus includes a Tablet Computer (FUJITSU FMV Stylistic, with a screen size of 21cm x 15.6cm, each pixel on the screen was 0.2055mm wide) and a plastic pen. The second group of apparatus includes a desktop personal computer (screen size: 43cm/17.0 " Diagonal, pixel pitch: 0.264mmH x 0.263mmV, each pixel on the screen was 0.264 mm wide) and a mouse (Agiler AGM 6124X).

3.2.3 Procedure

Similar to the original Fitts experiment [1], participants did reciprocal pointing on a pair of vertical strip targets with the plastic pen or the mouse according to the experimenters' instructions. The widths (W) of the target were set at W = 12, 36, 72 pixels and the center to center distances (A) between the two strips were set at A=120, 360, 840 pixels. The order of the 9 widths and distance combinations was randomized. 12 trials were presented in each pair of targets, with the first tap excluded in analysis. If tapped on the outside of the target, an auditory signal was played.

During the task, in the two rectangles, the non-target one was black, while the colors of target rectangle changed from the regularly used white into one of the tricolors (red, blue and green). Once tapped, the positions of the target rectangle and the non-target rectangle would reverse. The appearance of the three colors was balanced by a Latin square and set by the experimenter before the subject began to tap. Therefore the total number of the trials afforded for one subject to fulfill is 3 (colors) x 3 (distances) x 3 (widths) x 12 (trials) = 324.

The interface of the experiment tool was shown in Fig. 4.

(a) Desk-top PC (b) Tablet PC

Fig. 4 Experiment interfaces (when the target is blue)

3.2.4 Error rates

During the experiment, due to either the confusion of the participant, or instrument error, "accidental clicks" outside the general region of the target were registered[1]. The information of the accidental trials and error rates in Experiment 1 were listed by Table 1.

Table 1 Error rates and accidental trials of Exp. 1.

Apparatus and colors	Error rates	Accidental trials
Pen (mix)	0.016	5
Pen (red)	0.017	0
Pen (green)	0.019	2
Pen (blue)	0.013	3
Mouse (mix)	0.024	5
Mouse (red)	0.033	1
Mouse (green)	0.023	3
Mouse (blue)	0.018	1

3.3 Experiment 2: on interface with randomly changing colors

The same subjects and apparatus used in Experiment 1 were also applied in Experiment 2.

3.3.1 Procedures

The procedure of the task was the same with that of Experiment 1, except that the colors of the target rectangle were changed randomly during one section of the A and W combination, i.e. while doing the pointing task, the color of the target will change randomly without any warning. The total number of the trials afforded for one subjects to fulfill is 3 (distances) x 3 (widths) x 12 (trials) = 108.

3.3.2 Error rates

Apparatus and colors	Error rates	Accidental trials
Pen (mix)	0.019	18
Pen (red)	0.012	4
Pen (green)	0.027	7
Pen (blue)	0.018	7
Mouse (mix)	0.027	1
Mouse (red)	0.022	0
Mouse (green)	0.027	0
Mouse (blue)	0.032	1

3.4 Non-color experiment

To make comparison with the effects of whether using colors in the pointing task, we utilized some data from the experiments we had developed previously [7] [8] and called the related experiments as Non-color experiment for conveniences.

One part of the Non-color Experiment using tablet personnel computer and pen was developed by the project of [7]. Fifteen volunteers, 5 female and 10 male, aged 20 to 36 years old, participated in it. We picked up the part of the data of the experiment of Zhai

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[1] *We excluded the accidental trials (for example, target appears on the left, but the point fell into the right region of the screen) from further analysis to prevent their disproportional impact on modeling.* *region of the screen) from further analysis to prevent their disproportional impact on modeling.*

et al. [7] which had the similar procedure as in Experiment 1 for comparison. During the experiment of this part, the target rectangle was always white and the non-target rectangle was always black.

The error rate of the task is 4 %, and one accidental trial was excepted from the data for analysis.

The other part of the Non-color Experiment using regular personnel computer and mouse was developed by the project of [8]. Twelve subjects, of different genders and ages (3 female students and 9 male students, 21 to 32 years old, average 25) participated in the experiment. All the subjects' dominant hands were the right hands. The procedure of this part was similar with that of Experiment 1. During the experiment of this part, the target rectangle was always white and the non-target rectangle was always black.

3.5 Checking Experiment

Because we used different subjects between the experiments with colorful target and the experiments with the white target, to make the comparison reliable, we asked 5 subjects to perform all the experiments mentioned above (Exp. 1, Exp. 2 and Non-color Exp.) and organized the data as Checking Experiment[2]. However, in the Checking Experiment, since our purpose was merely to test the reliability of the comparison results of Exp. 1, Exp. 2 and Non-color Exp., we asked the subjects to perform the pointing task only under one *A*-*W* combination (*A*=840 pixels, *W*=12 pixels). The reason for this choice is that with low level of difficulty, different colors may not incur much difference in performance, only with big task difficulty, the difference can be visible.

3.6 Results and Discussions

3.6.1 Difference incurred by different colors

First, we performed ANOVA and found that there was no significant statistical difference among the mean time of the different colors afforded by the experiment if we used the pen as the input device.

However, from the Fitts' law analysis (based on *ID*), we can still observe that the colorful targets cost more time on average than the white target (Fig. 5).

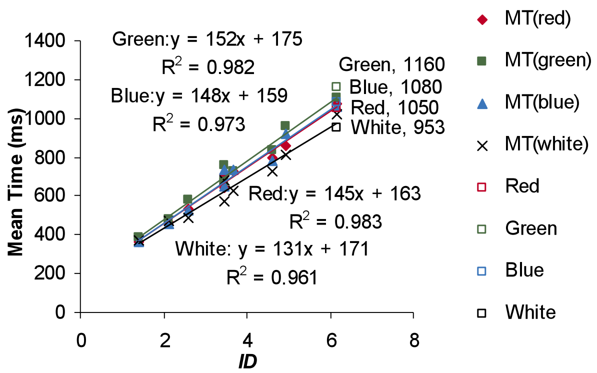

Fig. 5 ***MT~ID*** **regression lines with different colors of the target in Exp. 1 and Non-color Exp. (pen) and the** ***MT~ID*** **relationship with different colors of the target in Checking Exp. of Exp. 1 and Non-color Exp. (pen)**

Fig.5 also shows the Checking Experiment results of Exp. 1, through which we can test whether the sequences of the time cost by different colors for different groups of

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[2] *The purpose of the Checking Exp. is to check whether the comparison results of the experiments with different subjects are identical. The subjects included in the Checking experiment need to perform some parts of the experiments with different subjects.*

subjects are reliable. We did *T*-test to test the statistical significance of the difference between different colors of the Checking Exp. There is significant difference between white and red ($P_{108}(t>=2.23)<0.05$), white and green ($P_{108}(t>=5.13) < 0.0001$), white and blue ($P_{108}(t>=3.49) < 0.001$), green and blue ($P_{108}(t>=2.29) < 0.05$), red and green ($P_{108}(t>=2.48) < 0.05$), there is no significant difference between blue and red.

Therefore, the results of the Checking Exp. could support the comparison consequences of Exp. 1 and Non-color Exp.

ANOVA shows that there was neither significant statistical difference among the mean time of the different colors afforded by the experiment if we used the mouse as the input device.

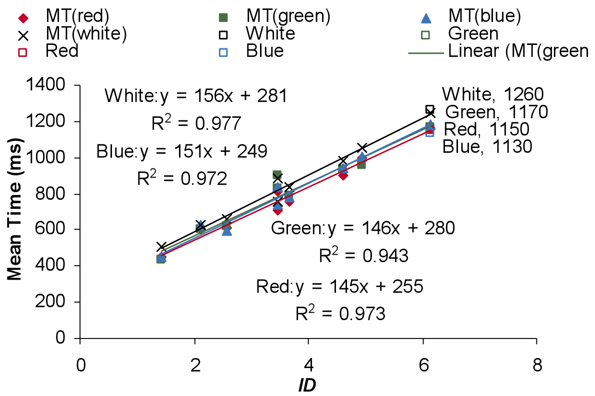

Fig. 6. *MT~ID* regression lines with different colors of the target in Exp. 1 and Non-color Exp. (Mouse) and the *MT~ID* relationship with different colors of the target in the Checking Exp. Of Exp. 1 and Non-color Exp. (Mouse)

Fitts' law regression lines (Fig. 6) also show that using mouse and desk-top PC, targets in different colors brings no big difference in mean time even though we vary the difficulty of the task.

Then we use the Checking Experiment to check whether the comparison between the color task (Exp. 1) and non-color task is reliable.

T-test results of the Checking Exp. only show significant difference between white and red ($P_{108}(t>=2.19)<0.05$), white and blue ($P_{108}(t>=2.61)<0.05$), but not between blue and red, white and green, green and blue, red and green.

Therefore, although the Checking Exp. results are not identical with those obtained from Exp. 1, considering the tiny difference between the regression lines in Fig. 6 and the *T*-test analysis, we think that the difference brought by different colors of the target can be ignored when we use the mouse as the input device.

3.6.2 Differences incurred from the color changing styles

Next we test the difference brought by the color changing styles.

According to ANOVA, there is no significant statistical difference among the mean time of different color changing styles either with the pen or mouse as the input device.

Figs. 7 and 8 coherently show that the targets in randomly changing colors cost more performance time than the targets in fixed color. When the difficulty increases, subjects need more time to track the targets in randomly changing colors. The difference with the mouse data is not as obvious as with the pen data.

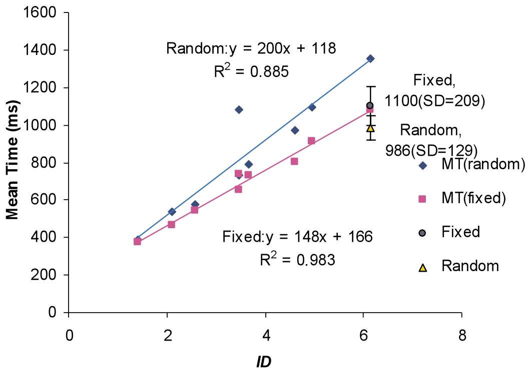

Fig. 7. ***MT~ID*** **regression lines of the mixed data of three colors in Exp. 1 (fixed) and Exp. 2 (random) (pen) and the** ***MT~ID*** **relationship of the mixed data of three colors in the Checking Exp. of Exp. 1 (fixed) and Exp. 2 (random). (pen)**

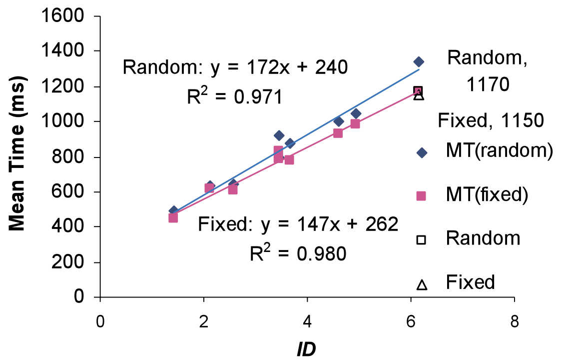

Fig. 8. ***MT~ID*** **regression lines of the mixed data of three colors in Exp. 1 (fixed) and Exp. 2 (random) (Mouse) and the** ***MT~ID*** **relationship of the mixed data of three colors in the Checking Exp. of Exp. 1 (fixed) and Exp. 2 (random). (Mouse)**

However, the Checking Exp. results contradict the comparison results of Exp. 1 and 2.

We did *T*-test to test the statistical significance of the difference between different color changing styles of the Checking Exp. There is significant difference between the Random and Non-random data ($P_{218}(t>=3.77)<0.001$).

The discrepancy may come from learning effects: first, all the subjects in Exp. 1 and 2 performed the random task first and fixed task secondly. This may incur the learning effect. Secondly, most of the subjects in Exp. 1 and 2 were novice subjects, and all of the five subjects in the Checking Exp. have experience in the pointing task. For the experienced subjects, the difference of the color changing styles may not be as great as for the novice subjects.

When mouse was applied as the input device, the Checking Exp. results are identical with those obtained from Exp. 1 and 2, and the time difference of performing with Random and Fixed tasks is smaller than that of using pen as the input device, these might be because mouse is a familiar tool for all the subjects. Even though some of the subjects have no experience of using mouse to perform the pointing task designed in this paper, their abundant experience of using mouse help them adapt to the task quite easy.

T-test results show that there is no significant difference between the Random and Fixed color tasks.

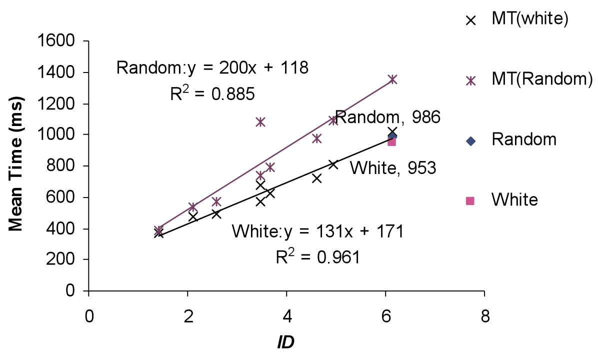

Fig. 9. ***MT~ID*** **regression lines of the interface with color (Exp. 2) and without color (Non-color Exp.) (pen) and the** ***MT~ID*** **relationship of the checking Experiment of the interface with color (Exp. 2) and without color (Non-color Exp.) (pen)**

3.6.3 Differences incurred by the colorful interfaces

Finally we compared the results of the experiments with and without colors.

The ANOVA results show that there is no significant difference among the mean time of the colorful interfaces and the black and white interfaces, either with fixed colors or randomly changing colors, pen or mouse.

Nevertheless, Fig.9 shows clearly that with the randomly changing colors in the interface, subjects need more time to track the target with pen.

The results of Checking Exp. are identical with the comparison results (Fig. 9). *T*-test results show that there is no significant difference between the Non-color and Random tasks of the Checking Exp.

However, the difference in movement time is not clear when mouse was applied as the input device (see Fig. 10.).

The comparison results of the Checking Exp. are not the same with the comparison between Exp. 2 and Non-color Exp. Nevertheless, the *T*-test shows no significant difference exists between the Non-color and randomly changing color, therefore, we may ignore the discrepancy.

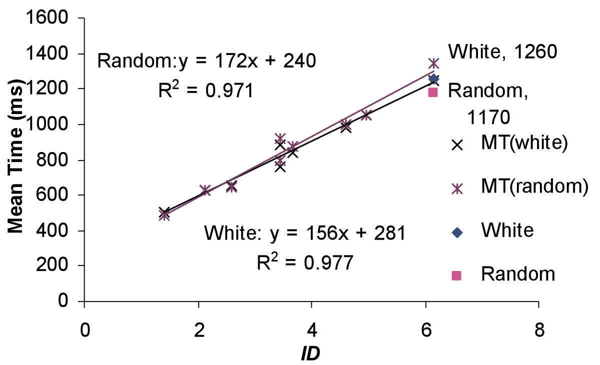

Fig. 10. ***MT~ID*** **regression lines of the interface with color (Exp. 2) and without color (Non-color Exp.) (Mouse) and the** ***MT~ID*** **relationship of the Checking Exp. of the interface with color (Exp. 2) and without color (Non-color Exp.) (Mouse)**

When the colors of the target are fixed, there is no obvious difference among the colorful interfaces and the non-color interface either with pen or mouse. (see Fig. 11 and 12.) Although the comparison results made by Exp. 1, Non-color Exp. and Checking Exp. are not the same, since in either group of comparison there is no significant statistical difference and the difference of direct observation of the regression lines is also tiny, the difference between the Non-color task and Fixed Color task can be ignored.

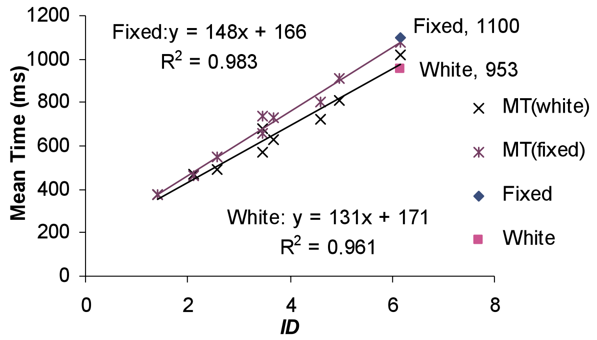

Fig. 11. ***MT~ID*** **regression lines of the interface with color (Exp. 1) and without color (Non-color Exp.) (pen) and the** ***MT~ID*** **relationship of the Checking Exp. of the interface with color (Exp. 1) and without color (Non-color Exp.) (pen)**

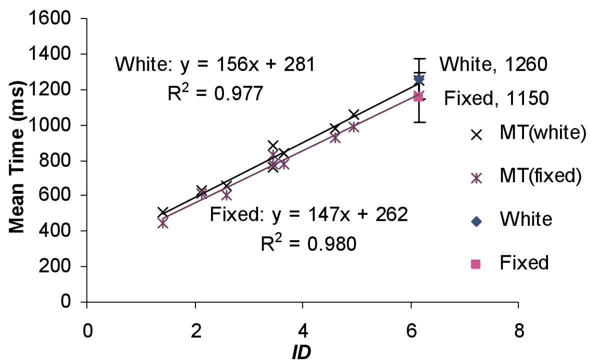

Fig. 12. ***MT~ID*** **regression lines of the interface with color (Exp. 1) and without color (Non-color Exp.) (Mouse) and the** ***MT~ID*** **relationship of the Checking Exp. of the interface with color (Exp. 1) and without color (Non-color Exp.) (Mouse)**

3.7 Conclusions

In this paper, we thoroughly compared the effects of whether using colors in the pointing tasks. Three colors (red, green and blue) are applied in the experiments. Moreover, we also tested the effect of different color changing styles during the pointing task (fixed colors and randomly changing colors). In case that there would be discrepancy brought by different subjects in the color and non-color experiments, we also carried out the Checking experiment for the three experiments (Exp. 1, Exp. 2 and Non-color Exp.).

First, the great regression of the relationship of mean time and *ID* demonstrates that Fitts' law can be applied to the interface with colourful targets.

With the experimental data, it is not difficult to make conclusions on colors' effects that:

1. in pointing task, different colors will not bring significant difference on subjects' performance. However, when the subjects used pen, they need more time to perform the colorful task.
2. for the novice subjects as describe in Exp. 1 and Exp. 2, when the color is changed randomly as tapped by subjects, the subjects' performance is worse than when the color is fixed, moreover, the difference is ignorable when the subjects used the mouse. When the novice subjects used the pen, there is difference in performance.
3. with or without color, for pointing task, subjects' performance keeps almost constant, except when they use pen to perform the randomly changing color task.

For the intervened effects of different colors and different input devices, we can also conclude that the performance situation will be different, although significant differences will not appear, either. When people use pen to tap the target with randomly changing colors, the performance time is a little longer than they tap the target without color or without color changing. The reason might be that when people use the mouse, there is friction, so the speed is not very big and it is easier for subjects to adjust the performance power when the mouse approaches the target, no matter the target is white, colorful or even with randomly changing colors. However, using the pen, there is no friction to limit the speed of the pen, and sometimes it is difficult to change the accelerating power to adjust the route of the pen. If the target's color is changed without previous warning, it is difficult for the subjects to make change according to what they suddenly watch. These phenomena were only apparent for the novice subjects. For the experienced subjects, the difference will be reduced.

These conclusions imply that even though there is no big difference for different color targets in the usual occasions, for some special situations, for instance, novice user, or tablet pen, the designers need to deliberatively consider the application of colors and the color demonstrating or changing styles.

3.8 Future works

In this research we studied the effect of three different colors except the traditional white one in the one dimensional pointing task. This study will be consummated if we consider the factor of the contrast, target shape, lighting along with more colors. Some factors in physiology will also be important for this study. For example, at present, all the subjects own normal color vision, but in fact, there were a certain number of male have color blindness. It will be helpful to include more physiological factors into consideration.

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4. Future work

In order to enhance research progress in this project, we will introduce some Ph.D. students in Special Scholarship Program in KUT. With these graduate students, research themes shown above will be continued and also, we are expecting to make new research themes in Perception region and Operation region for them. We hope achievements will be more and better and also, we are expecting to establish some researches in Communication region, starting in 2006 academic year soon.

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