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An associate model between interface color design, user's emotion and operation

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Abstract: Color information is one of influential factors which affects human behaviors. Relationships between coloration of interface and operational performance are well known, and many previous researches have shown evidences of relationships between coloration and users' emotion. Consequently, it is expected that there are important effects between interface color design, emotion and operation. Nevertheless, almost of the previous researches were done in which impact of color on emotion or task performances were investigated independently. In this paper, a novel model which represents relationships between color design, emotion and operation is proposed. Structural Equation Modeling (SEM) has been employed as the method for generating representative models. Users' performance and their impression for the interfaces are used for the data to generate SEM models. To obtain users' performance data, experiments have been conducted with simple computer software of arithmetical calculation in which touch panel interface is used. Furthermore, questionnaire approach has been used to obtain users' impressions for interfaces. By using the proposed scheme, we can verify the effects of touch panel coloration on operator's feeling, and clarify how the feelings affect the operations. To verify the efficiency of the proposed scheme, two representation models, one is based on the proposed scheme and the other is based on the traditional scheme, have been generated and analyzed. As a result, the former model can illustrate the relationships between color design and the operational performances better than the latter one.

Keywords: Interface color design, touch panel, usability

1. INTRODUCTION

Color information is one of the most influential factors which affects users' perceptions, physiological reactions and emotional reactions (Valdez & Mehrabian, 1994). Thus, appropriately using of colors in an interface can lead to better performance of the operators. Conversely, poor use of color might lead to decrease in performance and increase the ability of visual fatigue (Ling & Schaik, 2002).

There are many studies which inquired into relationships between color interfaces design and the operations. The results revealed that color affects users' working performances. However, users' perceptions for a coloration are difference depend on the individual. Consequently, it can be assumed that the difference might cause differences of users' feelings.

Several studies have provided evidences of relationships between colors and emotions. They have found that each different color has an individual impact on human. According to Pastoor (1990), subjective measure can be more sensitive to distinguish a difference in color display on monitors than measures with instruments. In addition, many previous researches have used emotional evaluation rather than physiological evaluation (Tsunetsugu et al, 2005). Therefore, it is expected that colors which decorate an interface design, the users' emotions and the task performances are related each other. Unfortunately, almost of the previous researches were done in which impacts of colors on emotions or task performances were investigated independently. Thus, in this paper, a novel representation model of relationship between interface color design and operation is proposed. The authors aim to demonstrate advantage of the model which is generated based on the proposed scheme in comparison with a model based on the traditional one. In order to achieve the research goal, correlations between colorations and users' emotions have been investigated. Moreover, the relationship between users' emotions and operational performances are also verified. In order to obtain data, two method approaches, user experiments and questionnaires, are conducted.

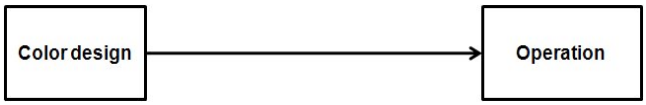

Figure 1(A): Traditional scheme

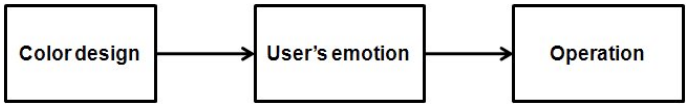

Figure 1 (B): Proposed scheme

2. LITERATURE REVIEWS AND RESEARCH MODEL

When designing a human-machine interface, the designer should consider both of usability and emotional appealing because users' feelings could influence operational performance (Sonderegger & Sauer, 2010). Thus, many studies have been conducted in order to find the factors which impact on user affections. The results revealed that each different color has an individual impact on human feelings [6]. Besides, people respond to colors differently based on some variables such as age, sex and culture (Elliot & Maier, 2007). For instance, Suto and Sakamoto

(2012) clarified the relationships between the effects of colorations used in an interface design and the operators' age. They have found that the relationships among contrast of background decorations, accuracy of operations and the operator's age. They have also concluded that the relationship between contrast of background decorations and operation speed was not affected by aging. However, Jalil et al. (2012) pointed out, the previous studies on the effect of color show conflicting and inconclusive. Thus, further research is required to clarify the issues.

With regard to interface design, effects on users' behavior also have been discussed. Cyr et al. (2010) found that website color appearance is a determining factor for websites' trust and satisfaction. Bonnardel et al. (2011) sought effects of colors used in web sites on users' cognitive processes, and the impact of the color on the users' revisit rate was found. The results showed that users spent longer time on web sites which have warm colors than which have cool colors. Similarly, Sakamoto et al. (2010) conducted experiments to find relationships between impressions of touch panel interfaces of electronic devices and the operations. As a result, it is concluded that the colors which are cool-casual scheme (i.e. mild green and mild yellow) have positive effects on users' performances. Moreover, Cai and Lin (2011) developed emotion-performance model in a context of vehicle driving. They have argued that emotion affects human performance through influencing individuals' judgments and behaviors. The above mentioned studies support the emotional of the operator are strongly related to performance of the operation.

All of above mentioned interface studies, relationships between design and users' behaviors were investigated. This scheme can be represented by a diagram shown in Figure 1 (A). However, design cognition might vary from a person to a person and the relationships also may change depend on an individual. Thus, the authors have proposed another scheme represented in Figure 1 (B) as a diagram. In this scheme, an interface design is recognized by an operator, and he/she has some feelings about the design. Then, his/her operations are influenced by the feelings. This scheme is expected to represent the effects of interface design on the user more clearly.

3. RESEARCH METHODOLOGY

In order to comprehend how design affects users' cognitions and behaviors, novel scheme of association between design and operation performance has been proposed as described in the previous section. In order to verify the validity of the proposed scheme, a representative model is generated by using Structural Equation Modeling method based on the scheme and the model is analyzed. Eventually, the result of proposed scheme is compared and discussed with the model based on the traditional one.

The outline of the process of this research is shown in Figure 2. The first step is the designing of experiments. In this step, an experimental equipments and tasks are designed. Next, the experiments are conducted in order to obtain data for generating models. In the experiments, participants are asked to do simple tasks and answer questionnaires. Afterward, a proposed scheme and a traditional scheme are applied to generate two models, i.e. a proposed model and a traditional model, with the results of the experiments. Structural Equation Modeling is utilized for the generating model process. Finally, correlation results are compared in the models which generated based on the traditional scheme and the proposed scheme.

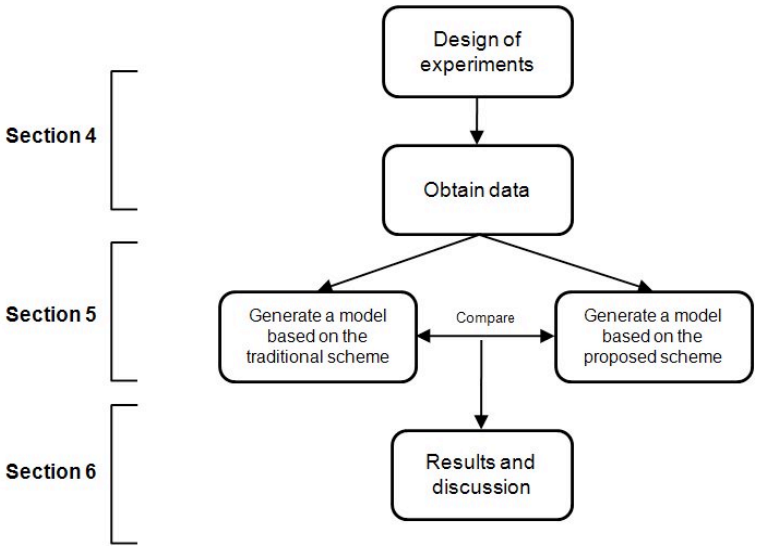

Figure 2: Outline of research methodology

4. DESIGN OF EXPERIMENTS

4.1. Target device

Recently, the demand of using electronic appliances with touch panel interface has been rising more and more. Touch screen technology is widely used for ATMs (Automated Teller Machines), ticket vending machines, interactive kiosks and so forth. Many personal devices such as smart phones, tablets PC, also use this technology. These devices are used in several fields e.g., service and health care (Shervin et al, 2011). Touch panel interfaces enable a user to interact directly with a device by using his/her fingers. Users can retrieve target information by touching the screen (Lundstrom & Weiss, 2008). Many researches claim that operation time of touch screen usage is significantly less than physical input devices such as keyboard and mouse on a same task (Karat et al, 1986; Sear & Shneiderman, 1991). Furthermore, touch interfaces are easy to adjust the interface design; size, color, and location of items on a screen (Colle & Hiszen, 2004). Due to the above advantages, i.e., easy use, flexible design, and better performance, touch screens have became popular, and user-friendly touch panel interfaces are required. Thus, a touch panel device was used in the experiments.

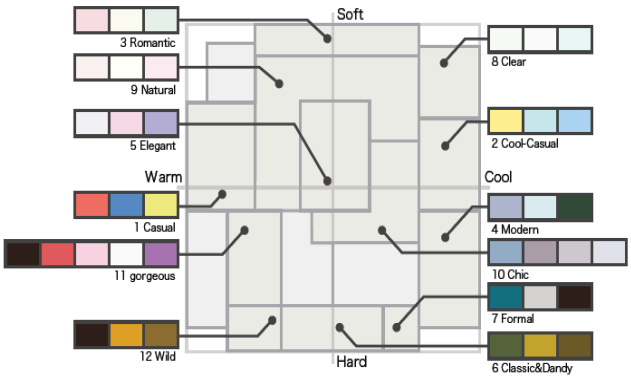

Figure 3: The twelve color schemes which were used in the experiments

4.2. Outline of experiment

Two methods are adopted to obtain data: observing task performances and questionnaires. Relationship between users' feelings and operation are investigated through the experiment. The participants were asked to work arithmetical tests (single digit ones). Then, questionnaires were prepared in order to examine users' feelings on each screen. Afterward, experiments data and questionnaires data were fit in order to generate proposed model. The participants were males and females students in their twenties to thirties.

4.3. Equipment

To get performance data, a simple computer application which quizzes addition questions was used. The bottom of the screen of this application is decorated by a color schemes. This color scheme can be chosen from the color sets on the mix color image scale (Kobayashi, 1987). The mix color image scale is an image map which transforms color schemata into impressions. This scale has two axes, "soft-hard" and "cool-warm." Twelve major descriptive phrases were selected as representative color schemes; "casual," "cool-casual," "romantic," "modern," "elegant," "classic and dandy," "formal," "clear," "natural," "chic," "gorgeous," and "wild." Each color scheme consists of three to five different colors. The representative color schemes are shown in Figure 3. The components colors used in each color scheme are shown in Table 1 by using Munsell color system.

Table 1: Colors which are used in the experiments

Image word	Color 1	Color 2	Color 3	Color 4	Color 5
01.casual	5R 5/12	5PB 4/10	10Y 8/12	—	—
02.cool-casual	6Y 8/10	5B 7/6	5PB 6/8	—	—
03.romantic	7.5R 8/4	7.5Y 9/6	2.5G 8.5/2	—	—
04.modern	6.25PB 5.6/6	5B 8/4	5BG 3/2	—	—
05.elegant	10PB 8/4	2.5RP 8/4	2.5P 6/6	—	—
06.classic&dandy	10GY 3/2	2.5Y 6/8	2.5Y 3/2	—	—
07.formal	5B 4/4	7.5PB 8/2	5PB 2/2	—	—
08.clear	10BG 9/2	10Y 9/0.5	10BG 7/4	—	—
09.natural	3RP 8/4	5Y 9.2/1	5P 8/4	—	—
10.chic	5PB 6/4	5P 6/2	5P 7.5/0.5	5PB 8/1	—
11.gorgeous	5P 2/1	3R 4/12	5RP 8/4	7R 9.2/1	2.5P 4/10
12.wild	N1	8YR 5/8	10YR 4/4	—	—

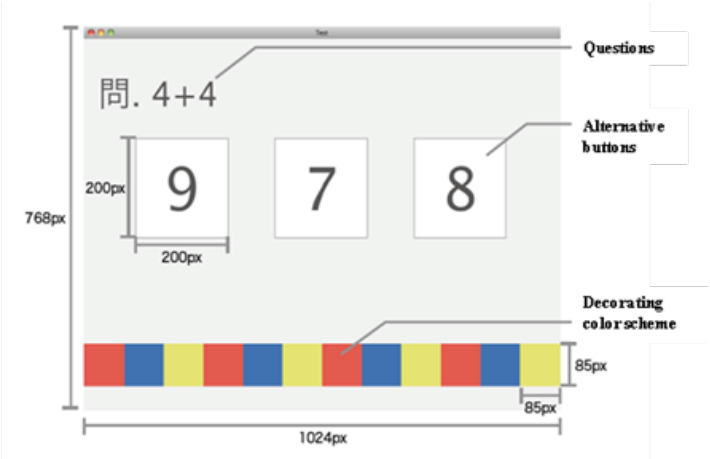

Figure 4: An example of screen which used in the experiments

An example of screen which is used in this research is shown in Figure 4. The background of the screens are colored by pale gray (N8), and the push panels' color are white (N9.5). The color of characters are dark gray (N3). The colors of these components were chosen by considering visibility of characters in the screen. The three alternatives are placed for each problem.

In the experiments, the decoration color scheme was chosen from representative color schemata which mentioned above. Each screen was displayed with a different color scheme without changing other components. Thus, the experiments have been conducted under twelve different conditions.

4.4. Tasks

In the experiments, the participants tried single-digit mental arithmetic tests. The participants were requested to select one correct answer from three choices by touching one of three push panels. If a participant does not touch any buttons within 1.5 seconds, the system moved on the next problem automatically. Thirty different problems were contained in each condition. The spending time and the accuracy rate were chosen as indicators to measure working performances, and recorded.

4.5. Evaluation of users' feelings

Questionnaires have been conducted to obtain participants' feelings data for each screen. Questionnaire comprised fifth-teen sensations query; eleven emotional indicators: preference, understandability, visibility, hesitation, familiarity, eye strain, readability, beauty, comfortableness, impressive, safety, were chosen from 59 indicators which are used to evaluate the web usability in Japan (Nakagawa et al., 2001) and four emotional indicators: number of tasks, enables concentration, volition, trouble, were developed by intense brainstorming session. Rating linear measurement method was utilized for the scoring. A part of questionnaire is shown in Figure 5.

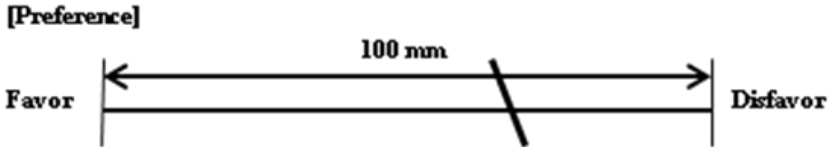

Figure 5: Rating linear measurement method which used in the experiments

4.6. Procedures

The experiments ran under the twelve different conditions as described above. In each condition, each participant was requested to do calculation tasks and ask the questionnaire. On the beginning, each participant got the instructions and trialed a training task. Secondary, the training task was conducted on a screen that had no color decoration. Following a practice step, the participant tried the tasks on the twelve screens. Afterward, the participants had to answer the questionnaires to evaluate their feeling with each decorated color scheme. A two minutes break was given between each condition for resting and decreasing the effect by previous screen. Figure 6 illustrates the procedures of the experiments.

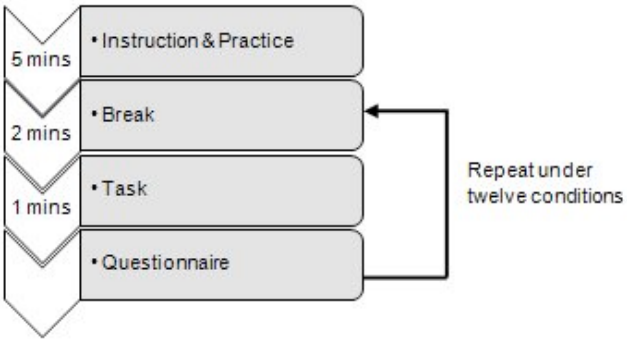

Figure 6: Procedure of the experiments

5. GENERATING REPRESENTATIVE MODEL

After the experiment process, the structural equation modeling (SEM) approach is adopted to generate representative models. SEM is a technique to express a complicated statistical model by a path diagram which expresses causation between variables with an arrowed line clearly. A SEM model can be represented as a diagram by using squares and arrows. A square represents variable and an arrow means causation between two variables. A numerical value added to an arrow expresses a degree of effect (Takaya, 2003). Two types of scheme, traditional scheme which is shown in Figure 1 (A) and proposed scheme which is shown in Figure 1 (B), have been generated by using the SEM method. The results from SEM method were shown by using comprehensible graphic. Sample models were generated from data which obtained from the experiments and the questionnaires which mentioned in the previous section. In order to improve the fit of the models, input data was prepared by using Discretization method and Pruning method. Figure 7 shows a diagram of generated model which based on the traditional scheme.

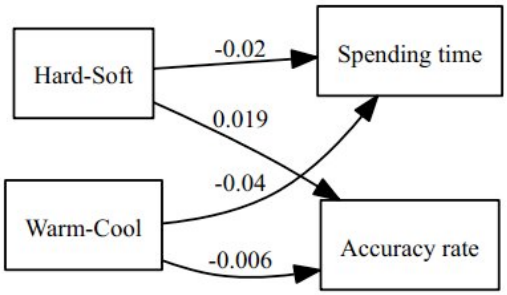

Figure 7: A SEM diagram based on the traditional scheme

The model which is generated based on the proposed scheme showed that there are five emotions which linked up operations; hesitation, number of tasks, safety, beauty, and understandability. Thus, the emotion nodes which are not connected with operation nodes were eliminated and the model has been re-generated. The re-generated model is exhibited in Figure 8.

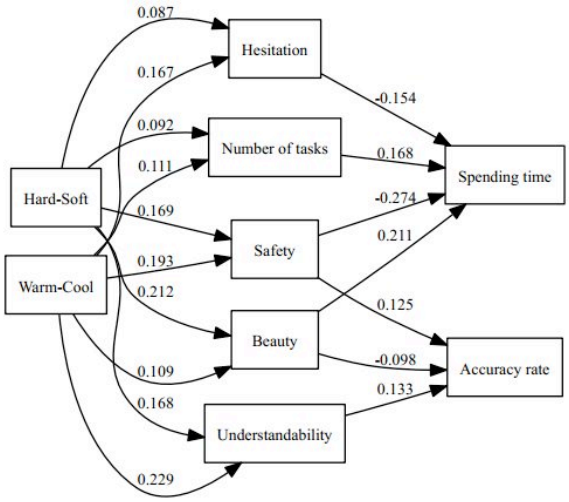

Figure 8: A SEM diagram based on the proposed scheme

6. RESULTS AND DISCUSSION

In this section, the efficiency of the proposed scheme is clarified and discussed by comparing two models, generated based on the proposed scheme and based on the traditional scheme. In the case of the model based on the traditional scheme, the result shows that the soft-hard value has negative effect on working time, whereas has positive effect on accuracy of operation. Meanwhile, both of operation indicators were affected negatively by the warm-cool value. However, coefficient of each path is quite low as shown in Figure 7. Thus, we cannot find any significant effects of the interface design on working performance indicators when investigating through the model which is generated based on the traditional scheme. This is to say, the analysis with this model cannot clear up effects of the interface color design on the users' operation.

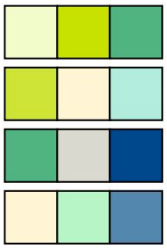

Figure 9(A): The color schemes which have safety image

Figure 9 (B): The color schemes which have beauty image

As shown in Figure 8, in the model based on the proposed scheme, there are fifth emotions connected with working performances. Hesitation enhances spending time to complete work whereas sensation of number of tasks effect negatively on the spending time index. For the accuracy rate indicator, understandability tends to increase number of correct answers in the tasks. Moreover, there are positive correlations with both of working performance and safety. On the other hand, there are negative correlations between the performances and beauty. Therefore, it can be confirmed that the operational performances and the users' feelings have a causal association. The color schemata which have safety image and beauty image are shown in Figure 9 (A) and (B) respectively. Following, the hard-soft node and the warm-cool node are connected with all nodes of emotions positively.

From the results of correlation analysis, we can notice that the model based on the traditional scheme is hard to explain that how colorations take an effect on users' working behaviors. While the model based on the proposed scheme can assist us to better understand about how colors decoration of interface design influence operational performance through users' emotion perspective. The results show how colorations have effects on users' feelings and how operational performance was affected by users' feelings. Furthermore, the proposed scheme can illustrate the effect of colors interface design on users' operation more precisely than the traditional scheme.

7. CONCLUSION

Many researches were done to investigate effects of coloration on operational performance. Many of them considered relationships between colors and operations. This scheme is called as traditional scheme in this research. However, users' perceptions for the interface are difference depend on the individual. Thus, a new scheme has been proposed for better understanding how colors interface design influence users' operational performances. The new scheme represents relationship between design, user's feeling and operation. The experiments and the questionnaires have been conducted to generate example models based on the proposed model and traditional model in order to demonstrate advantage of the proposed scheme in comparison with the traditional one. It has been revealed that the proposed scheme can illustrate the relationship between interface color design and the operations more accurately than traditional scheme as a result of analysis of the models. Therefore, we can understand the mechanisms in which how an operator feels about an interface design, and how the operations get effects from the feelings with the proposed scheme.

The results of this study have shown that there are causal relationships between interface colors design, users' feelings and operational performances. When the scheme is introduced into a practical system, the relationship between coloration and each operator should become clear. However, it is difficult to know how coloration effects on each person. An efficient method to find the relation is expected to develop a design support system based on the proposed scheme.

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