DESIGNING INTERNATIONAL USER INTERFACES: A CROSS CULTURAL STUDY OF THE IMPACT OF COLOR ON USER PERFORMANCE

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Designing International User Interfaces: A Cross Cultural Study of the Impact of Color on User Performance

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Abstract: An important determinant of user performance is the degree of fit between user interface (UI) attributes and user characteristics, moderated by cognitive and demographic variables. Culture is one moderating variable which is often overlooked by UI designers. This study evaluates the effect of the presence of color in the UI on user performance for two distinct cultural groups, Japanese and Americans. We report the findings of a laboratory experiment involving American subjects (N=12) and Japanese subjects (N=12) performing 40 elementary database retrieval tasks using an interface with 8 background colors. The results suggest that American subjects react more strongly than Japanese subjects do to color stimuli, Japanese subjects appear to be disrupted by the use of color in the user interface, and there is no relationship between color preferences and performance.

Keywords: Colors, Human-Computer Interaction, User interface, Japanese culture, American culture.

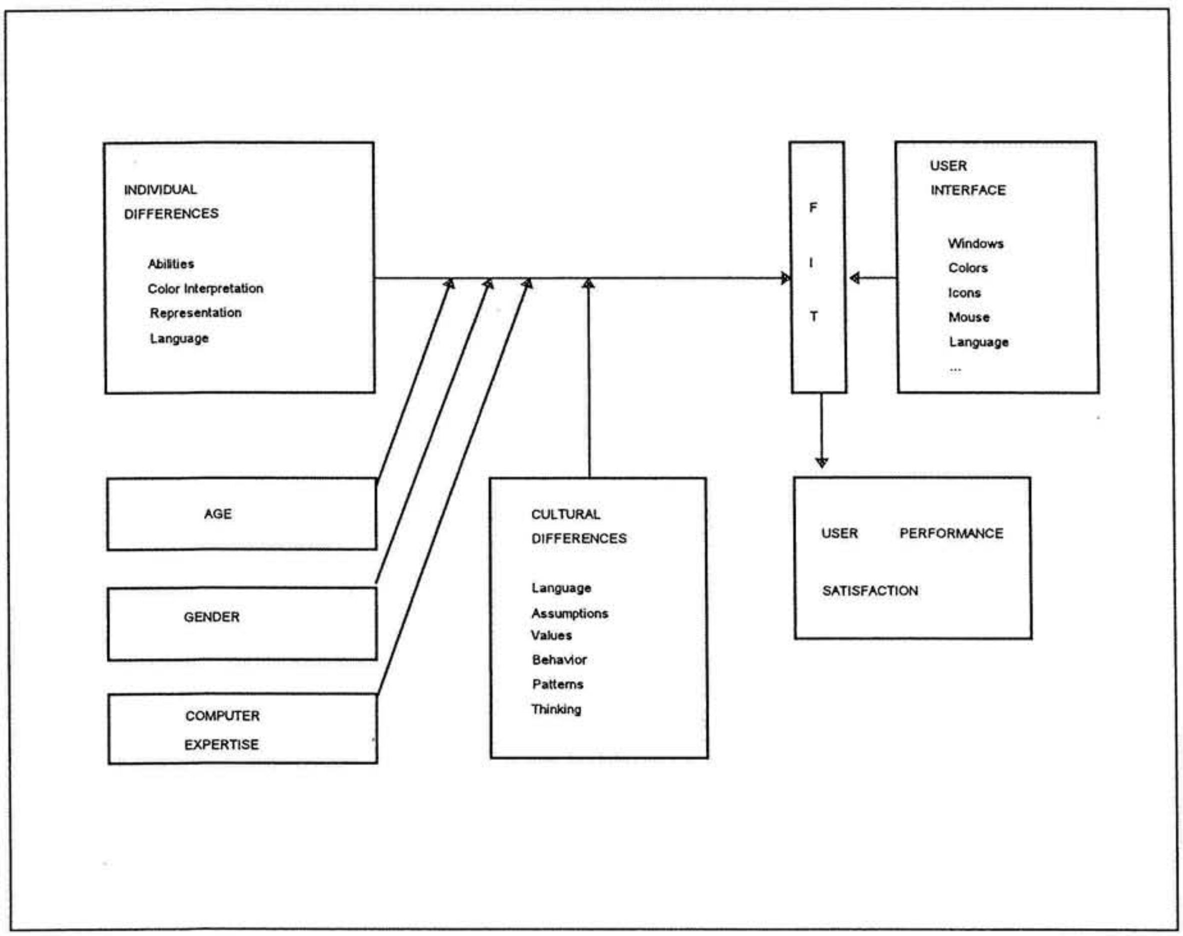
Introduction

Over the last decade, the rapid improvement in computing technology has led to tremendous changes in users' expectations of what their interaction with computers should be. While the widespread use of DOS and UNIX operating systems have sustained their utilization, traditional command-based interfaces are slowly slipping into history. Windows, icons, menus and other pointing devices, which increase the accessibility and usability of computer systems, are becoming mandatory features for user acceptance (Mandelkern 1993). Research investigating human-computer interactions paralleled this evolution. Early results highlighted the need to adapt the man-machine exchange to different classes of users (Whiteside et al. 1985), and research subsequently focussed on the relationships between human characteristics and user interface (UI) attributes (Trumbly and Arnett 1989). These studies have thoroughly investigated demographic and cognitive differences, and have reported significant associations between user characteristics, UI features, and performance. However, little attention has been given to cultural differences among users and their importance in determining UI properties that will best satisfy the needs of various user groups. In this paper, we report the results of a laboratory experiment involving subjects from two distinct cultures, Japanese and American, and how their performance in completing simple tasks differ as a function of UI color.

End-user, UI and Performance

Worker performance is an issue of importance to a majority of managers. Indeed, improving human-computer interaction is receiving increasing attention as a means of addressing some issues associated with the diffusion of information technology in organizations. If fact, the quality of the user interface to computer systems has been linked to user acceptance of a system, user satisfaction, user performance, and market share of software product (Shneiderman 1987). The role of UI in influencing user performance has been widely investigated (Trumbly and Arnett 1989, Hendrickson 1989, Whiteside et al. 1985, Sukaviriya and Moran 1990). It is generally accepted that user performance is a result of the fit between user characteristics, such as attitudes, learning abilities, personality, or color preferences, and UI attributes such as the interaction mode, the use of icons, colors, or the type of dialogue the interface supports. Trumbly and Arnett (1989) have summarized these relationships in a framework which presents performance as the outcome of a user characteristics-UI attributes match. However, the impact of user characteristics on performance is moderated by a number a demographic attributes, such as age, gender, or level of computer expertise. For example, it was demonstrated that novices perform better with dynamic and self explanatory interfaces, whereas experts feel unnecessarily constrained by the cumbersomeness of excessive assistance, and are more efficient using standard interfaces with minimum support (Whiteside et al. 1985). Culture also affects individual differences that are critical determinants of the user-UI fit, such as spatial representation or color interpretation (Courtney 1992). In figure 1, we propose a modification of the Trumbly and Arnett (1989) framework which relates user performance to UI attributes and users characteristics, along with the moderating demographic and cultural attributes.

Figure 1 - Framework relating UI attributes/Individual characteristics to User performance



Culture was defined by the anthropologist Sir Edward Tylor (1881) as *that complex whole which includes knowledge, belief, art, morals, law, customs, and any other capabilities and habits acquired by man as a member of society.* Culture is a learned behavior as opposed to a genetically related one. The history, geographical location, interaction with other cultures and countries, ecology, technology, are among the various elements that influence a given culture. While intertwined with the concept of culture, language and communication styles are two salient factors which reflect the richness and complexity of culture. Language and communication styles are also major determinants of how people from a particular culture interact with computers. The selection of a language and particular sets of symbols in the UI are determined by the designer's culture. Often, some of the UI attributes can be customized by the user. However, customization provides limited benefits when the user's native language is based on a grammar, semantics, and an alphabet that are different than that of the UI. Similarly, if the symbols or colors used in the UI holds different values and meanings in the user's culture, the effectiveness of the UI as a communication medium will be greatly reduced. Thus, it is important that the designer of the UI be aware of possible culture differences in order to build interfaces free of the biases of her own culture, which can be customized to adapt the culture of the final user.

Designing UI for international use

Many large companies derive a significant part of their revenue from international trade. To achieve objectives of higher performance and profitability, organizations rely heavily on information technology and computers. In this context, a single information system is likely to span many countries (Nielsen 1990). It is important that the local user interact with the system via a UI adapted to her environment. The UI designer has to be sensitive to cultural differences to develop culture-free software.

As Nielsen (1990) noted: *An international approach to user interfaces has to go further than the simple translation. It must take into account individual differences that arise from different countries and different cultures.* However, there is a lack of research on the question of how cultural diversity relates to other individual difference factors in the context of UI design. For example, graphical user interfaces (GUIs) make extensive use of icons to illustrate various functionalities of a system. However, the meaning of an icon is culturally dependent. Sukaviriya and Moran (1990) argue that the trashcan icon used to discard a file is not intuitive at all for Thai users. The trash container in Thailand is better represented by a wicker basket with flies around it than by the covered metal can used in most GUIs. Many icons are based on representations and associations specific to American culture, which can easily be misinterpreted by culturally different users. Therefore, it is important that UI designers understand cultural differences and their impact on UI design.

This study focusses on one facet of culture: the impact of individual color preferences, perception and interpretation that are routed in culture, and their relationship to UI and user performance. We selected subjects from 2 different cultures, Japanese and American, and measured their performance in completing a computer task, using a UI involving alternating background colors. The relevance of the choice of color as the treatment variable in the UI, and reasons for the selection of the Japanese and American cultures are discussed next.

Color in UI

The use of color in UI serves different purposes. Color combinations make interfaces attractive to the eye. Color coding can lead to rapid recognition and identification (Bauersfeld and Slater 1991). Color conveys information, due to commonly accepted associations in everyday life. For example, red can indicate danger, or stop, while yellow can indicate caution, and green a normal situation, the absence of a problem. Color is also associated with more emotional responses. Red is usually perceived as stressful, and can be used to bring up attention. Blue is often perceived as a peaceful color, and can be used in more normal situations, or to acknowledge success.

Although proper color selection may lead to improved user performance (Shneiderman 1987), there are a number of dangers when using colors. Excessive use of color can produce overwhelming effects, while being aesthetically pleasant. Poor color pairing can lead to excessive fatigue, or stress. Inappropriate color selection may generate misleading interpretations. But despite these potential drawbacks, standards for color use in UI have yet to be established.

The perception of colors is universal across international borders. However, one culture's idiosyncracy pertains to color associations with concepts and situations (Rosch 1973, Kay and McDaniel 1978, Lakoff 1987, Courtney 1986). For example, Courtney found that the red for *stop* and green for *go* color associations, used almost systematically in the western world, are weak in the Chinese culture. Also, since the symbolism of particular colors is different in various cultures, color preferences and color interpretations may also vary across cultures (Oyama 1962, Lamacraft, 1988, Jacobs 1991). For example, Lamacraft found that in East Asian markets, products designed for a female audience are packaged using pastel and subtle colors, while in the North American market, brighter colors tend to be used. It is therefore legitimate to hypothesize that culture affects the user characteristic-UI color attribute match.

The two cultures: USA and Japan

We selected the American and Japanese cultures for the following three reasons. First, American and Japanese represent two very contrasting cultures. Hofstede (1980) operationalized a measure of differences between cultures along four dimensions: power distance, individualism, uncertainty avoidance and masculinity. Japanese scored high in uncertainty avoidance and masculinity, while Americans showed high levels of individualism. Overall, Japanese and Americans are highly differentiated along these three dimensions, while both have average power distance scores. Moreover, the Japanese culture embeds a long and rich history which is reflected its artistic originality. Japanese literature, architecture, painting, theater and other art forms, strongly influenced by Buddhism, exhibit wide disparities with their American counterparts. This cultural diversity is expected to result in differences in the human-computer interaction.

The second reason to select the Japanese and American cultures was to maximize the likelihood of differentiation on color preferences, perception and interpretation. A number of studies have investigated how Japanese and Americans differ in their relationship to color. Americans have been found to be more responsive than Japanese to primary colors (Oyama et al. 1962). Also, in a study on color associations, Jacobs (1991) found that, although most colors hold similar connotation across various cultures, some colors like Grey and Violet hold opposite meanings in the American and Japanese cultures. Grey is associated with *inexpensive* in Japan, and *expensive* in the US. Violet is associated with *expensive* in Japan, and *inexpensive* in the US. Last, both countries are extensive consumers of information technology.

Hypotheses

As an extension of previous research, the following hypotheses will be tested:

Hypothesis 1: Americans will perform better than Japanese when primary colors -Blue, Green, Yellow, Red- are dominant in the UI.

Hypothesis 2: Most preferred colors will be associated with more time spent on the task and by a lower error rate.

Hypothesis 3: Japanese performance across colors will be more consistent than Americans' performance (eg Americans will react more strongly to the color stimuli).

Method

Experimental Design

The experiment was conducted using a 2 x 8 factorial design. Cultural background was treated as a between subject variable, with 2 groups, Americans and Japanese. Screen color was treated as a within subject variable, with 8 values representing each color involved in the study. The eight colors used in the study were: Blue, Green, Red, Yellow, Violet, Brown, Black, Grey.

The subjects were asked to perform 5 elementary database retrieval tasks for each color. The task is described below. The two independent variables were the culture group and the color. The subjects were administered a color preference test prior to the actual treatment.

Dependent Measures

Performance was measured along two dimensions: the time spend to complete the task (in seconds), and the error rate. The error rate is a composite of two numbers, the number of faulty items in the query, and the number of mouse clicks.

Subjects

Twenty four MBA student from the Stern School of Business, New York University, participated in the study. Twelve subject were Japanese students who have not been in the U.S. for more than one year. The other twelve were Americans. All the subjects had little or no computer experience. They were all in the 25-35 years old age range, and they all had a GMAT score in the 550-650 points range. Three women participated in the Japanese group, while four women enrolled in the American group. Every subject received $10 for doing the experiment.

The task

Information retrieval and data manipulations are common operations performed by information systems' users. The task was designed to mimic database queries familiar to most people who have been exposed to computers. It consisted in constructing a query by selecting the appropriate items from small windows. The windows were spread over the screen (see figure 2). The windows were small and featured the same color across the experiment: black characters, with white background. The rest of the screen appeared in one of the eight colors of the experiment[1]. Overall, the screen was dominated by the color of interest. The selection windows were far from the validation buttons, which forced the user to constantly interact with the UI when accomplishing the task.

Insert Figure 2 about here

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[1]Most GUIs allow users to customize background color. However, there is evidence that users do not use customization features.

The query was of the form:

Retrieve information on <item1> and <item2> and <item3>

Item1 comes from a list of French restaurants in New York, item2 comes from a list of Entrees served in French restaurants, Item3 comes from a list of French wines. Each list includes 30 items. One task consisted in constructing 1 query. The items to be retrieved were listed in a booklet provided to the user at the beginning of the experiment. The window labels were written in French, a language foreign to both Japanese and American subjects.

This task had many advantages: It maximized the degree of interaction between the UI and the user; Each query could be performed in less than a minute, which was short enough to limit the degree of fatigue, and long enough to observe variability; Users used a standard black and white window, which minimized the color interaction effect; The task was simple, and the training session could be kept short.

Material

The experiment was conducted in individual rooms, using a standard IBM compatible 386 computer with a color monitor and a mouse. The monitor was the same for all the subjects. The UI was developed using Visual Basic, and recorded the time spent on the task, the query generated by the user during the task, and the number of mouse clicks needed to accomplish the task. This information was stored in individual files. These files were subsequently consolidated into a database for statistical analysis.

Procedure

briefing Once installed in the testing room, the subject was explained the tasks involved in the experiment. If asked about the objective of the study, the experimenter replied that it was related to the impact of foreign languages in the user interface.

query construction - training The subject was trained on the task, and was asked to perform a minimum of twenty tasks. These tasks were completed using White only as the background color.

White was not one of the colors involved in the experiment. The performance of the training session was recorded in a separate file. The performance of the last five tasks was used as a within subject performance base.

color preferences - 1 At the end of training, the subject was asked to perform a simple color preference test. The experimenter presented eight cards with the eight colors used in the experiment in random order. The subject was then asked to order them by preference. A similar procedure was conducted after the query construction experiment. These two color ordering sequences are part of the standard color preference test as designed by Luscher (1969).

query construction - experiment The subject was then asked to perform 46 database retrieval tasks, following a task booklet. In order to control for possible extraneous influences such as fatigue, the first three and the last three tasks involved only the color White. The colors of the experiment appeared in random order beginning at the fourth task. Only one color was involved during each task.

color preferences - 2 At the end of the database retrieval tasks, the subject was asked to do the color preference test again. The procedure was similar to the previous test. The subject was asked not to try to remember the initial ordering, and not to order the color in the context of its use in the UI.

debriefing The experimenter discussed the real objective of the study with the subject.

Results

Color Preferences

The results of color preferences are presented in table 1.

Table 1 - Color Preferences

Rank	1	2	3	4	5	6	7	8
Americans	Green	Blue	Yellow	Red	Violet	Black	Grey	Brown
Japanese	Red	Yellow	Green	Violet	Blue	Grey	Brown	Black

Americans and Japanese have similar color preferences. Black, Grey and Brown have consistently been ranked among the least preferred colors, while the other 5 colors were systematic favorites of the subjects. Both group disliked achromatic colors -eg Grey and Black-, with the addition of Brown, which is also less colorful. Interestingly, Japanese tend to favor Yellow and Red over Green and Blue, while positioning the color Violet close to the Blue color. Americans favored the Blue and Green colors over the Yellow and Red, while placing Violet near Red.

To evaluate the consistency of these preferences, we looked at the probability for a given color to be classified as a most preferred or least preferred color. A color ranked among the top three in the color preference test is considered a most preferred color. Likewise, a color ranked among the bottom three is a least preferred color. Table 2 presents the colors with the highest and smallest probability to be considered a most preferred color, for each group. Table 3 presents the colors with the highest and smallest probability to be considered a least preferred color, for each group.

Table 2 - Most Preferred Colors

Most Preferred Colors	Americans	Japanese
Color ranked first / P(most preferred) - n = 24	Green / 0.71	Red, Yellow / 0.54
Color ranked last / P(most preferred) - n = 24	Brown / 0.08	Black / 0.13

Table 3 - Least Preferred Colors

Least Preferred Colors	Americans	Japanese
Color ranked first / P(least preferred) - n = 24	Grey / 0.79	Black / 0.58
Color ranked last / P(least preferred) - n = 24	Green / 0.00	Green / 0.13

For both most and least preferred colors, the distribution of probabilities is narrower for the Japanese. Green, a favorite color to both groups, has a higher probability to appear as one of the most preferred color in an American than in a Japanese selection. Likewise, it is less likely to appear as a least preferred color in the American selection. This wider probability range reflects stronger, more consistent and well defined color preferences in the American group. These findings provide some support to hypothesis 3 that Japanese subjects's performance is more consistent than that of American subjects.

Performance - Time

Despite the training session preceding the experiment, the results of the time spent to perform a task exhibited a small learning effect. The mean performance time was about 3 seconds smaller for the last task than for the first task, a 10% difference. This learning effect was removed by regressing time on task number, and taking the residuals of the regression. The overall mean time was added to the residuals to reflect the actual time spend on a task. Table 4 presents the task performance when no color is used, ie White as the background color never changes. These numbers are based on the last 5 values from the training session, and therefore, have not been adjusted for the learning effect.

Table 4 - Task performance with White color only

White	Americans n = 60	Japanese n = 60	P(No Difference)
Mean	30.78	31.96	Not significant
St. dev. / Variance	6.92 / 47.92	6.14 / 37.67	Not significant

The mean time to perform the task is not significantly different between the two groups. The variance is similar for both groups. When no color is used, Japanese and Americans have a similar performance level.

When color is introduced in the UI, the difference between Americans and Japanese in the mean time required to perform the task does not disappear (see Table 5). This difference becomes statistically significant, but has little meaning in the context of this study. It may mean that Japanese are uncomfortable using windows in the UI, or simply that they had more problems with the French language than did the Americans. More interesting is the variance, which is twice as large for Japanese than for Americans. Compared to the initial variance when White is the background color, it is larger for Japanese and smaller for Americans. While smaller variance can be expected as a consequence of the learning effect, larger variance is intriguing.

Table 5 - Task performance with All Colors

All Colors	Americans n = 480	Japanese n = 475	P(No Difference)
Mean	28.24	29.41	< 0.01
St. dev. / Variance	5.68 / 32.26	7.56 / 57.15	< 0.001

To investigate the evolution of variance during the experiment, the task variance was regressed on the task number. The results of the regression for each cultural group are presented in table 6.

Table 6 - Variation of the variance of task performance during the experiment

Regression of Variance on Task Number	Americans	Japanese
Intercept	5.74	5.81
Coefficient	-0.018	0.064
R-square	0.04	0.23
P(Coefficient <> 0)	0.18	< 0.001

The regression is not significant for the Americans, but highly significant for the Japanese. Both have a similar value for the intercept, which means that the variance is homogeneous between the two groups for the initial tasks. However, as they progress into the experiment, Japanese subjects seem to be more and more affected by the use of color, resulting in erratic performance and increasing variance. It is important to note that the learning effect mentioned earlier was equally true for Japanese and Americans. Therefore, the Japanese subjects' overall level of performance remains constant during the experiment. Only the variance increases. The variance increases independent of the background color used in the task. This increase in variance may be explained by individual differences within the group: some Japanese subjects may have experienced a strong learning effect, while others may have experienced a fatigue effect. This hypothesis is consistent with the observed increasing variance and decreasing mean. In order to evaluate this possible explanation, we analyzed task performance as a function of time during the experiment. We did not find any support for this hypothesis: for most Japanese subjects, time spent on a task exhibits increasing variance with decreasing mean. Moreover, we did not find evidence of a fatigue effect.

The results of the performance as a function of color are presented in table 7. We observed a larger response to the color stimulus from the American group compared with the Japanese group. The Japanese subjects do not exhibit significant differences in performance between colors (ANOVA at a 95% confidence level). In contrast, the American group had three clusters with homogeneous performance levels. These findings provide additional support to hypothesis 3 that American subjects react more strongly to color. The performance was best when a bright color, such as Red and Yellow, was dominant in the UI. Symmetrically, performance was poorest when darker colors, such as Black, Violet and Blue were used. This is an intriguing result which may be explained by the desire of individuals to rest when darker colors are present, and hurry when colors are bright. The degree of lightness appears to be the criterion that determines performance of the American subjects. However, when we measured the lightness of the screen with various colors, and regressed these values on performance level, we did not obtain significant results.

Table 7 - Mean task performance and standard deviation on colors

Mean / St dev	Americans n = 60		Japanese n = 60		P(Equal Mean)
		Cluster		Cluster	
Black	29.69 / 6.45	1	29.41 / 7.54	1	
Violet	29.41 / 5.56	1	30.17 / 7.38	1	
Green	28.76 / 5.40	1-2	28.39 / 6.61	1	
Blue	28.73 / 5.87	1-2	29.14 / 6.95	1	
Grey	28.06 / 5.39	1-2	29.74 / 7.73	1	
Brown	27.85 / 5.93	1-2-3	30.23 / 9.07	1	
Red	27.04 / 5.17	2-3	28.82 / 7.61	1	
Yellow	**26.34 / 5.08**	3	**29.31 / 7.55**	1	**< 0.01**

Although Americans prefer brighter colors to darker colors, there is no clear relationship between color preferences and performance: Green, the most preferred color for Americans, led to poor performance, similarly with Violet or Blue. Therefore, hypothesis 2 is not supported by our data.

The results from table 7 also conflict with hypothesis 1 which posited better performance from American subjects when primary colors were used. No significant difference was found.

We investigated possible performance differences between the two cultural groups on a color per color basis. Of the eight colors, Yellow is the only one for which significant divergence occurred. The absence of significant differences in the performance between American and Japanese subjects on specific colors is a little surprising. The small variations in task performance across colors resulting from the simplicity of the task, may have made reaching statistical significance difficult.

Performance - Error rate and Mouse clicks

The analysis of error rate and number of mouse clicks was not significant. The main reason is that there was little variance in these parameters: only 15 errors for the 955 tasks performed, and an average of 1 extra mouse click every 10 tasks.

Discussion

The motivation for this study was to provide support for the claim that culture strongly determines user characteristics relevant to UI designers. We investigated the performance of 2 cultural groups of subjects executing a task using an UI with various colors. The findings of this study support the proposition that culture is a personal characteristic salient enough to impact the level of performance of individuals performing similar tasks. The results support the following propositions which highlight interesting differences in the way Japanese and Americans interact with computers.

American subjects reacted more strongly to color stimuli: On the color test, American subjects' preferences appear to be more consistent and well defined than those of the Japanese subjects. Bright colors were preferred by American subjects. Japanese subjects preferences were not as extreme. For American subjects, task performance was a significant function of color. However, color did not significantly alter the level of performance of Japanese users. Consequently, the effectiveness of using colors in the UI to convey information or meaning may be limited for Japanese users.

Japanese subjects are disrupted by excessive use of colors in the UI: The learning effect observed during the database retrieval task was similar for both groups. While the initial variance of time spent on the task was comparable for both subject groups, it was twice as large at the end of the experiment for Japanese subjects. Although the variance in the American group was constant, a steady increase in the variance for Japanese subjects was observed as the experiment progressed. The most plausible explanation for this phenomenon is that Japanese subjects were disturbed by the continuous change in the background color of the UI. This finding is important in the context of current research on the use of color in the UI to assist users and convey information because it suggests that color can be disruptive. For example, Shneiderman (1993) calls for the use of color to improve intuitive understanding of output, facilitate exploration, and enhance browsing. The results of this study suggest that although color may prove efficient for American users, its success for Japanese may be limited.

American subjects seem more comfortable using windows environments and pointing devices than do Japanese subjects: The performance of Japanese subjects on the database retrieval task was consistently inferior to that of American subjects, independent of the presence of color. This finding was unexpected. Because the experiment was not designed to investigate this hypothesis, it is not possible to provide an explanation based on data. We speculate it may be due to the use of the French language in portraying menu choices, or to the fact that Japanese subjects have less exposure to computers in their working environment, and therefore feel uneasy using them. However, this result reinforces earlier findings that culture is a factor that affects the way individuals interact with computers.

There is no relationship between color preferences and performance: This study found no relationship between color preferences and performance. Brightness, or perceived brightness, seemed to be a better predictor of performance of American subjects than did color preferences. Indeed, the fact that Yellow or Red led to significantly better performance was surprising. Both Yellow and Red were bright colors on the screen and rather uncomfortable to view. It is likely that subjects performed the task faster in order to limit their exposure to these colors. An alternative explanation is that Red and Yellow being exciting colors compared to Blue or Green, they may have generated a physiological response which was translated into faster task execution. The performance of Japanese subjects, on the other hand, seems unrelated to either preference or brightness.

Conclusion

While it is now recognized that reactions to interface design are likely to be dependent on individual differences, culture as a source of differences has been neglected. In this study, we investigate the extent to which culture determines an individual's reactions to color and how this influences performance. Using subjects from two contrasting cultures, Japanese and American, we found that the use of color in the UI led to different levels of performance among the groups. Further research is needed to understand what other aspects of the user interface may be affected by the cultural background of the user. Ultimately, we would like to see "culture free" UI be developed. At a minimum, UI designers should understand how users from different cultures are likely to react to their creations.

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Figure 2 - The screen used in the database retrieval task