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A cross cultural study on knowledge representation and structure in human computer interfaces

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Abstract

This study investigates the effects of cultural differences on computer performance of users with different cultural backgrounds, and ways to design appropriate interfaces to accommodate cultural differences in order to enhance computer performance for Chinese users. The cognitive and cultural differences for the Chinese and the American populations documented in past studies include cognitive style (concrete versus abstract) and thinking process (thematic and functional). An experiment was conducted in Taiwan to examine the differences and to compare the results with those of the previous study in America and Mainland China. In the previous study, 40 American participants, and 40 Chinese participants in Mainland China participated. Forty Chinese participants in Taiwan participated in this study. The independent variables were knowledge representation (abstract and concrete) and interface structure (functional and thematic). Information search tasks with different manipulations of the knowledge representation and interface structure were designed. Results indicate that, for Chinese participants, in Taiwan as well as in Mainland China, advantages were associated with thematic structure in terms of error rate.

Relevance to industry

The results of this study will benefit Information technology companies who wish to develop software or information services for the Chinese population.

Keywords: Knowledge representation; Interface structure; Cultural effects; User interface design

1. Introduction

Software development for international users has always been a challenge. However, with the explosion of the Internet, the need for global Web sites has become very important for the purpose of international business. Consequently, interest in

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the influence of culture on user interface design has grown within the HCI community. For software, translating all the text items, such as commands, help, and prompts, is basic and necessary for localization, but text translation is not the only translation issue. Other issues like date, time, number formats, symbols, colors, and functionality are also important (del Galdo, 1990; Fernandes, 1995; Ossner, 1990; Russo and Boor, 1993; Spencer, 1988).

People from different cultures are different in their perceptions, cognition, thinking styles, and values. Thus, it is important to thoroughly understand different cultural traits in designing computer interfaces for international users, rather than simply translating language. This is particularly true in the Asian Pacific area, since one of the greatest user populations in the future is the Chinese. Chinese users include people in Mainland China, Taiwan, Hong Kong, Singapore, and other areas, so even within the Asia Pacific Chinese population, multilingual and cultural issues exist. Chinese people speak Mandarin and other dialects, and there are diverse Chinese cultural groups. For example, Chinese users in Taiwan use traditional Chinese characters and Chinese users in Mainland China use simplified Chinese characters. In general, Chinese users in Taiwan have had more opportunities to learn American culture than Chinese users in Mainland China within the past 50 years. Thus, the differences between users in Taiwan and users in the US would be expected to be smaller than the differences between users in Mainland China and users in US.

The objective of this study was to investigate the ways cultural differences might affect computer performance of users with different cultural backgrounds, and to develop ways to design appropriate interfaces to accommodate cultural differences to enhance human-computer performance for the Chinese population. This study extends the study of Choong and Salvendy (1999) on Chinese and American target cultures. The goal is to provide different options of user interface design for diverse groups in a specific culture with a potentially huge number of users, and to demonstrate the importance of considering the cultural factors in user interface design.

2. Cultural differences and implications for HCI

2.1. Implications of cultural differences on HCI

The American way of thinking tends to be analytic, abstract, and imaginative—beyond the realm of the immediately apprehended; whereas, the Chinese way of thinking tends to be synthetic, concrete, and remain within the periphery of the visible world (Chiu, 1972; Lin, 1939; Northrop, 1946; Yang, 1986; Yang et al., 1963). The Chinese prefer to categorize on the basis of interdependence and relationship, whereas the Americans prefer to analyze the components of stimuli and to infer common features (Chiu, 1972). One of the major differences between analytical and relational styles is how subjectivity is treated. The analytical style separates subjective experience from the inductive process that leads to an objective reality. The relational style of thinking rests heavily on experience and fails to separate the experiencing person from objective facts, figures, or concepts (Stewart and Bennett, 1991). Social encouragement to obey and the strength of parental authority are two factors associated with the development of less differentiated functioning for Chinese people (Witkin and Berry, 1975), meaning they are more field dependent (FD). In contrast, Americans tend to be more field independent (FI). A number of studies have indicated less differentiated functioning of Chinese people (Abel and Hsu, 1949; Douglas and Wong, 1977). It has also been reported that the provision of a concrete (analogical) conceptual model rather than an abstract model would enhance users' performance (Sein and Bostrom, 1989; Sein et al., 1993). This is especially true for more FD users, such as Chinese people. The use of the thematic cognitive mode by the Chinese is probably associated with field-dependence. The Chinese people tend to display a cognitive style of seeing things or phenomena in wholes rather than in parts, while the Americans tend to do the reverse (Yang, 1986). When first using a software system, Chinese users may tend to need a concrete representation of the system to help them develop accurate mental models and perform the interaction tasks properly and efficiently.

The cognitive style of Americans is inferential–categorical (functional), which means that they have a tendency to classify stimuli on the basis of functions or inferences made about the stimuli that are grouped together (Chiu, 1972). In contrast, Chinese people have a relational–contextual cognitive style (thematic), tending to classify stimuli on the basis of their interrelationships and thematic relationships (Chiu, 1972). The way that the interface displays are structured plays an important role for users, and different structures for user interfaces may be needed to accommodate different styles of categorization.

2.2. Previous findings

Choong and Salvendy (1999) investigated the effects of cultural differences on computer performance of Chinese and American users and the design of appropriate interfaces for Chinese users. Experiments, in which 40 Chinese participants in Mainland China and 40 American participants participated, were carried out to study cognitive style differences and thinking process differences.

The results indicated that, for the Chinese participants, advantages were associated with concrete representation and with thematic structure in terms of initial performance time, but the advantage associated with thematic structure in performance time vanished for later performance due to learning. No significant differences were found for American participants in performance time and errors between abstract and concrete tasks. A concrete representation provided a visualization aid in helping the Chinese participants, who were more field dependent compared to the American participants, to perform the information search task faster in later trials when they were familiar with the target system.

For Chinese participants, there were also advantages associated with thematic structure in terms of error rate throughout the experimental trials. A significant difference was found between functional and thematic assignments for Chinese participants in making errors. The number of errors made by the American participants using an interface designed based on functional assignment during a first trial was statistically smaller than that made by those participants with an interface design based on thematic assignment.

3. Hypotheses

Three hypotheses were proposed for novice users of both cultural groups who had little or no experience in the target computer application.

Hypothesis 1. For Chinese users, computer performance would be better (i.e., accuracy and speed) with a concrete representation, rather than with an abstract representation of the system.
The cognitive characteristics of the Chinese users are concrete, synthetic, and less differentiated (FD). However, the significant difference in performance time in the previous study was marginal, and no significant difference was found in number of errors (Choong and Salvendy, 1999). Thus, it was predicted that Chinese users in Taiwan would benefit slightly from a concrete knowledge representation.

Hypothesis 2. Chinese users in Taiwan would have better computer performance using a thematic rather than a functional system.
Chinese people tend to classify stimuli according to their thematic relations. Due to these different classification traits between Chinese and American people, the compatibility of the interface structure with thinking styles was predicted to have a significant influence on performance in using information systems. It was predicted that Chinese users in Taiwan, as well as the Chinese users in Mainland China, would benefit from a thematic system, especially in accuracy.

Hypothesis 3. The user would retrieve items from memory more easily if the interface structure provided was compatible with the user's thinking style.

Human memory is influenced by the operations and processing performed on the information that is experienced. Memory for information depends on the depth to which that information has been processed; thus, stimuli will be remembered better if processed deeply (i.e. meaningfully or semantically) than processed in a shallow manner (Craik and Tulving, 1975). It was hypothesized that the provision of an information structure compatible with the user's thinking style would enhance the user's memory performance. Previous results (Choong and Salvendy, 1999) indicated that information was processed at the same level of depth with a functional or a thematic structure for American participants. However, the information was retrieved more easily from memory by Chinese users if they were provided with a thematic rather than a functional information system.

4. Method

4.1. Participants

In the previous study, 40 American participants, and 40 Chinese participants in Mainland China participated. In this study, 40 Chinese participants in Taiwan participated were engaged in the experiment. It was essential to properly select participants because this study involved individuals from different cultural backgrounds. To reduce undesired variations from sources other than cultural differences, such as education levels, major fields of study, gender, age, etc., participants were restricted to male undergraduate students who had little or no prior knowledge about the tasks to be performed during experimentation.

The ages of the American participants ranged from 18 to 25 years (Mean = 20.7, SD = 1.35). The mean computer experience of the American participants was 8.0 years (SD = 3.18 years). The participants in Taiwan were all enrolled at Chung Yuan Christian University. The ages of the participants ranged from 18 to 23 years old (Mean = 19.4, SD = 1.08). The mean computer experience of the Chinese participants in Taiwan was 3.4 years (SD = 1.82 years). The background of the participants in Taiwan was expected to be as close to the background of the American participants and Chinese participants in Mainland China in order to isolate any influence of cultural differences on performance. The prior experience of Chinese participants in Mainland China (Mean = 1.0, SD = 0.92) and Chinese users in Taiwan in this study did not remain the same due to practical constraints. In Taiwan, most students usually start using computers in junior high school. Therefore, the results of this study should be interpreted with caution due to the disparity of computer usage experience.

4.2. Apparatus

A Pentium personal computer was used for experimentation in Taiwan. A notebook computer was used for experiments in both the United States and China. Each participant was required to perform the tasks independently using a mouse for pointing and selecting, with no other participants present except for the experimenter. The participants' movements throughout the system were automatically timed to the nearest 0.001 s and traced by a keystroke-capturing program on the computer.

4.3. Task

Information search tasks with different manipulations of the knowledge representation and interface structure were designed, as in the previous study. The system was presented in simplified Chinese for the participants in Mainland China, and presented in traditional Chinese for the participants in Taiwan. Each participant within a particular sample population was randomly assigned to one of the four interfaces and was asked to search for items on a task list. There were three consecutive trials of tasks for each participant, and 30 items were listed in each. Each participant was given the three trials in the same sequence. The tasks to be performed were the same in each session but with items listed in different orders.

Four types of interface designs were developed for the system to manipulate the knowledge representation and structure of information presented. They were

1. Abstract representation with functional structure,
2. Abstract representation with thematic structure,
3. Concrete representation with functional structure,
4. Concrete representation with thematic structure.

Each participant was given online instructions describing the system in either one of the knowledge representation types. The abstract representation of the system was a plain description of the hierarchical organization of the information in the target system such as categories, subcategories, and items. The concrete representation was a metaphor analogous to a department store with several floors representing the categories. There were sections representing subcategories under each category on each floor, and the items displayed in each section were items in each subcategory. The two representations are illustrated in Figs. 1 and 2.

The functional structure classified items into groups according to the functions or inferences drawn from these items in a group. The thematic structure classified items into groups based on their thematic relations or interrelations. The functional grouping focused more on common inferences; whereas, the thematic grouping focused more on relations. For example, cleaning liquids like dishwash liquid, bathtub cleaner, toilet bowl cleaner, and detergent are usually grouped together as cleaning products in supermarkets, because of their cleaning function. These cleaning liquids will not be grouped together according to their relations. Dishwash liquid will be grouped with other items in Kitchen by the thematic grouping. The two structures are illustrated in Figs. 3 and 4.

4.4. Experimental design

A 2∗2 factorial between subject design was used in this study. Two independent variables were manipulated to test the proposed hypotheses. The first one was the knowledge representation of the training material for the target system, with two levels (abstract and concrete). The other one was the interface structure of the information presented in the target system, with two levels (functional and thematic). No significant differences were found in age, gender, education, and computer experience between the four groups within each population. The dependent variables were overall performance time in seconds for all 30 tasks of each trial, the number of errors, the number of items recalled after the tasks, and degree of satisfaction.

4.5. Procedure

This experiment took American participants approximately 60 min, Chinese participants in Mainland China approximately 90 min, and Chinese participants in Taiwan approximately 60 min. All participants began by filling out a general information questionnaire concerning their personal characteristics, including age, major, year in school, and past computer experience. There were 10 participants randomly assigned to each of the four treatment cells. Each participant was given on-screen instructions, depending on the type of knowledge representation and information structure the participant received.

A brief practice session was then conducted to help the participants understand the operation of the system and the tasks to be performed. Following the practice, each participant performed the information search tasks with one of the four assignments. Participants were instructed to perform the information search tasks as quickly as possible without sacrificing accuracy.

On the completion of the information search tasks, each participant was given a memory free recall test in order to assess the level of depth of information retrieval. Participants were not told about the memory test before or during the tasks to ensure that no participant would try to memorize information during task performance. The memory test required participants to give a written free recall of the names of the categories, subcategories, and items from the interface in 10 min.

5. Results and discussion

5.1. Results of ANOVA

The results of ANOVA for Chinese participants in Taiwan were presented in Table 1. There was a significant difference in errors between functional and thematic interface structures. No significant differences were found in error for interface structures. Also, no significant differences were found in performance time for knowledge representations and interface structures. Significant differences were found in both performance time

Fig. 1. An example of an abstract knowledge representation.

and error between trials for Chinese participants in Taiwan. The comparison of these results with the previous results are further presented and discussed in the following sections.

5.2. Testing of Hypothesis 1

The intention of this hypothesis was to examine how different kinds of knowledge representation of an information system might influence computer performance of users with different cultural backgrounds. It was hypothesized that for Chinese participants a concrete knowledge representation would result in better computer performance in comparison to an abstract knowledge representation. The mean values and standard deviations of each dependent variable for each knowledge representation type are presented in

Fig. 2. An example of a concrete knowledge representation.

Tables 2, 3, and 4. No significant differences were found for American participants (Table 2). Hypothesis 1 was partially supported for Chinese participants in Mainland China on the performance time during the third trial (Table 3). As shown in Table 4, there were no significant differences found in performance time and errors for the three trials for Chinese participants in Taiwan. There was a marginally significant difference found in degree of satisfaction for the participants. The abstract type of knowledge representation was slightly preferred to the concrete type for Chinese participants in Taiwan.

Our results indicated that a concrete knowledge representation did not help the Chinese participants in Taiwan to perform more efficiently, as it did for the Chinese participants in Mainland China in the third trial. The Chinese in Mainland

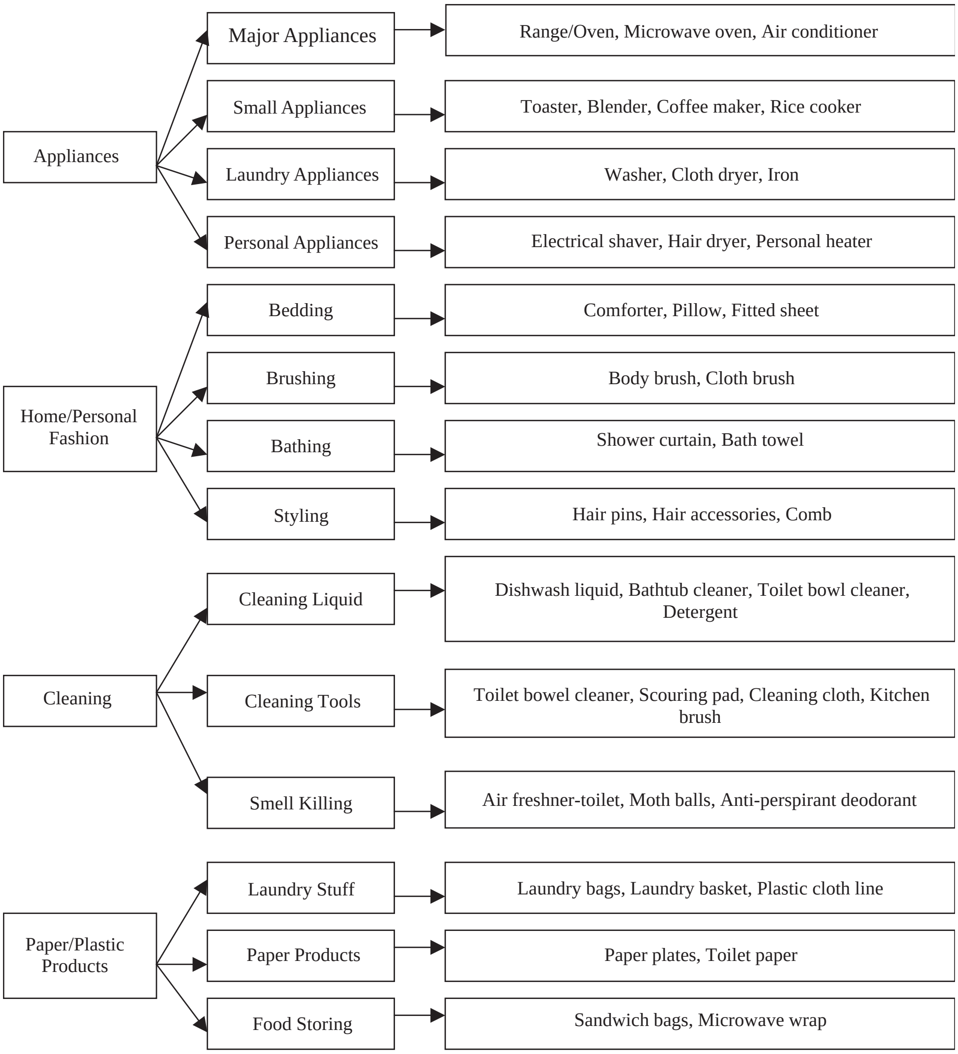

Fig. 3. An example of a functional structure.

are more field-dependent than their American counterparts (Choong and Salvendy, 1999), and a concrete representation helped them visually to perform the information search tasks faster in the third trial after they were familiar with the target system, compared to those Chinese participants using an abstract representation. The results of group embedded figure test (GEFT) showed that the mean score for the Chinese participants in Taiwan (Mean = 14.5, SD = 3.15) was 14.17% higher than the mean score for the Chinese participants in Mainland China (Mean = 12.7, SD = 4.46) ($t = 6.681$, $p = 0.01$). A higher score on the GEFT is representative of lower field-dependency. Also, the Chinese participants in Taiwan were more field-dependent compared to the American participants (Mean = 16.1, SD = 2.17) ($t = 2.429$, $p = 0.0198$). The results that the Chinese participants in Taiwan were less field-dependent than the Chinese participants in Mainland China may suggest that the more field-dependent Chinese users are, the more helpful a concrete representation will be for users to perform information search tasks.

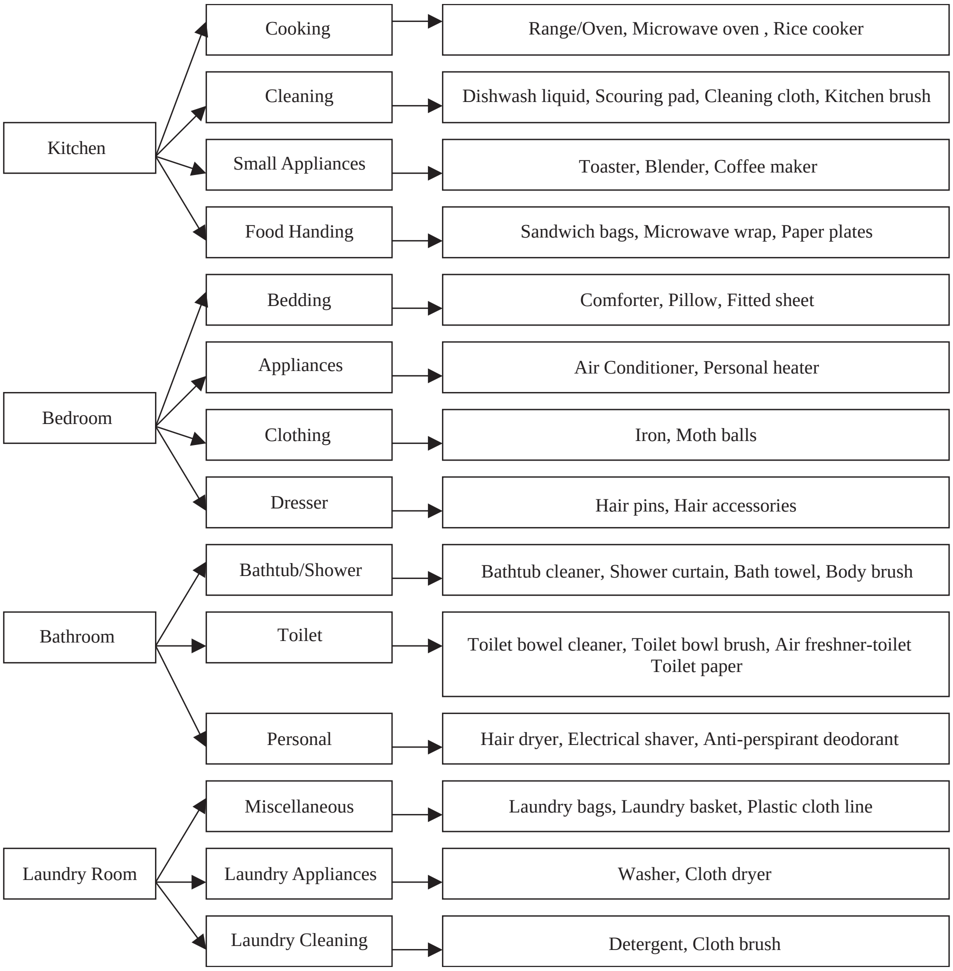

Fig. 4. An example of a thematic structure.

5.3. Testing of Hypotheses 2 and 3

Hypothesis 2 examined the ways different kinds of interface structures of an information system might affect the computer performance of users. It was hypothesized that Chinese users presented with a thematic, rather than a functional, interface structure would perform better. It was also hypothesized that information would be retrieved more easily from memory if an interface structure compatible with the users thinking style was provided. Results of the time, error, and memory recall are presented in Tables 5, 6, and 7.

No statistically significant differences were found in performance times for American participants (Table 5). There was a significant difference in errors between functional and thematic assignments during the first trial for American participants. As shown in Table 6, a significant difference in mean performance time was found during the second trial for Chinese participants in Mainland China. There were significant differences found in errors between the functional and thematic assignments throughout the three trials for Chinese participants in Mainland China.

No statistically significant differences were found in performance time among Chinese participants in

Taiwan. The results on errors for these participants indicated a marginally significant difference among interface structures in the second trial ($F_{(1,36)} = 3.27$, $p = 0.0789$). In the second trial, the participants with thematic assignment (Mean = 13.7, SD = 11.27) made 39.9% less errors than the participants with functional assignment (Mean = 22.8, SD = 18.13). Also, a significant difference was found in the third trial ($F_{(1,36)} = 5.04$, $p = 0.0310$), where the participants with thematic assignment (Mean = 6.5, SD = 5.45) made 61.5% less errors than the participants with functional assignment (Mean = 16.9, SD = 16.13). As shown in Table 5, significant differences in errors were found in all the three trials for Chinese users in mainland China. In Table 7, significant difference in errors was found in the trial 3 for Chinese users in Taiwan. These results indicated that interface structure had an effect on the number of errors made by the Chinese participants.

A significant difference among interface structure was found in memory recall for Chinese participants in Mainland China (Table 6). The examination of the mean memory recalls in Table 6 indicated that no significant difference was found between the functional and thematic assignments for Chinese participants in Taiwan. The mean

Table 1
Results of ANOVA for Chinese participants in Taiwan

Variable	Performance time		Error	
	F	*p*	*F*	*p*
KR[a]	0.04	0.8446	0.02	0.8809
STR[b]	0.27	0.6088	5.00	0.0317
KR[a]STR	0.69	0.4105	0.01	0.9362
TRIAL	188.53	<0.0001	41.15	<0.0001

[a] KR: Knowledge representation.
[b] STR: Interface structure.

Table 2
Effects of abstract and concrete representations of task on performance time and errors for American participants (Choong and Salvendy, 1999)

Variables	Trials	Abstract[a]		Concrete[a]		$F_{(1, 36)}$	*p*
		Mean	SD	Mean	SD		
Time (s)	1	219.951	50.460	225.694	48.199	0.18	0.6732
	2	134.280	26.777	129.082	33.420	0.99	0.3259
	3	102.522	22.168	101.513	25.683	0.29	0.5955
Errors	1	26.6	12.12	31.8	20.875	0.44	0.5125
	2	7.8	5.24	10.0	5.525	1.65	0.2074
	3	4.2	3.15	5.6	3.471	1.96	0.1698

[a] $n = 20$.

Table 3
Effects of abstract and concrete representations of task on performance time and errors for Chinese participants in Mainland China (Choong and Salvendy, 1999)

Variables	Trials	Abstract[a]		Concrete[a]		$F_{(1, 36)}$	*p*
		Mean	SD	Mean	SD		
Time (s)	1	433.468	135.757	440.878	93.679	0.09	0.7604
	2	257.202	61.014	249.033	72.016	0.17	0.6786
	3	200.765	54.700	181.926	36.098	8.81	0.0054
Errors	1	30.9	13.089	31.6	14.29	0.04	0.8476
	2	19.9	9.59	16.9	10.36	2.02	0.1641
	3	10.3	7.22	10.5	7.40	0.00	0.9769

[a] $n = 20$.

Table 4
Effects of abstract and concrete representations of task on performance for Chinese participants in Taiwan

Variables	Trials	Abstract[a]		Concrete[a]		$F_{(1,\ 36)}$	p
		Mean	SD	Mean	SD		
Time (s)	1	303.477	86.8324	300.295	50.3630	0.02	0.8874
	2	180.293	37.4370	180.382	33.7398	0.00	0.9940
	3	143.492	26.6763	153.915	35.3570	1.06	0.3104
Errors	1	41.5	36.28	47.3	72.27	0.00	0.9742
	2	19.7	19.06	16.9	11.48	0.12	0.7355
	3	13.9	16.93	9.4	7.03	0.07	0.7884
Satisfaction		4.5	0.67	4.0	0.78	3.58	0.0665

[a] $n = 20$.

Table 5
Effects of functional and thematic interface structures of task on performance time and errors for American participants (Choong and Salvendy, 1999)

Variables	Trials	Functional[a]		Thematic[a]		$F_{(1,\ 36)}$	p
		Mean	SD	Mean	SD		
Time (s)	1	209.800	38.485	235.844	55.214	2.98	0.9290
	2	132.919	24.225	130.442	35.469	0.06	0.8007
	3	98.470	14.461	105.565	30.264	0.89	0.3518
Errors	1	22.1	8.51	36.3	20.44	8.62	0.0058
	2	9.9	5.82	8.0	4.98	1.23	0.2749
	3	5.4	3.47	4.4	3.23	1.02	0.3186
Memory recall		40.8	5.62	40.2	4.45	0.08	0.7798

[a] $n = 20$.

Table 6
Effects of functional and thematic interface structures of task on performance time and errors for Chinese participants in Mainland China (Choong and Salvendy, 1999)

Variables	Trials	Functional[a]		Thematic[a]		$F_{(1,\ 36)}$	p
		Mean	SD	Mean	SD		
Time (s)	1	466.954	148.953	407.392	56.396	2.69	0.1098
	2	274.527	77.183	231.707	44.965	4.45	0.0419
	3	200.552	58.675	182.139	29.340	1.56	0.2191
Errors	1	39.0	13.85	23.5	7.58	18.38	0.0001
	2	24.8	8.96	12.0	6.19	29.00	0.0001
	3	14.7	6.18	6.1	5.45	24.58	0.0001
Memory recall		31.0	5.80	34.9	5.28	5.23	0.0282

[a] $n = 20$.

number of memory recalls of thematic assignment (Mean = 19.9, SD = 5.72) was 6.5% higher than for that of functional assignment (Mean = 18.6, SD = 7.42).

Design suggestions developed on the basis of the results of this study and the previous study (Choong and Salvendy, 1999) are shown in Table 8. For American users, both abstract and concrete

Table 7
Effects of functional and thematic interface structures of task on performance time and errors for Chinese participants in Taiwan

Variables	Trials	Functional[a]		Thematic[a]		$F_{(1,\ 36)}$	p
		Mean	SD	Mean	SD		
Time (s)	1	290.705	70.6798	313.066	69.4466	1.00	0.3233
	2	179.951	37.6330	180.724	33.4827	0.00	0.9471
	3	150.687	39.3287	146.720	21.5382	0.15	0.6977
Errors	1	54.3	73.68	34.5	30.35	1.33	0.2565
	2	22.8	18.13	13.7	11.27	3.27	0.0789
	3	16.9	16.13	6.5	5.45	5.04	0.0310
Memory recall		18.6	7.42	19.9	5.72	0.48	0.4930

[a] $n = 20$.

Table 8
Design suggestions according to the results of this study and the previous study (Choong and Salvendy, 1999)

Components	Variables	American participants	Chinese participants	
			Mainland China	Taiwan
Knowledge representation	Performance time	Abstract/Concrete	Concrete	Abstract/Concrete
	Errors	Abstract/Concrete	Abstract/Concrete	Abstract/Concrete
Interface structure	Performance time	Functional/Thematic	Thematic	Functional/Thematic
	Errors	Functional	Thematic	Thematic
	Memory recalls	Functional/Thematic	Thematic	Functional/Thematic

knowledge representations were suggested because no significant differences were found in performance time and errors in the previous study. For Chinese users in Mainland China, concrete knowledge representation is suggested if improving performance time is the primary concern of the computer system. Thematic interface structure was strongly recommended for Chinese users when the error rate is the primary concern of the computer system.

6. Conclusions

The purpose of this study was to investigate the ways that cultural differences can affect computer performance of users with different cultural backgrounds, and to assess ways to design appropriate interfaces to accommodate cultural differences for Chinese users to enhance human use of computer performance. Following the previous study conducted in Mainland China and America, this study examined the cultural effects on computer performance of users within the Chinese user population in Taiwan.

According to the results of the experiments conducted to test the three hypotheses, the influences of a thematic interface structure on error rate were quite effective for the performance of the Chinese participants in Taiwan. In addition, the error rate for participants using a thematic interface structure was lower than for those using a functional interface. The provision of a thematic structure, rather than a functional structure, reduced the errors. This study provides additional evidence in-line with results from past studies that the Chinese employ a different thinking style from Americans. It also agreed with the previous study that thematic interface structure was advantageous to Chinese users, in Taiwan as well as in Mainland China. When the error rate is the most important factor in task performance, this implication is especially crucial.

The level of computer experience among the sample populations was substantially different. Greater control of computer experience need to been exercised in sampling the populations, to allow a more accurate assessment of the influence of cultural background. Based on the background psychological literature, it would appear that structural interface requirements for Chinese users may be attributable to cultural differences rather than to differences in computer experience between the three groups of participants in this and the previous study. The results of this study are expected to benefit Web providers who wish to develop information services for the Chinese population.

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