The Influences of Cognitive Styles in User Interface Design: with Scanners as Examples

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Abstract

The purpose of this study is to construct proper set of criteria for interface design suitable for specific user groups. Four scanners chosen as experimental samples covered various interface designs, such as: texts, icons and mixed format in information representation, and tab and pull-down menu in information structure. Subjects were categorized into nine cognitive styles using CSA test (Riding, 1998). A performance experiment and a questionnaire survey of subjective preferences were conducted to compare these interface designs among the nine cognitive styles. Finally, MANOVA was employed to analyze the data collected.

The results indicate that a significant variation on both performance and preference in using each interface design was found among different cognitive styles. In the Wholist-Analytic dimension, Wholist users showed better performance and preference in using either tab or pull-down menu, and tab even better; while Analytic better in performing tasks without tab or pull-down menu. In the Verbal-Imager dimension, Verbal users showed descending priority order of text, mixed format and icon in both performance and preference measures; while Imager the order of mixed format, text and icon.

Keywords: Cognitive Styles, User Interface Design, Scanners

I.INTRODUCTION

Cognitive style as an individual's characteristic and consistent approach to organizing and processing information, Tennant [6] is the key to understanding various patterns of users' needs. Its two principal dimensions, the Wholist-Analytic and Verbal-Imagery, [3] well correspond to the two major aspects affecting human information processing preference: information structure and information representation.

The primary motivator of consumer's purchasing has moved away from physical objects toward the more abstract notion of information or content. [2]. In other words, a successful product must equip with appropriate functions and thoughtful user interface; and the latter is going to be the focal point for product design in the 21st century [1].

Products communicate with users through interface in the information age. However, if human-centered design is to be fully realized, one single interface design will not be able to accommodate the full range of market's needs. Design differentiation based on users' different needs is the key to win the global competition in the next century.

Therefore, this research compares both the performances and users' preferences of different interface designs among different cognitive styles, and tries to establish guidelines for interface design for each cognitive style.

II.COGNITIVE STYLES ANALYSIS

Cognitive style has been defined by Tennant [6] as: "an individual's characteristic and consistent approach to organizing and processing information". After reviewing the descriptions of cognitive styles, correlation between them, methods of assessment, and effect on behavior, Riding and Cheema concluded that they could be grouped into two principle cognitive style dimensions: the Wholist-Analytic and the Verbal-Imagery style dimension, which were further defined as:

- The Wholist-Analytic style dimension: whether an individual tends to organize information into wholes or parts.
- The Verbal-Imagery style dimension: whether an individual is inclined to represent information during thinking verbally or in mental pictures [3].

The two basic dimensions of cognitive style are shown in Figure 1. The Wholist tends to organize information into lump wholes while the Analytic into well-organized parts. The Verbal is inclined to think about whatever they read, see and hear in words while the Imagery in mental pictures instead. Studies showed that different cognitive style performed just the opposite under different conditions [5].

A computerized Cognitive Styles Analysis (CSA) tool was developed [3] for categorizing subjects' cognitive style based on the ratio of the two values scored on the two dimensions described above. Figure 2 shows the nine cognitive styles and their abbreviates. They are composed of the above mentioned two dimensions, Wholist-Analytic and Verbal-Imagery, and abbreviated with first letter of each word. The abbreviations will be used throughout this paper.

III.METHOD AND EXPERIMENTS

This study tried to explore the relationships of operation time (performance) and subjective satisfaction between various interface designs and cognitive styles. And eventually, an interface

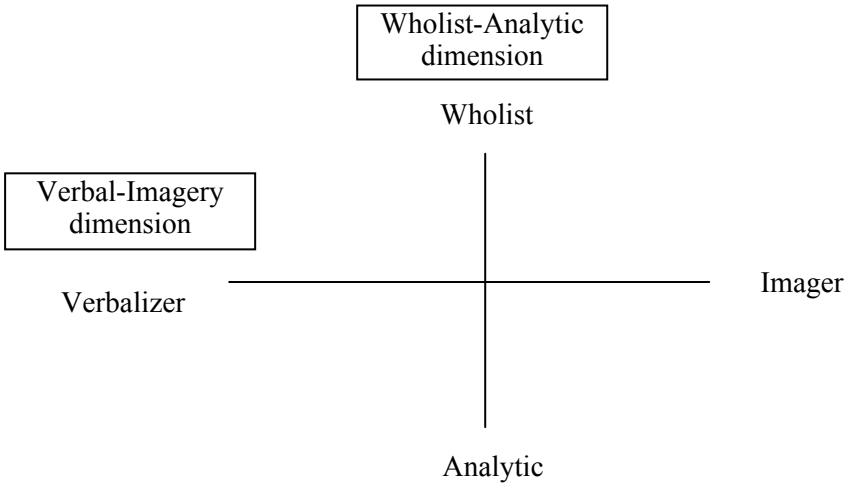


Figure 1. The two cognitive style dimensions (Riding 1998)

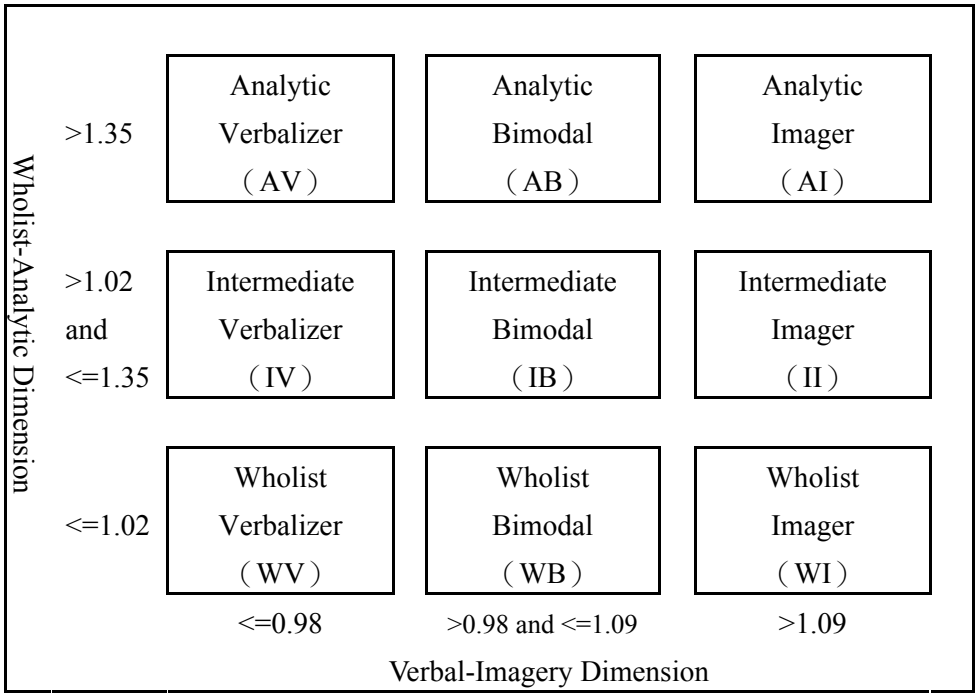


Figure 2. Nine types of cognitive styles (Riding 1998)

design model can be constructed accordingly. Two experiments were included in this research to fulfill these purposes:

I). Ten tasks, shared among four scanners, were used to compare among the nine cognitive styles via two indicators: operation time and subjective satisfaction. And an overall subjective preference about information structure and representation were also compared.

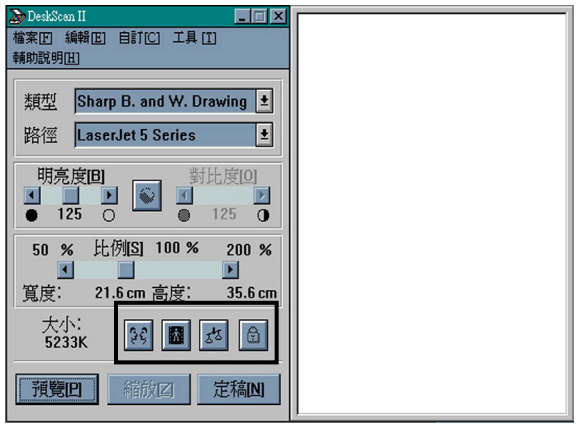
II). Two proposed interface designs following experiment I's results were used in the second experiment to further verify the findings. This part will be described in detail in section 5.

IV.EXPERIMENT I: COGNITIVE STYLES VS. INFORMATION STRUCTURES AND REPRESENTATIONS

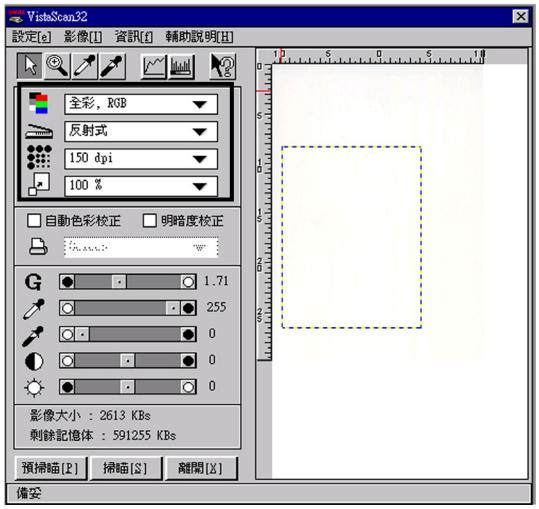
4.1 Setups of experiment I

All subjects tested were Cheng Kung University students with Window interface experience, but not familiar with or no experience of scanners' interface. 273 subjects, tested with Riding's CSA, were categorized into 37 WVs, 27 WBs, 32 WIs, 31 IVs, 20 IBs, 24 IIs, 33 AVs, 27 ABs, and 42 AIs (please refer abbreviations to Figure 2). 20 subjects from each cognitive style were randomly selected for the experiment, total to 180. Four scanner makes used for this study: PLUG-N-SCAN 600 A3 EP (Mustek), DeskScanII (HP), Astra 1200S (UMAX) and ScanMaker E6 (Microtek) are different in their interface design, such as: information representation (including: icon, text and text + icon) and information structure (including: main page, tab and pull-down menu) (Figure 3). Table 1 shows the ten tasks adopted and the information representation and structure of the four scanners.

PLUG-N-SCAN 600 A3 EP (Mustek)



DeskScanII (HP)



Astra 1200S (UMAX)

ScanMaker E6 (Microtek)

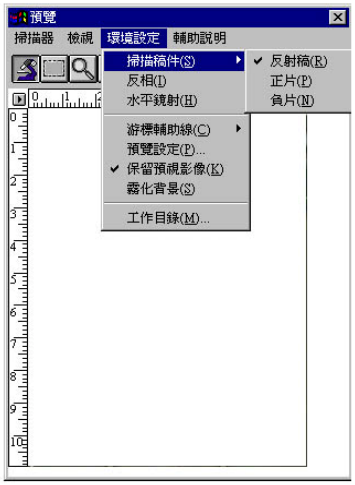


Figure 3. Four types of interface design used in the experiment I

Table 1. The ten tasks and the information representation and structure of four scanners

Task a: adjust resolution to 100dpi				* : not apply
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	*	main page	main page	main page
Information representation	*	text	text + icon	text
Task b: adjust current brightness & contrast				
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	main page	tab	main page	main page
Information representation	text + icon	text	icon	text
Task c: adjust scaling factor to 200%				
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	main page	tab	main page	main page
Information representation	text	text	text + icon	text
Task d: change the ratio of width to height to 2:1				* : not apply
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	main page	main page	*	*
Information representation	icon	text + icon	*	*
Task e: set up mode to clean up screen spots				* : not apply
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	*	main page	*	main page
Information representation	*	text	*	text
Task f: set up scanning area to be the size of B5				* : not apply
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	pull-down menu	*	pull-down menu	*
Information representation	text	*	Text	*
Task g: adjust current value range (darkness to brightness)				* : not apply
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	*	*	main page	main page
Information representation	*	*	icon	text
Task h: set up mode for scan with blurry effect				* : not apply
Scanner makes	HP	Mustek	Umax	Microtek
Information structure	*	tab	*	main page
Information representation	*	text	*	text
Task i: change unit from cm to inch				
Scanner makes	HP	Mustek	Umax	Microtek
information structure	pull-down menu	tab	pull-down menu	main page
information representation	text	text	Text	text
Task j: invert the picture				
Scanner makes	HP	Mustek	Umax	Microtek
information structure	main page	tab	pull-down menu	pull-down menu
information representation	icon	text	Text	text

4.2 Procedures of experiment I

(1) A brief introduction was given explaining the meaning of the ten tasks. (5 min.)
(2) Four scanners were randomly ordered while ten tasks were counterbalanced in order for each subject. Each subject was asked to check on a 7-point satisfaction scale for each task, while the time consumed was also recorded with stopwatch by experimenter. Two-minute break was taken between each scanner. (5-10 min. for each scanner)
(3) After finishing up with all four scanners, each subject was asked to answer two questions about his/her subjective preferences on the type of information presentation (pull-down menu or tab) and information structure (text, icon or text+icon). (2 min.; and total up to 33-53 min. per each subject)

4.3 Results and discussion

MANOVA was used to analyze the collected data, and Fisher's LSD employed for comparison pair-wise in this study to verify the significance of differences in both performance and satisfaction ($P<0.05$ was used).

The results of the analysis for performance are summarized in tables 2 and 3 and the results of the analysis for subjective satisfaction are in tables 4 and 5. The initials of the cognitive styles will be used in summarizing tables 2 and 3. And for the sake of convenience, the following abbreviations for five types of interface designs will be used in summarizing tables throughout this paper. T1: main page & text; T2: main page & text + icon; T3: main page & icon; T4: pull-down menu & text; T5: tab & text. If there is difference between two makes with same interface design, it'll be noted within parentheses.

4.3.1 Performances analysis

Table 2 summarizes the performance comparison in the Wholist-Analytic style dimension for different interface design types. It shows that with main page design, the merit order in performance is as follows: Analytic >= Intermediate >= Wholist; while with tab or pull-down menu designs, the order is just the opposite: Wholist >= Intermediate >= Analytic. Which means that the performance of different cognitive styles in Wholist-Analytic dimension is affected by information structure. On the other hand, as there was no significant difference in performance shown among text, icon or mixed designs for cognitive styles in Wholist-Analytic dimension, it is considered that the performance of different cognitive styles in Wholist-Analytic dimension is not affected by information representation.

Table 3 summarizes the performance comparison in the Verbal-Imagery style dimension for different interface design types. It reveals that with text design, the merit order in performance is as follows: Verbaliser >= Bimodal >= Imager; while with text+icon or icon only designs, the order is just the opposite: Imager >= Bimodal >= Verbaliser. Especially the design with icon, the differences shown among the three styles were most significant. Thus, it can be inferred that the performance of different cognitive styles in Verbal-Imagery dimension is affected by information representation. As

Table 2: Performance comparison in the Wholist-Analytic style dimension

	main page & text	main page & text + icon	main page & icon	tab & text	pull-down menu & text
Task a	A >= I >= W	A >= I >= W			
Task b	A >= I >= W	A >= I >= W	A >= I; I >= W; A > W	W > I > A	
Task c	A > I >= W	A >= I >= W		W > I >= A	
Task d		A >= I >= W	A > I > W		
Task e	A > I >= W (Microtek); A >= I; I >= W; A > W (Mustek)				
Task f					W > I > A
Task g	I >= A >= W		A > I > W		
Task h	A >= W >= I			W >= I > A	
Task i	A >= I >= W			W >= I > A	W > I > A
Task j				W >= I >= A	W >= I > A

> : significant difference; >= : better but not significant

there was no significant difference in performance shown in main page, tab or pull-down menu designs for cognitive styles in Verbal-Imagery dimension, it is considered that the performance of different cognitive styles in Verbal-Imagery dimension is not affected by information structure.

Table 3: Performance comparison in the Verbal-Imagery style dimension

	main page & text	main page & text + icon	main page & icon	tab & text	pull-down menu & text
Task a	V >= B; B >= I; V > I	I >= B; B >= V; I > V			
Task b	V >= B > I	I >= B >= V	I > B > V	V > B >= I	
Task c	V >= B >= I	I > B >= V		V >= B >= I	
Task d		I >= B >= V	I > B > V		
Task e	V > B >= I (Microtek); V >= B > I (Mustek)				
Task f					V > B > I
Task g	V >= B > I		I > B > V		
Task h	V >= B; B >= I; V > I			V >= B; B >= I; V > I	
Task i	V >= B >= I			V >= B; B >= I; V > I	V > B > I (HP); B >= V > I (Umax)
Task j				V >= B >= I	V >= B > I

> : significant difference; >= : better but not significant

4.3.2 Subjective satisfaction analysis

Table 4 summarizes the satisfaction comparison among five interface design types in Wholist-Analytic style dimension for the ten tasks. It shows that the merit order for satisfaction is roughly the same in all three styles (Wholist, Intermediate and Analytic), as: T1 (main page & text) = T2 (main page & text + icon) > T5 (tab & text) > T4 (pull-down menu & text) >= T3 (main page & icon).

Table 4: Satisfaction comparison among 5 interface design types in the W-A style dimension

	Wholist	Intermediate	Analytic
Task a	T2 >= T1(Mustek); T1(Muste k) >= T1(Microtek); T2 > T1 (Micr otek)	T2 >= T1(Mustek); T1(Mustek) >= T1(Microtek); T2 > T1(Micro tek)	T2 >= T1(Mustek); T1(Mustek) >= T1(Microtek); T2 > T1(Micro tek)
Task b	T1 >= T2 > T5 > T3	T1 >= T2 > T5 >= T3	T1 >= T2 > T5 >= T3
Task c	T2 >= T1(HP) >= T1(Microtek) >= T5	T2 >= T1(HP) >= T1(Microtek) > > T5	T1(HP) >= T1(Microtek) >= T2 > > T5
Task d	T2 > T3	T2 > T3	T2 > T3
Task e	T1(Mustek) >= T1(Microtek)	T1(Mustek) >= T1(Microtek)	T1(Mustek) >= T1(Microtek)
Task f	T4(Umax) > T4(HP)	T4(Umax) > T4(HP)	T4(Umax) > T4(HP)
Task g	T1 > T3	T1 > T3	T1 > T3
Task h	T5 >= T1	T1 >= T5	T1 > T5
Task i	T1 > T5 >= T4(Umax) > T4 (HP)	T1 > T5 > T4(Umax) > T4 (HP)	T1 > T5 > T4(Umax) > T4 (HP)
Task j	T5 > T4	T5 > T4	T5 > T4

> : significant difference; >= : better but not significant

Table 5 summarizes the satisfaction comparison among five interface design types in Verbal-Imagery style dimension for the ten tasks. It reveals that Verbalizers are satisfied with interface types in such order, as: T1 (main page & text) >= T2 (main page & text + icon) >= T5 (tab & text) > T4 (pull-down menu & text) > T3 (main page & icon); the Bimodals are as: T2 (main page & text + icon) = T1 (main page & text) > T5 (tab & text) >= T4 (pull-down menu & text) > T3 (main page & icon); while the Imagers are as: T2 (main page & text + icon) > T1 (main page & text) >= T5 (tab & text) > T4 (pull-down menu & text) >= T3 (main page & icon).

Table 5: Satisfaction comparison among 5 interface design types in the V-I style dimension

	Verbalizer	Bimodal	Imager
Task a	T1(Mustek) >=T2 >=T1 (Microtek)	T2 >= T1(Mustek) > T1 (Microtek)	T2 > T1(Mustek) >= T1 Microtek)
Task b	T1 > T2 > T5 > T3	T1 >= T2 > T5 > T3	T2 > T1 > T5 >= T3
Task c	T1(HP)>=T1(Microtek)>=T2 >=T5 T1(HP)>T5;T1(Microtek)>T5	T2 >=T1(HP) >=T1 (Microtek) >T5	T2 > T1(HP) >= T1(Microtek) >T5
Task d	T2 > T3	T2 > T3	T2 > T3
Task e	T1(Mustek) >= T1(Microtek)	T1(Mustek) >= T1(Microtek)	T1(Mustek) >= T1(Microtek)
Task f	T4(Umax) > T4(HP)	T4(Umax) > T4(HP)	T4(Umax) > T4(HP)
Task g	T1 > T3	T1 > T3	T1 > T3
Task h	T1 >= T5	T1 >= T5	T1 >= T5
Task I	T1 > T5 > T4(Umax) > T4 (HP)	T1 > T5 >= T4(Umax) > T4 (HP)	T1 > T5 > T4(Umax) > T4 (HP)
Task j	T5 > T4	T5 > T4	T5 > T4

> : significant difference; >= : better but not significant

4.3.3 Preference for different information structures and representations

The overall subjective preferences for different information structures and representations in the nine cognitive styles are shown in Tables 6 and 7 respectively. In Table 6, it is obvious that except for IV (Intermediate Verbalizer) and AV (Analytic Verbalizer), all the rest of cognitive styles preferred the tab (> 50%) to the pull-down menu in information structure. In Table 7, more than half of the subjects preferred the text + icon in information representation for all the nine cognitive styles, and most significant (> 60%) especially in II (Intermediate Imager, 79%), IB (Intermediate Bimodal, 65%), WI (Wholist Imager, 63%), and AI (Analytic Imager, 61%). It shows that Imagery cognitive styles prefer the text + icon information representation to others.

Table 6. Preference for different information structures in nine cognitive styles (%)

	WV	WB	WI	IV	IB	II	AV	AB	AI
Pull-down menu	44	32	27	52	25	33	62	42	12
Tab	56	68	73	48	75	67	38	58	88

Table 7: Preference for different information representations in nine cognitive styles (%)

	WV	WB	WI	IV	IB	II	AV	AB	AI
Icon	0	5	11	5	10	5	0	15	28
Text	44	37	26	42	25	16	45	27	11
Text + icon	56	58	63	53	65	79	55	58	61

The results from the experiment described above can be aggregated according to the operation time, satisfaction and overall preference into Figure 4. Different interface designs are listed in descending order with numerals for each cognitive style quadrant. 1 represents the most appropriate, 2 the second, and 5 the least.

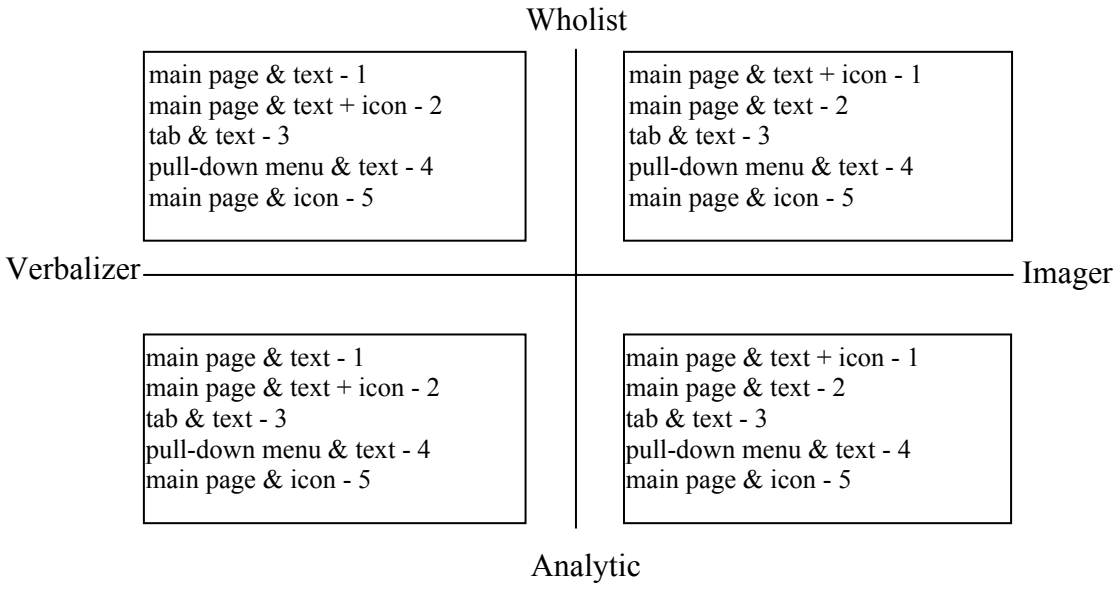


Figure 4. Interface design types appropriate for each cognitive style quadrant

V. EXPERIMENT II: PROPOSED DESIGNS AND VERIFICATIONS

5.1 Two types of interface design

The results of the first experiment were adopted as the blueprints for the design of two interface types which were considered as the most appropriate for two cognitive styles: Wholist-Verbalizer (WV) and Analytic-Imagery (AI). Two reasons for choosing these two cognitive styles as subjects for experiment: 1) they were two extremes, and 2) there were most subjects belonging to these styles. Type I was designed for Wholist-Verbaliser style, and hence, text was used as information representation; and main page as information structure, unless necessary, tab was the second choice, according to the results of the first experiment. Type II was designed for Analytic-Imagery style, and hence, text + icon and main page were adopted as information representation and structure respectively throughout ten tasks. Table 8 summarizes it, and Figure 5 shows the picture of these two types.

5.2 Comparison of type I and other makes

The comparison of operating time and subjective satisfaction among Type I (good for Wholist-Verbalizer cognitive style) and other makes are exhibited in Tables 9 and 10 respectively. The ones with significant difference （$p<0.05$）between Type I and each other makes are indicated with " * ". Gray shade signals that the interface design is different from Type I.

Both Tables 9 and 10 all indicate that the proposed Type I is obviously better than others under comparison for Wholist-Verbalizer in both performance and satisfaction. Especially much better than those interface designs not with main page & text (in gray shades). In other words, if equipped with the most appropriate interface design (main page & text) for WV, a piece of software will increase both of the operating performance and users' subjective satisfaction.

Table 8. Two interface design types and tasks allocation

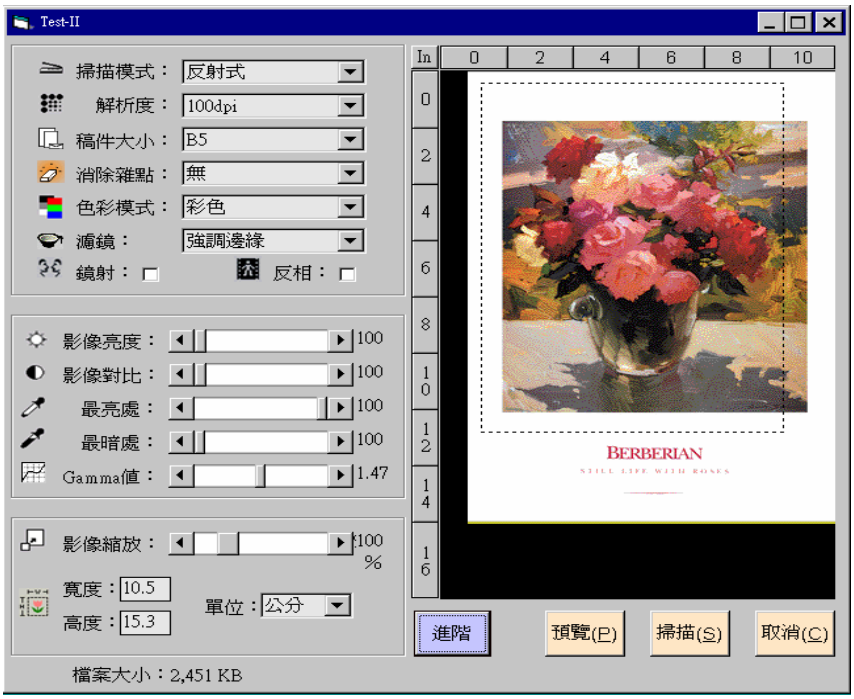
	Cognitive style	Interface design types (tasks involved)
Type I	WV	Main page & text (Task a ~ Task g) Tab & text (Task h ~ Task j)
Type II	AI	Main page & text + icon (Task a ~ Task j)

Table 9. Operating time used in all types of interfaces by Wholist-Verbalizer (unit: seconds)

	Type I	Hp	Mustek	Umax	Microtek
Task a	4.55	NA	5.60	6.40*	6.83*
Task b	6.23	8.57*	10.23*	24.73*	7.42
Task c	5.20	7.04	8.79*	8.54*	8.01*
Task d	6.98	48.18*	9.07	NA	NA
Task e	4.79	NA	14.49*	NA	14.93*
Task f	4.63	27.53*	NA	20.63*	NA
Task g	7.01	NA	NA	39.64*	7.06
Task h	5.78	NA	7.72	NA	7.19
Task i	4.22	21.42*	6.78*	7.08*	3.74
Task j	4.32	NA	5.02	9.05*	NA

* : significant difference; gray shade depicts interface design different from Type I

Type I: for Wholist-Verbaliser Style



Type II: for Analytic-Imagery Style

Figure 5. Two interface design types used for verification in experiment II

5.3 Comparison of type II and other makes

Type II, main page & text + icon, was designed for Analytic-Imager cognitive style. The comparison of its operating time (performance) with other makes is exhibited in Tables 11. As the interface designs of HP under Task b and Umax under Tasks a and c were all as: main page & text + icon, same as Type II, no significant difference was found between them. Other than that, for those

with different designs, all have shown significant differences. As for subjective satisfaction, reflecting the same tendency as that of the operating time, the results are shown in Table 12.

Table 10. Subjective satisfaction among all types of interfaces by Wholist-Verbalizer (range: 1-7)

Type I	Hp	Mustek	Umax	Microtek
5.73	NA	5.17*	5.06*	5.00*
5.20	4.72	4.44*	3.28*	5.11
5.20	4.83	4.67*	4.72*	4.89
5.00	1.61*	4.67	NA	NA
5.60	NA	4.00*	NA	3.89
5.60	2.56*	NA	3.44*	NA
4.93	NA	NA	2.28*	4.83
5.27	NA	4.94	NA	4.83
5.60	3.06*	5.33	5.00	5.56
5.33	NA	5.72	4.67	NA

* : significant difference; gray shade depicts interface design different from Type I

Table 11. Operating time used in all types of interfaces by Analytic-Imager (unit: seconds)

	Type II	Hp	Mustek	Umax	Microtek
Task a	4.68		6.04*	4.89	7.08*
Task b	6.52	7.23	15.66*	10.75*	8.87*
Task c	4.80	6.66	11.74*	5.98	7.61*
Task d	7.09	21.72*	7.4		
Task e	5.06		14.52*		15.27*
Task f	5.38	46.09*		39.29*	
Task g	8.09			21.57*	9.18
Task h	4.56		11.68*		8.50*
Task I	4.60	39.38*	10.71*	22.49*	4.58
Task j	4.83		8.62	31.45*	

* : significant difference; gray shade depicts interface design different from Type II

Table 12: Subjective satisfaction among all types of interfaces by Analytic-Imager (range: 1-7)

	Type II	Hp	Mustek	Umax	Microtek
Task a	5.73		5.22*	5.56	4.89*
Task b	5.00	5.11	3.89*	3.94*	4.83
Task c	5.66	4.89*	4.22*	5.17	4.83*
Task d	5.00	3.22*	5.11		
Task e	5.33		4.11*		4.06*
Task f	5.53	1.78*		2.22*	
Task g	4.86			3.39*	4.67
Task h	5.60		4.33*		4.72*
Task i	5.53	2.33*	4.44*	3.94*	5.50
Task j	5.33		4.83	2.94*	

* : significant difference; gray shade depicts interface design different from Type II

VI. CONCLUSIONS AND DISCUSSIONS

From the results of the two experiments, some conclusions can be made:

1). On Wholist-Analytic cognitive dimension, the difference is significant in both operating time (performance) and subjective satisfaction with different information structure. For beginners, no matter where their cognitive styles float, arranging all the major functions on the main page is the best solution; especially appropriate for Analytic ones. Multiple layers can be adopted with tabs instead of current applications of pull-down menus, in which, Wholist performed better than Analytic.

2). On Verbal-Imagery cognitive dimension, the difference is significant in both operating time (performance) and subjective satisfaction with different information representation. It shows that icons are not necessarily the best. Verbalizers like words more than icons while Imageries prefer a combination of both. No group likes icons alone.

Design that conforms human's minds will become the winner of the next century. We, as designers, must offer users the most appropriate interface designs, as we did before the most appropriate artifact design. Cognitive styles are different among users, so as their preference of interface designs. The findings of this study hopefully can contribute a little to help better interface design for the future. Even though only scanners were used as examples, and only five interface design types were covered, the application of the findings shouldn't be restricted anyway.

VII. ACKNOWLEDGMENTS

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認知風格對使用者介面設計之影響：以掃描器為例

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摘要

本研究的目的在於爲不同認知風格之使用者建立合適之使用者介面設計準則。實驗樣本包括四廠牌的掃描器介面，其中包含了各類的介面型式，在資訊呈遞方面有：文字、圖像及文圖混用，在資訊結構方面有：頁籤與下拉式選單。受測者以 CSA（Riding, 1991）測驗分爲九類認知風格，並接受任務實驗，分別記錄這九類認知風格者對各任務的操作績效及主觀滿意度，並以 MANOVA 作爲數據分析的統計方法。

結果顯示不同的認知風格者在使用每一個介面型式時的操作績效與滿意度方面均有顯著差異；在 Wholist-Analytic 認知風格向度上，Wholist 的操作績效及滿意度以頁籤或下拉式選單較好，而頁籤則又比下拉式選單要更好一些；而 Analytic 的操作績效與滿意度則以主頁較好。至於在 Verbal-Imagery 認知風格向度上，Verbal 的操作績效與滿意度依高低排列如下：文字、文圖混用及圖像；而 Imager 的操作績效與滿意度依高低排列則是：文圖混用、文字及圖像。

關鍵字：認知風格、使用者介面設計、掃描器