

# The Effect Of Cognitive Style On User Performance In Tasks Using Different Types Of Media

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## ABSTRACT

This paper reports on a series of experiments that examine the effect of cognitive style on the performance of subjects in tasks using different types of media. Performance is defined as a ratio of score over duration. A series of experiments were devised to test the performance of each cognitive style group in a range of tasks using audio, text, images, text plus images, and video. Tasks were categorised in terms of the cognitive style group was expected to perform them best. The relative performance of the cognitive style groups between the different styles of task were compared within each type of media and between each type of media. General Linear Model Univariate calculations were performed to determine whether the cognitive style groups performed significantly different from each other within each media and t-tests for related samples calculations were performed to determine whether the performance of the cognitive style groups were significantly different between different media. Cognitive style was found to affect performance but not within all types of media and not always in the expected manner. Comparing the performance of the cognitive style groups between the media it is possible to identify the types of media that are more suitable for each cognitive style group.

## INTRODUCTION

This paper describes the results of a series of experiments that follows up the work examining the effects of cognitive style on user performance with audio as reported in EuroMedia 2000 (John & Boucouvalas 2000a). The results of the audio experiment have been augmented by the results of experiments using text, images, text plus images, and video.

The experiments were part of the Telecare Companion project that was concerned with developing a telecare application that enabled text, audio and video communications over the Internet and provided simple, easy-to-use interfaces. In order to further assist the non-expert computer users the system was designed to automatically adapt aspects of the interface to suit the needs of individual users (John, Jerrams-Smith et al 1998). An earlier experiment was conducted to assess the benefits of adapting

the interface to cognitive style of the users. Cognitive style is defined as the consistent underlying method of thinking and perceiving that effects the way in which an individual perceives and responds to events and ideas (Tennant 1988; Riding & Cheema 1991; Riding 1994; Riding, Glass et al 1997). The Cognitive Styles Analysis package (CSA) was used to determine whether subjects were Wholist (understand situations or things as a whole) or Analytic (understand situations or things as collections of parts) along one dimension and Verbaliser (prefer words to images) or Imager (and think in terms of mental pictures or images) along the other dimension (Riding 1991; Riding 1998). The results of the experiment indicated that there were significant differences in performance between the cognitive style groups, but the observed differences were not always as expected and that relative performance using one style of interface was not balanced by a corresponding difference when using the opposite style of interface (John & Boucouvalas 1999). A number of experiments have found that performance for each cognitive style group can be predicted depending on structure of information and format of information (Riding and Rayner 1998; Riding and Sadler-Smith 1997). The above experiment did not replicate these findings therefore differences between the above experiment and the experiments described in literature were examined. The above experiment used a multimedia interface while the other experiments used paper-based text and images, and the CSA text itself while being computerised does not use a multimedia interface. Therefore the effect of using different media was identified as an area that required further investigation and a series of experiments investigating the effect of cognitive style on user performance in tasks using audio, text, images, text plus images, and video were designed.

The results of the experiments using audio (John and Boucouvalas 2000a) and text and images (John and Boucouvalas 2000b) have been analysed in order to identify the types of task that subjects perform relatively well or badly for each media in order to make recommendations of which tasks to present to users in order to improve the performance of users using each type of media. Here the relative performance of the cognitive style groups between the different styles of question are compared between each type of media in order to determine whether the type of media used has affected performance and if so which media are suited to which cognitive style groups.

## DESIGN OF THE EXPERIMENT

The experiments examined the performance of subjects in tasks using audio, text, images, text plus images, and video. A range of tasks were used in the experiment to reflect the manner in which the CSA program assesses cognitive style and to explore the individual nature and uses of the different media. Each task presented subjects with some information and their understanding of the information was tested by a series of questions that required subjects to select *yes* or *no*, choose the correct answer from a multiple-choice list or perform simple calculations. The comparison tasks presented two words or images that represented objects or concepts and subjects were asked to determine whether they were of the same type. The comprehension tasks presented information that included extracts of fiction and non-fiction, procedural instructions and maps, and subjects were asked to answer a series of multiple-choice questions about the information. Mathematical questions involved subjects performing calculations based on the information presented in the comprehension task and also simple addition, multiplication and division questions. There were also a series of non-speech audio questions that required subjects to identify musical instruments and sound effects. Due to the differing nature of each media it was not always possible to produce equivalent tasks for each media however using the CSA package (Riding 1991; Riding 1996; Riding 1998) it was possible to identify which cognitive style was expected to perform best in each type of task. Therefore it is possible to make comparisons across the different media based on the style of task.

Performance was measured as a ratio that was calculated by dividing the percentage of questions answered correctly by the average time to answer one question in seconds. For subjects to have a high performance ratio they have to score high in a short duration.

The audio experiment presented information using pre-recorded human voice or sound effects. Each piece of audio started automatically but subjects were provided with an option to hear the audio again (figure1). Subjects entered their answers by clicking on labels or images.



Figure 1: Audio Experiment Comprehension Task interface

The text experiment presented all information using text (figure 2). Subjects entered their answers to questions by clicking on labels.

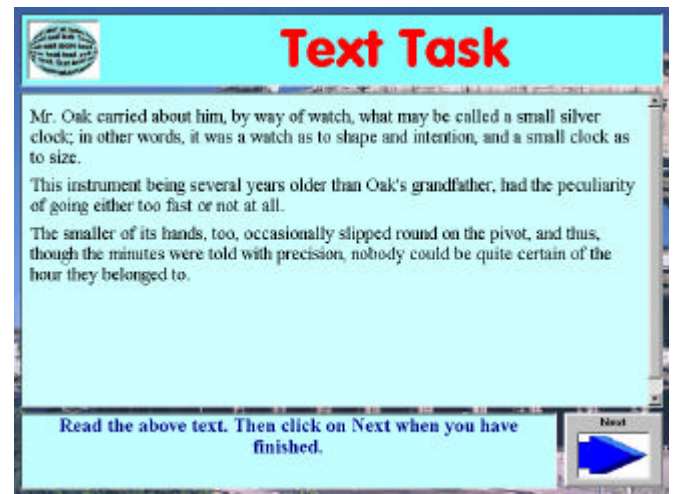


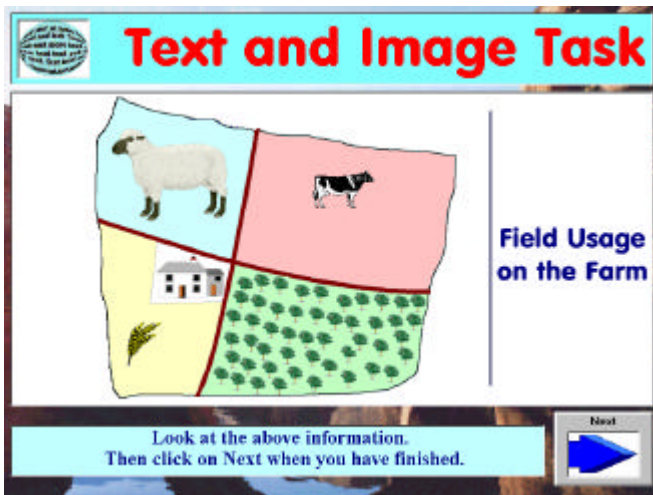
Figure 2: Text Experiment Comprehension Task interface

The images experiment presented information using drawn diagrams and photographs (figure 3) although a minimum amount of text was also needed to give instructions and ask questions. Subjects entered their answers by clicking on labels or images.



Figure 3: Image Experiment Comprehension Task interface

The text plus images experiment presented information using a mixture of text and drawn diagrams and photographs (figure 4). Subjects entered their answers by clicking on labels or images.



**Figure 4: Text plus image Experiment Comprehension Task**

The video experiment presented information using a combination of audio, text, still images, animation and live-action video (figure 5). Subjects entered their answers by clicking on labels or images.



**Figure 5: Video Experiment Comprehension Task**

The experiment was performed on a multimedia PC by 50 subjects chosen at random from the student and staff population of the University. All subjects performed all the experiments although the order in which the different experiments were presented was randomised. Subjects also performed the CSA test separately.

## RESULTS OF THE EXPERIMENT

There was a fairly even division of subjects with 23 Wholist subjects and 27 Analytic subjects along the Wholist-Analytic dimension and 21 Verbaliser subjects and 29 Imager subjects along the Verbal-Imagery dimension.

The mean performance ratio results of each cognitive style group were calculated for each media experiment. The performance of Wholists were compared against Analytics in the Wholist-Analytic style tasks (table 1) and the performance of Verbalisers were compared against Imagers in the Verbal-Imagery style of question (table 2).

Media/ Style	ALL		Wholists		Analytics	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
A_W	9.15	2.39	8.50	2.23	9.71	2.42
A_A	10.18	2.77	10.39	2.68	10.01	2.88
T_W	5.59	3.86	6.63	4.98	4.71	2.30
T_A	6.55	2.26	6.41	2.28	6.67	2.28
I_W	12.09	3.24	11.53	3.09	12.57	3.34
I_A	8.08	1.89	8.14	1.87	8.03	1.94
TI_W	9.14	3.67	8.46	3.68	9.72	3.62
TI_A	6.98	2.20	7.07	2.47	6.91	1.98
V_W	13.32	3.79	14.06	3.76	12.68	3.78
V_A	8.59	2.61	8.65	2.49	8.55	2.75

**Table 1: Mean performance in Wholist-Analytic style tasks**

Media/ Style	ALL		Verbalisers		Imagers	
	Mean	Std. Dev	Mean	Std. Dev	Mean	Std. Dev
A_V	9.79	1.85	10.49	1.66	9.29	1.85
A_I	11.48	1.79	10.92	1.95	11.88	1.57
T_V	8.13	2.45	8.14	2.85	8.13	2.17
T_I	18.07	7.47	17.56	7.29	18.44	7.70
I_V	10.21	3.48	10.42	4.04	10.07	3.07
I_I	8.89	1.95	9.42	1.96	8.51	1.89
TI_V	8.61	2.50	8.69	1.89	8.55	2.89
TI_I	10.85	3.13	11.55	3.37	10.35	2.90
V_V	9.09	2.59	9.62	2.89	8.72	2.33
V_I	8.37	3.37	9.35	3.96	7.65	2.73

**Table 2: Mean performance of in Verbal-Imagery style tasks**

The Media/Style column identifies the media experiment and style of tasks (on the left of the label A\_ = audio, T\_ = text, I\_ = images, TI\_ = text plus images, V\_ = video, and on the left of the label \_W = Wholist style tasks, \_A = Analytic style tasks, \_V = Verbaliser style tasks, \_I = Imager style tasks).

It was expected that each cognitive style group would perform better than the opposite style group in the tasks that suited their own style. Before the relative performance of each cognitive style group could be assessed it was necessary to establish whether the results of cognitive style groups were significantly different from each other. This was done by performing General Linear Model Univariate calculations and examining the significance figures of the between-subjects effects (table 3).

Where the significance figures are below 0.05 (highlighted in yellow on table 3) cognitive style has significantly effected the performance of subjects and it is possible to compare the results of the cognitive style dimension groups as shown in table 1 and 2. Where the significance figures are between 0.05 and 0.10 (highlighted in green on table 3) a marginally significant influence on performance due to cognitive style has been detected and there is less evidence to indicate that the cognitive style groups performed differently. A significance figure of greater than 0.10 indicates that the cognitive style groups did not perform the task differently from each other.

Cog. style dimension	Media/ Style	F	Sig.	Eta Squared	Observed Power
Wholists/ Analytic	A_W	3.63	0.06	0.07	0.46
	A_A	0.10	0.75	0.00	0.06
	T_W	3.12	0.08	0.06	0.41
	T_A	0.03	0.87	0.00	0.05
	I_W	1.42	0.24	0.03	0.22
	I_A	0.01	0.91	0.00	0.05
	TI_W	1.55	0.22	0.03	0.23
	TI_A	0.02	0.90	0.00	0.05
	V_W	1.17	0.29	0.03	0.19
	V_A	0.01	0.93	0.00	0.05
Verbaliser/ Imager	A_V	5.72	0.02	0.11	0.65
	A_I	3.52	0.07	0.07	0.45
	T_V	0.00	0.96	0.00	0.05
	T_I	0.22	0.64	0.01	0.08
	I_V	0.20	0.66	0.00	0.07
	I_I	2.54	0.12	0.05	0.35
	TI_V	0.03	0.86	0.00	0.05
	TI_I	1.56	0.22	0.03	0.23
	V_V	1.22	0.28	0.03	0.19
	V_I	3.07	0.09	0.06	0.40

**Table 3: General Linear Model Univariate between-subjects effects**

As shown in table 3 the overall the effect of cognitive style was not found to be consistent effect. Only one set of results indicated that cognitive style had significantly effected performance. As expected Verbalisers (mean performance ratio of 10.49, table 2) performed the audio Verbaliser tasks significantly better ( $p = 0.02$ , table 3) than the Imagers (mean performance ratio of 9.29, table 2). Two marginally significant results also gave expected results. Wholists (mean performance ratio of 6.63, table 1) performed the text Wholist tasks better ( $p = 0.08$ , table 3) than the Imagers (mean performance ratio of 4.71, table 1) and Imagers (mean performance ratio of 11.88, table 2) performed the audio Imager tasks better ( $p = 0.07$ , table 3) than the Verbalisers (mean performance ratio of 10.92, table 2). There were, however, two marginally significant results that were opposite to what was expected. Analytics (mean performance ratio of 9.71, table 1) performed the audio Wholist tasks better ( $p = 0.06$ , table 3) than the Wholists (mean performance ratio of 8.50, table 1) and Verbalisers (mean performance ratio of 9.35, table 2) performed the video Imager tasks better ( $p = 0.09$ , table 3) than the Imagers (mean performance ratio of 7.65, table 2).

These results indicate that cognitive style does have an influence on performance for some media, but the level of influence varies depending on the media used. The effects were detected in the found mainly in the tasks that used spoken or written language while the experiments using images and text plus images did not find any significant differences in performance between the cognitive style groups.

The relative performance of each cognitive style group between each type of media was compared. Table 4 compares the performance of Wholists and Analytics in the Wholist-Analytic tasks between each media while table 5 compares the performance of Verbalisers and Imagers in the

Verbal-Imagery tasks between each media. The tables show the name of the medium in which the cognitive style group achieved the highest performance ratio when comparing performance between two media. The two-tailed t-test for related samples was used to determine whether the performance of each pair was significantly different from each other. Where the significance figure of the t-test was less than 0.05 performance was significantly different. This is indicated in the tables by the yellow background. Where the significance figure of the t-test was between 0.05 and 0.10 performance was marginally different. This is indicated in the tables by the green background. Where the significance figure is greater than 0.10 there was no significant difference in performance. This is indicated in the tables by the white background.

		Text	Image	Text/Image	Video
Wholists Wholist Task	Audio	Audio	Image	Audio	Video
	Text		Image	Text/Image	Video
	Image			Image	Video
	Text/Image				Video
Analytics Wholist Task	Audio	Audio	Image	Text/Image	Video
	Text		Image	Text/Image	Video
	Image			Image	Video
	Text/Image				Video
Wholists Analytic Task	Audio	Audio	Audio	Audio	Audio
	Text		Image	Text/Image	Video
	Image			Image	Video
	Text/Image				Video
Analytics Analytic Task	Audio	Audio	Audio	Audio	Audio
	Text		Image	Text/Image	Video
	Image			Image	Video
	Text/Image				Video

**Table 4: T-Test comparing performance of Wholist-Verbaliser tasks between media**

		Text	Image	Text/Image	Video
Verbal Verbal Task	Audio	Audio	Audio	Audio	Audio
	Text		Image	Text/Image	Video
	Image			Image	Image
	Text/Image				Video
Imager Verbal Task	Audio	Audio	Image	Audio	Audio
	Text		Image	Text/Image	Video
	Image			Image	Image
	Text/Image				Video
Verbal Imager Task	Audio	Text	Audio	Text/Image	Audio
	Text		Text	Text	Text
	Image			Text/Image	Text/Image
	Text/Image				Text/Image
Imager Imager Task	Audio	Text	Audio	Audio	Audio
	Text		Text	Text	Text
	Image			Text/Image	Image
	Text/Image				Text/Image

**Table 5: T-Test comparing performance of Verbal-Imager tasks between media**

Tables 4 and 5 can be used to predict the relative performance of the cognitive style groups when presenting different styles of task using different types of media. For example Analytics are expected to perform the Wholist tasks significantly better using text plus images than text while there would not be a significant difference in the performance of Wholists using either media (table 4) and

Verbalisers are expected to perform the Verbaliser tasks marginally significantly better using video than text while there would not be a significant difference in the performance of Imagers using either media (table 5).

Most of the differences in performance between the cognitive style groups are reflected in the results of the General Linear Model Univariate between-subjects effects. For example, there is a difference in the relative performance of Verbalisers and Imagers in the Verbaliser tasks using audio and text plus images. Verbalisers perform the Verbaliser tasks significantly better using audio than text plus images while there is no difference in performance of Imagers using either media (table 5). This is reflected by the General Linear Model Univariate between-subjects effects calculation that found significant differences between the performance of Verbalisers and Imagers in the audio Verbaliser tasks (table 3).

Comparing the relative performance of the cognitive style groups between media can also identify differences in performance that are not found by performing the General Linear Model Univariate between-subjects calculations. A difference was detected in the relative performance of Wholists and Analytics performing the Analytic tasks. Wholists performing the Analytic task performed significantly better using video than images while there was no significant difference in the performance of Analytics using either media (table 4). This difference was detected while no significant differences in performance was found between the Wholists and Analytics in either the in the video Analytic tasks or the image Analytic tasks (table 3).

## CONCLUSIONS

A series of experiments were carried out to examine the effect of cognitive style on tasks using audio, text, images, text plus images, and video. Each experiment contained a number of tasks using a separate medium or combinations of media. Each task was categorised in terms of the cognitive style that was expected to perform best. Comparisons between media were made between the styles of task.

Cognitive style was shown to effect performance within different media but the effect was not consistent for all cognitive style groups and the effects were not always as expected. The effects were detected mainly in the tasks that used spoken or written language rather than images. Changing the media type was also found to effect performance and the effect was different for different cognitive style groups.

Using the results of the experiments it is possible to predict the relative effect of presenting different styles of tasks to different cognitive style groups and identify the types of media that are more suitable for each cognitive style group.

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