Information Visualization Techniques and Decision Style: The Effects in Decision Support Environments

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Abstract

The importance of individual characteristics has been emphasized in the human computer interaction and information visualization (IV) literature. However, decision style, which is recognized as one of the key individual cognitive differences that affects system success, has received little attention in these areas. This study aims to examine how decision style, IV techniques and task complexity affects decision performance and user preferences in a managerial decision support environment. The study adopted an experimental method, based on within-participants design approach. The results showed that there were significant differences in decision performance between IV techniques, individual differences and task. The results suggest that decision style moderates the relationship between IV techniques and performance. The findings have important implications for the DSS designers, and provide important research issues for future work.

Keywords

Decision Style, Information Visualization, Decision Support System, Human Computer Interaction.

1. Introduction

Information visualization (IV) is an emerging technology that relies on the human's perception and cognitive abilities to visualize. Incorporating IV techniques to decision support systems (DSS) is a potential solution to improve system effectiveness and to provide decision makers with powerful decision support environments. The aim of applying IV techniques is to support a deeper understanding and to foster new insights to decision makers about the data that they are analyzing. Many innovative IV techniques have been developed. However, empirical evaluation on IV techniques is still in early stage and still lacking in numbers [1], particularly in the area of business decision support applications [2]. Besides, the adoption of IV techniques in decision support environments as reported in the literature is still minimal. More evidence of measurable benefits supporting the use of IV is needed, and more attention to individual cognitive differences is recommended, to realize its potential advantage [3]. In the human computer interaction (HCI) and IV literature, the importance of individual differences has been emphasized. However, decision style, which is recognized as one of the key individual cognitive differences that affects system success, has received little attention. Meanwhile, in the DSS literature, decision style has been acknowledged to affect decision-making performance and individuals' preferences for human-machine-interface [4]. Unfortunately, it has frequently been overlooked and rarely been given priority in the design of decision support systems [5, 6].

The purpose of this paper is to examine the extent to which individual differences, in particular decision style, affects decision performance and user preferences while using different IV techniques for different task types.

2. Theoretical Background

The technology characteristics, task characteristics and individual differences have been empirically studied and recognized as an important element in the DSS and HCI literature. DSS literature claims that individual characteristics including the individual cognitive differences affect systems' utilization and success [4,7]. Meanwhile, HCI literature acknowledges that a clear understanding of individual characteristics

including cognitive style is helpful in designing interfaces for specific user communities [8]. In addition, studies related to the technology acceptance model (TAM) emphasize the interaction between individuals and the technology and argue that system acceptance and utilization are affected by individuals' preferences or attitudes about the system [9]. Current research also continues to address the need to consider cognitive differences among decision makers and determine ways in which these differences can be best supported [3,10]. A DSS which is designed to support a decision maker's preferred style could enhance user's satisfaction [11]. Thus, it can be concluded that interface technology, task, and individual characteristics are important components in the study of a system's success and user performance. In this study, IV techniques were used to represent the interface technology and decision style was used to represent the individual characteristic.

3. Method

This study adopted an experimental method, based on within-subject design approach. IV techniques and task complexity are within-subject variables and decision style is between-subject variable. The experiment examined three types of IV techniques and two types of tasks. The decision style was categorized based on the Decision Style Inventory developed by Rowe and Mason [12]. Decision performance is measured based on the time taken to complete a task.

An academic workload planning application was developed and used in this study to simulate a real workload planning decisions. The application is chosen as it is a common application and equally familiar to all participants.

3.1. Hypothesis

The study was based on the following five hypotheses:

H1. There is significant difference in an individual's performance across IV techniques.
H2. Exploration tasks will require longer completion time than extraction tasks.
H3. There is a significant difference in performance between different decision styles.
H4. There is a significant interaction effect between IV techniques and decision style on completion time.
H5. *O+D* technique will have higher ranking in user preference than *Z+P*.

3.2. Experimental design and procedure

This experimental study was conducted with 16 participants who were members of the administration staff of Universiti Teknologi MARA (9 females and 7 males). They were decision makers from the middle management level with more than 5 years of working experience. Participants answered a questionnaire covering demographic data and 20 item-questions about decision style before doing the experiments. The participants took approximately two and a half hours to complete the experiment including the training session. All participants started with a set of two simple tasks of extraction type, followed by a set of two complex tasks, the exploration task for each of the three IV techniques studied. The order of IV techniques was counter balanced to avoid learning effects and bias in results. After using all the three IV techniques, participants were given a user preference questionnaire, to list down the order of preference for IV technique and to provide reasons for their choice of most and the least preferred IV technique.

3.3. Independent Variables

3.3.1 Information Visualization Techniques

This study examined three types of information visualization techniques: overview+detail with Window Explorer-based (*O+D WinExp*), overview+detail with tree-based (*O+D Tree*) and zoom+pan (*Z+P*). Interface with overview+detail (*O+D*) technique shows the selected details of information space together with an overview of the entire information space. There are differences between *tree-based* and *WinExp* of *O+D* techniques. In the *tree-based* technique, the overview structure is presented from the beginning of the application. However, for *WinExp*, only the root of the structure is displayed at the starting point. It can be exploded by a click at its parent node, which is similar to the window explorer file organization. On the other hand, the zoom+pan technique only allows for having either a detailed view or the global overview of the information space at a time. This technique requires frequent changes between detail and overview. This may result in a greater cognitive load. Users often lose track of their current position with respect to the global structure. Thus, this may have a negative impact on user performance.

3.3.2 Decision style

The decision making style of participants are judged using a 20-item questionnaire called the Decision Style Inventory (DSI), a test instrument developed by Rowe and Mason [12]. The DSI instrument has been widely used for administration purposes and in several researches. Its validity testing has been reported in several published studies [12, 13, 14].

The identification of each respondent's predominant style is based on the highest intensity level of DSI scores. This instrument identifies four distinct categories of decision styles: directive, analytical, conceptual, and behavioral. These decision styles are different in regards to their methods of perceiving and evaluating information.

3.3.3 Task

The tasks used in this study are categorized as extraction tasks and exploration tasks. These tasks require participants to search and explore the information space structure and extract the correct answers. The complexity of these tasks differs in terms of three main criteria: the search criteria, the scope of search and the solution. For low complexity extraction tasks, the search criterion is specified. The high complexity exploration tasks require participants to explore a larger search area, possibly the entire information space with a greater number of solutions required.

3.4. Dependent Variables

There are two dependent variables: decision performance, and user preference. The decision performance was measured based on the time taken to complete a task using given IV techniques. All participants' interactions with the IV techniques were automatically logged by the system and the task completion times were derived from the logged data. The differences across the IV techniques are investigated based on user preferences. After having used all three IV techniques, participants filled in the user-preferences questionnaire.

4. Analysis and Results

The analysis conducted in this study includes both inferential and descriptive statistics. This study follows standard conventions for significance levels, where p-value <= 0.05 is significant. The data was examined by employing a repeated measure analysis of variance (RM ANOVA) to detect statistically significant differences in task performance, and preferences between the conditions. A comparable non-parametric test was used, when the data differed extensively from RM ANOVA assumptions. The SPSS version 13.0 was used to analyze the results.

The results of this study showed that there were significant differences in decision performance between IV techniques, task and decision style with $p < 0.05$. Therefore, H1, H2 and H3 were supported. Participants' comments demonstrate that one's efforts to perform a task vary for different types of IV techniques used. *O+D* recorded better performance and required lesser effort than *Z+P*. Besides, user preferences for the IV techniques were strongly in favor of *O+D* techniques. Both *O+D* techniques were equally preferred with 43.8% voted as their first preference. The Wilcoxon test was conducted to evaluate the significance of participant's preferences across the three techniques. The results showed a significant difference in user preference between the *O+D* and *Z+P* techniques, and thus H5 was supported. There was no significant difference between the two *O+D* techniques in decision performance as well as user preference. From the participants comments, it can be concluded that location reference were easier to establish in both *O+D* techniques compared to *Z+P*.

This study also found that there was a significant main effect of decision style on completion time with $F(3,16) = 6.421$, and $p < 0.05$. Post hoc test for the exploration tasks indicated that there was significant difference between the analytical and the behavioral styles. The analytical style recorded the shortest time and the behavioural style the longest time. The results strongly support the arguments that decision styles affect decision performance. More significantly, the finding has shown that decision styles moderates the relationship between the IV techniques and decision performance with $F(6,16) = 4.536$, and $p<0.01$. Therefore, H4 was supported. Further analysis was conducted to analyze the interaction effects of decision style on each of the task type. No difference was found for extraction type. However, result showed that there was significant difference in performance for the exploration task with $F = 5.062$, and $p< 0.05$. This provide an important issue for further research since the results strengthen the argument which states that decision style is critical in the DSS design. The summary of the results is shown in Table 1.

Table 1: Summary of Hypothesis testing

Dependent Variable	Independent Variable	Result
Decision Performance (completion time)	H1:IV techniques	Supported **
	H2:Task	Supported **
	H3:Decision style	Supported **
	H4: IV * decision style	Supported **
User preference	H5: *O+D* is more preferred than *Z+P*	Supported **

Note: ** $p<0.05$

5. Direction for Further Research

This study investigates the decision style effects in higher education institution with participants from middle management level, using academic workload planning application. Further investigation on decision style effects using different application domain as well as different user domain is recommended. Having user domain from top management members would provide an additional support to the literature. However the greatest challenge would be to get enough participants to participate in the study.

Other possibilities for further research would be to replicate the research on groups with different demographics characteristics, and also using different decision style instruments to support for generalization of the decision style effects.

6. Conclusions

The theoretical contribution of this study is to introduce a new dimension, decision style, to the framework of HCI/IV studies. The study also explores and reports interaction effects of decision style on decision outcome while using different IV techniques. The view taken is that the good fit across DSS user interface technology, IV in particular, with individual decision styles and task characteristics, is not only significant, but essential for the success of overall system use. The study provides empirical data on the interaction effects of decision style on decision performance in using different IV techniques. In terms of practical contribution, these findings have important implications for DSS designers, and provide important research issues for future work. The empirical findings support the construction of more user aware interfaces that adapt to the individual cognitive and perceptual needs. It is believed that building a DSS that meets the need of decision makers, in task requirements and individual cognitive requirements, is essential and beneficial.

7. References

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