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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 individual differences, IV techniques and task complexity influence decision performance and user preferences in a business decision support environment. The study adopted an experimental method, based on within-subject 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 is a significant moderator on the relationship between IV and performance. The findings have important implications for the DSS designers, and provide important research issues for future work.

Keywords: Information Visualization, Decision Style, Human Computer Interaction, Decision Support System, Individual Differences.

Introduction

An interface with effective information presentation is critically important in a decision support environment. Incorporating visualization technology to the interface is a promising approach for supporting decision-making (Zhang 1996). It provides decision makers with a powerful decision support environment that enables them to explore available information more effectively.

In developing a successful system, users' needs from the task requirements and individual cognitive requirements are crucial. Decision support system (DSS) and human computer interaction (HCI) literatures have revealed that cognitive differences are important factors in decision-making performance and system success. Turban & Aronson (2001) argue that cognitive differences in particular decision styles may influence one's preferences for human-machine-interface and decision-making aid. Unfortunately, the effects of individual decision styles have frequently been ignored or overlooked, and have rarely been given priority in the DSS design (Dhaemer 1991). Empirical research examining the relationships between decision style and performance is limited. In addition, at present no research effort has been devoted to investigating the effects of decision styles on decision performance across information visualization (IV) techniques. Hence this study aims to bridge these gaps.
The purpose of this paper is to determine the extent to which IV techniques and individual differences, particularly the decision style and gender, affect decision performance and user preferences.

Theoretical background

An in depth study by Salle and Hunter (1990) has claimed that the lack of attention to the user interface issues to be the main reason for the poor acceptance of an information system. In the DSS literature, the importance of the cognitive fit has been highlighted. Prior studies showed that the fit between representation of information and task has a positive impact on performance (Benbasat, et al., 1986). A similar argument has been proposed in the Task Technology Fit theory, which claims that the fit leads to individual performance impact (Goodhue & Thompson, 1995). The mismatch between technology and task characteristics could burden the cognitive load and require greater effort. Thus, this leads to a slow decision-making performance. This theory has the potential to explain the underlying phenomena in HCI research that compares differences in IV techniques of interface design and tasks.

Besides the technology characteristics and task characteristics, individual differences have been empirically studied and recognised 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. Meanwhile, HCI literature acknowledges that a clear understanding of individual characteristics including cognitive style is helpful in designing interface for a specific community of users. 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 (Davis et al. 1989). 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 (So & Smith 2003).

From the discussion above, it can be concluded that interface technology, task, and individual characteristics are important components in the study of a system success and user performance. These components are incorporated in this study's research model. The following are discussions on the main constructs of interest.

Information Visualization Techniques

Many innovative IV techniques have been developed to improve decision performance. However, empirical evaluation of IV is still in its early stage and still lacking in numbers, particularly in the area of business decision support environment (Speir & Morris, 2003). Studies on interface design using IV have shown conflicting of findings. Literature recognizes the lack of strong conclusive empirical evidence supporting the effect of IV on decision performance (Speir & Morris, 2003).

Individual Characteristics

Individual characteristics have been considered as important determinants affecting the manager's ability to interpret information, and make effective decisions (So & Smith 2003). However, not all the empirical evidence has supported a positive relationship between these individual differences and decision performance. Prior studies recommended that further examination of individual difference, including decision styles and gender are required. Investigating the effect of individual differences is extremely important especially in the HCI studies for a system success (So & Smith 2003).

Decision Style

Literature recognises decision style as a critical element in DSS design. Turban & Aronson (2001), among others, argues that a DSS would be more widely used, more accepted and produce better decision making if it matches individuals' decision styles. In addition, Mintzberg (1976) attributes poor decision making to the way in which one processes information. He suggests that methods of representing data should be compatible with an individual's information processing preferences and style of decision-making. According to Rowe and Mason (1987), decision style is primarily a cognitive process that combines the mental activities of perception, information processing, making a judgment, and problem solving. It reflects the way that a person visualizes and thinks about situation. In their Decision Model, they argue that decision style affects the decision behaviour and decision behaviour has an impact on the outcome or the action taken. Studies by Fox and Spence (2005) showed that decision style is significantly related to performance in using project management tool, which is measured by completion time. Further research on the interaction effect of decision style is required for exploring its importance in DSS design.

Gender

The empirical findings on gender and decision making performance have shown mixed results. King et al. (1990) demonstrate no significant differences of gender on the accuracy of outcomes, even though males are generally considered more variables in coming to decisions. On the other hand,the Selectivity Model by Meyer (1989) supports the concept that males and females differ in information processing. It theorises that females are more efficient than males on a complex task. In addition, based on review studies on gender and DSS, Powell and Johnson (1995) suggest that gender differences in decision making can be approached by variance in decision style. Taylor (2004) argues that theories in the area of gender are limited, further research on analysing gender difference is required.

Task Complexity

The majority of DSS experimental studies have classified tasks based on difficulty. The difficulty is related to its level of complexity. The level of complexity is different in terms of the scope of search (the breadth and depth), the amount of input/information provided, and the extent of the output required. In HCI and IV literature, task is known as an important factor that affects the user's performance (Shneiderman, 1998).

Research Method

This study adopts a controlled experimental method, the best design for identifying causal relationship. It implements a multi-factor experimental design, so that the interaction effects can be analysed besides its main effects. Instruments used in this experiment include logging data for measuring the completion time, and questionnaires for identifying decision style and user preferences.

Hypothesis

The study was based on following six hypotheses:

H1 O+D techniques will lead to better performance than Z+P.
H2. Exploration tasks will require longer completion time than extraction task.
H3. There is a significant difference in performance across decision styles.
H4. There is a significant difference in performance between male and female.
H5. There is a significant interaction effect between IV and decision style on completion time.

H6. O+D techniques will have higher user preference ranking than Z+P.

Experimental Design

An experimental study was conducted to test the research hypotheses. This study adopts a within-subject approach. This study examines four factors: two within-subjects conditions (IV techniques and task), and two between-subjects condition (participant' gender and decision style). The experiment was conducted in a one-to-one basis at the participants' own office, which would provide a natural setting working environment. This would avoid criticism of artificial environment issues.

This 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.

Experimental Procedures

Participants answered a set of questionnaire on demographic data and 20 item-questions about decision styles before doing the experiments. This experiment was divided into two sessions: Training and Experimental sessions. The participants took approximately two and a half hours to complete the experiment including the training session. All participants started with a set of simple task, the extraction type, followed by a set of complex tasks, the exploration task for each of the IV techniques. The order of IV techniques was counter balance to avoid learning effects and bias in results. After using all the three IV techniques, participants were given a user preferences questionnaire, to list down the order of the interface based on their preferences.

Experimental Variables

Independent Variables

- Interface design: Information visualization techniques:

This study examined three types of IV techniques: overview+detail with Window Explorer-based (O+D WE), 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. It allows users to maintain a global overview and simultaneously examine details. There are differences between tree-based and WinExp-based 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 start point. It can be exploded by a click at its parent node, which is similar to the window explorer file organization. Another difference between the two techniques is the use of indicator for the overview structure. In O+D tree-based, an indicator is used to point out the current node position. However, a multi-colored indicator is used in WinExp to show the current position and all the visited nodes.

On the other hand, Z+P technique only allows having either a detailed view or the global overview of the information space at a time. Its overview structure is similar to the tree-based structure. This technique requires frequent change between the detailed and the 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.

- Decision style:

The decision making style are judged using a 20-item questionnaire called Decision style Inventory (DSI), a test instrument by Rowe and Mason (1987). The allocation of the style is based on the highest intensity level of DSI scores. This instrument identifies four distinct categories of decision styles: *directive*, *analytical*, *conceptual*, and *behavioural*. These decision styles are different in regards to their methods of perceiving and evaluating information.

- Task:

An academic workload planning application is used in this study to simulate real workload decisions. The tasks are categorized as extraction task and exploration task. 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 task, 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.

Dependent Variables

There are two dependent variables: decision performance, and user preferences. 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 starting point is captured when the user clicks the *Start* button. The task is considered completed when the user click the *Stop* button. 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.

ANALYSIS AND RESULTS

This study follows standard conventions for significance levels, where p-value <= 0.05 are significant. The data was examined by employing a repeated measure analysis of variance (RM ANOVA) to detect significant differences in task performance, and the Wilcoxon test to evaluate participants' preferences. The SPSS version 13.0 was used to analyze the results.

Task Completion Time

The results from the RM ANOVA showed that there was a significant main effect of IV on completion time ($p < .05$). As anticipated, significant differences were detected across the IV techniques, with both O+Ds outperformed the Z+P technique. This finding is similar to prior studies (Hornbaek et al, 2003) and supports H1. It was also found that there was a significant main effect of task complexity on completion time (H2) with $p < 0.01$. The exploration tasks had longer completion time in all the three IV techniques compared to extraction tasks. No obvious difference was shown across the IV techniques for extraction task. For exploration task, results showed that there was a significant difference in completion time between O+D and Z+P ($p < .05$). No difference between O+D techniques ($p>0.1$) was recorded. This suggested that for a complex task, the presence of overview provides significantly better performance compared to the Z+P with no overview.

The key objective of this study is to examine the effects of decision style and gender on decision performance across IV techniques. It was found that there were significant main effects of decision style (H3) with $p<0.05$ and gender (H4) with $p < 0.01$. A Post test based on the Bonferrani suggested that the significant difference across decision style was between

analytical and *behavioural* styles. *Analytical* had the shortest and *behavioural* had the longest completion time. These two styles have been characterized to have different approach of problem solving. *Analytical* is classified as more structured than *behavioural*. The differences in the problem solving approach explain the differences in their performance. This result is consistent with prior study by Fox and Spencer (2005) on project management tool. Meanwhile, in the case of gender differences, females were found to have better performance than males. This result is consistent with prior studies by So and Smith (2003) that suggest female has better performance when working with visual representation.

Further investigation on the interaction effect between IV techniques and individual differences was conducted. The results showed that there were significant differences in completion time across IV for different decision style (H5) with $p<0.05$. This indicates that decision style affects the relationship between IV and completion time. In addition, the results showed that there was a significant interaction effects between decision style and gender on completion time ($p<0.05$). This result supports prior argument by Taylor (2004) and Powell & Johnson (1995).

User Preferences

Overall preferences for the interfaces were strongly in favor of overview-detailed interfaces. Both O+D techniques were equally preferred with 43.8% voted as their first preference. The Wilcoxon test showed that there was a significant difference between the O+D and Z+P techniques (H6). There was no significant difference between the two O+D techniques. The Z+P, by comparison performed poorly, with majority ranking it as the least preferred.

Conclusion

This study provides theoretical contribution by introducing decision style into the framework of HCI/IV studies. The view taken in this research is that the good fit across DSS user interface technology, IV in particular, with individual decision styles and task characteristics, is not only admirable, but also essential for the system success. This study provides empirical contributions as it explores and reports the potential of main and interaction effects of decision style on decision performance in using different IV techniques. More significantly, the finding that indicates decision style moderates the relationship between the IV techniques and decision performance provide important issues for further research. These results strengthen the argument that states decision style is critical in the DSS design. In addition, these empirical findings support the construction of 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.

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