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Under pressure: a psychophysiological analysis of the effect of temporal constraints on information processing and decision making

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UNDER PRESSURE: A PSYCHOPHYSIOLOGICAL ANALYSIS OF THE EFFECT OF TEMPORAL CONSTRAINTS ON INFORMATION PROCESSING AND DECISION MAKING

by

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ABSTRACT

In recent times, decision making under time pressure has become more common than ever and hence, it has become a hot topic for behavioral researchers. This research studies the effects of temporal constraints on users' decision quality and decision strategy. The paper primarily addresses two research questions: (i) Does time pressure affect decision quality? (ii) Does time pressure affect decision strategy? The decision accuracy and decision strategy of the participants were measured for three time-pressure conditions namely, No time pressure, Reasonable time pressure and Extreme time pressure. Research results from the past revealed that, Cognitive style is also observed to have an impact on decision quality under time pressure and thus, has also been introduced as a moderating variable to study the interaction effect. Physiological responses from users when subjected to time pressure have also been studied.

The task instrument used to study the decision making behavior of users was a financial dashboard which consisted of financial information of three companies and the participants were asked to rank-order the companies in the order of their performance. Eye tracking was used to gauge the decision strategy. Electro-dermal activity, which is a measure of stress, was measured using a device called Q sensor. A pilot study was conducted with 20 participants to determine time pressure thresholds for the reasonable time pressure and extreme time pressure conditions. In the experiment phase, 20 users each were subject to reasonable and extreme time pressure conditions individually and were asked to provide their responses to a survey based on the task provided to them. Eye tracking and Q sensor results were also collected for all participants.

Statistical analysis performed on the responses from the survey revealed that the decision quality increased as time pressure increased. Also, a majority of the users subject to time pressure adopted a non-compensatory decision strategy for making their decision. The fit between cognitive style and decision strategy was observed to have a significant effect on decision quality. It was also found that the analytical users performed better than the intuitive users under no time pressure. Statistical analysis performed on physiological responses revealed that stress experienced increased as time pressure induced on a participant increased.

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Firstly, I would like to express my sincere gratitude to Dr. Hong Sheng, my advisor, who has been an inspiration throughout the process and helped me grow both technically and professionally. The thesis would not have been possible without her support, guidance and encouragement. I've learned a lot from her expertise in Human Computer Interaction and ways of conducting user experience research. Her constructive comments helped me develop a project am really proud of today.

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Last but not least, I would like to thank my wonderful parents, Panduranga Rao and Sarada, who have been an inspiration to me all my life and have been responsible for the person I am today. I dedicate my thesis to them.

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1. INTRODUCTION

Human decision making has been studied over years and numerous cognitive styles, decision making models and information search strategies have been derived from various studies. Decisions are formed based on an understanding the problem, figuring out the possible outcomes and narrowing down on one outcome, the final decision of the decision maker [13]. Decision making in it-self is sometimes a cumbersome process and imposing deadlines or time-limits can make the whole process even more complex [28]. The introduction of a deadline into the decision making process has the capability of altering the way the users interpret the information presented to them [3]. Past research has examined how time pressure affects the decision making of an individual, which will be the main objective of this research [2, 4, 5-7].

Time pressure has seldom been studied as an independent variable to determine its effect on decision making. Time pressure is important as decision makers often need to make faster decisions in today's world. According to past research, decision making can greatly be affected by time pressure when the user is presented with a lot of information to scan through in a limited amount of time [7]. However, findings from the past haven't all been the same. There were some studies which found time pressure to have a negative impact on decision accuracy or performance where as others found time pressure to have a positive impact on performance and decision accuracy [2, 26]. There have also been results from the past research which revealed that time pressure, when manipulated on different levels, had both positive as well as negative effects on performance. A reasonable increase in time pressure was found to affect performance positively whereas a severe increase in time pressure caused the performance to decline. Thus, time pressure has been manipulated to observe the effects of different levels of time pressure on decision making.

Past research revealed that cognitive styles of individuals affect decision making under time pressure. Researchers have tended to group cognitive styles into two groups, analytical and intuitive [2]. Analysts basically tend to adopt a compensatory strategy to perform extensive analysis and make decisions where as intuitive individuals usually adopt a non-compensatory strategy and just "glance" through the cues to reach a final

decision [1]. People adopting the analytical style believe in detailed, methodical work and tend to study each aspect of a problem in detail to reach a conclusion where as people belonging to the intuitive style believe that too much concern about an issue leads to an inability in making a decision. Hence, it is better to make "any" decision than make none [29]. Armstrong (2000) found that intuitive participants were more successful than analytical participants in tasks presented to them as a part of the experiment [11]. In some studies, it was expected that since the analytic mode of processing is slower and demands more resources than the intuitive mode [13], participants would be more likely to engage in intuitive rather than analytic processing while under time pressure. They found that under time pressure, intuitive individuals solved more problems when compared to the analysts and cognitive styles had a non-significant effect on decision accuracy. Decision strategies in line with cognitive styles have been studied and have been categorized into compensatory and non-compensatory decision strategies. Decision makers using compensatory strategies evaluate each attribute of each alternative separately and then compare all the alternatives to choose the best one. On the other hand, decision makers using non-compensatory strategies were the ones who chose not to perform intensive information processing [14]. It was hypothesized that under time pressure, users chose a non-compensatory strategy for decision making. All the studies mentioned above [29.13.14] relate to the fact that users who adopt non-compensatory strategy under time pressure while decision making can make faster and more accurate decisions when compared to the users who adopt a compensatory strategy.

However, there exists a considerable gap in the literature mentioned above pertaining to the study of effects of time pressure on decision making and the choice of cognitive style Few studies have focused on studying the effect of time pressure on choice of cognitive styles adopted by the user to make their decision, which in turn might affect the decision accuracy. Hence, this research primarily addresses the following research questions: (1) Does time pressure affect decision quality? (2) Does time pressure affect decision strategy? It also examines how the decision quality of a user is affected when he chooses a decision strategy not in line with his cognitive style, under time pressure. Physiological measures have also been studied to measure stress of the user.

This study will contribute to the field of behavioral studies in decision making under time pressure. It consists of additional elements such as how the choice of cognitive styles under time pressure affects the accuracy of decision making and it also uses eye-tracking and physiological measures to study human emotion and attention respectively.

The rest of the paper is organized as follows. Section 2 briefly discusses the relevant literature from the past on time pressure, decision strategies and cognitive styles relevant to the hypotheses of this research. Section 3 describes the research design, including the research model, hypotheses development and methodology implementation. Section 4 presents the data analysis methods and results. Section 5 discusses the findings from the results obtained and provides deeper insight into the results. Section 6 discusses the implications of this study and Section 7 lists the limitations. Finally, Section 8 presents conclusions drawn from this study and plans for future work.

2. LITERATURE REVIEW

This section consists of findings from prior literature on decision making under time pressure. This research focuses on studying the effects of time pressure on decision accuracy and also how time pressure affects the choice of decision strategies, which in turn affects decision accuracy. In addition to the above, this section also consists of findings from past research on information presentation format.

2.1. TIME PRESSURE

Time pressure in human decision making has been studied extensively in various fields to measure its effects on decision accuracy and/or decision effectiveness. Time pressure can be defined as a situation where insufficient is time provided for making a decision or reaching a conclusion [29]. Former researchers found that time constraint was an important variable influencing decision making. Various studies in numerous fields, some of which are referenced below, studied the effects of time pressure on decision accuracy and the results were not consistent.

Findings from some studies showed that time pressure had a significant negative effect on decision accuracy and performance, when a user was subject to time pressure, his performance or decision quality decreased where as when the user was not subject to any time pressure, his performance increased. Svenson and Edland (1993) researched the effect of time pressure on decision accuracy and found that the decision accuracy decreased under high time pressure and the performance increased under the no time-pressure condition. They concluded that "the accuracy of human judgment decreases under time pressure" due to closure of mind. When the individuals are subject to time pressure, it has been observed that they become sensitive to wrong choices or negative information and cannot think as effectively under time pressure as individuals under no time pressure. Ahituv, Igbaria and Sella (1998) designed an experiment for the IAF commanders and manipulated time pressure to see the latter's effect on performance and concluded that "Time pressure usually, but not always, impairs performance". The reason behind this being the increase in stress in an individual due to induced time pressure. Similar results have been found from Sharma and Mc Kenna's (2001) study. In their

findings from the color coding experiment, the participants, when subject to time pressure, concentrated on negative information and made the wrong decision. On the other hand, performance improved when they were not subject to time pressure because they were not as sensitive to negative information and assessed all cues to obtain the solution to the task. Kocher and Sutter (2006) in their experiment, the beauty contest game, found that time pressure has, indeed, a negative effect on the quality of decision making in an interactive context, which was observed due to an increased level of stress and led to the users making worse decisions than under no time pressure. De Donno (2008), also reported from his study which investigated the effect of time pressure on the Iowa Gambling task, that the participants who were advised that the amount of time allotted was typically insufficient to complete the task performed significantly worse than those who were advised that time was typically sufficient to complete the task. In this case, the users' perceived time pressure for an increase in cognitive load and it adversely affected the users' ability to assess the information accurately under time pressure.

Apart from all these findings above which report that time pressure had negative effects on decision performance, there have been studies which reported positive effects of time pressure on decision accuracy and performance i.e. the users, when subject to time pressure performed better when compared to users under no time pressure. One such study which reported similar results was by Bryan and Locke (1967). They presented the college students with simple arithmetic tasks as a part of their experiment and found that the subjects who were given twice the amount of time to complete the tasks gave worse results. Hence, they found that time pressure affected performance positively. In this case, the factor that helped improve decision quality was motivation. When the users were subject to reasonable deadlines, an increase in motivation was observed, which in turn lead to an increase in decision quality. Also, Latham and Locke (1975) found that the logging crews in their experiment, worked faster when deadlines were short and also persons working under time restrictions would exert a greater rate of effort toward task completion than would their counterparts who had no such time restriction. Hence, an increase in effort towards work increased the decision quality of the logging crews. Similar results were reported from the study by Bassett (1979). He conducted an experiment on bank employees in an organization and gave them simple clerical tasks to

perform under time pressure. He concluded from the results of his study that individuals performed a simple clerical task faster and more accurate when given short time limits. This has been observed due to increase in motivation when the participants were given short time limits when compared to participants working under no time limit.

There have also been some studies which reported that effect of time pressure on performance and decision quality was non-linear. Results from such studies have reported a curvilinear relationship between time pressure and performance, i.e. when time pressure increased from no time pressure to reasonable time pressure, an increase in performance has been observed and when time pressure rose from reasonable time pressure to extreme time pressure, the performance of the participants dropped drastically. A study conducted by Andrews and Farris (1972), which was a five year panel design field study revealed that performance tended to increase with increasing time pressure only to fall off as time pressures became too severe. The NASA scientists, used as participants in this experiment, worked on their routine tasks but they tended to perform better when subject to reasonable time limits. Also, an increase in effort put towards their tasks was noticed but when time pressure became too severe, the scientists were over stressed and the increase in cognitive workload led to a drop in their decision quality. Similar effects were reported from the study by Peters and O'Connor (1984). They suggested the importance of absolute level of time pressure on performance. In their research note on the field test of Parkinson's Law, they conducted an experiment considering bank employees as their sample. They manipulated time pressure in three levels, no time pressure, reasonable time pressure and extreme time pressure. They came up with a model which was called the Inverted U model (in Fig. 2.1) which suggests that performance increases with time pressure to an extent but decreases when time pressure becomes too severe. They hypothesized that when time pressures becomes reasonably stronger, performance increases as suggested by Parkinson's Law and when time pressure induced on an individual is very severe, the performance decreases. As a part of their experiment, the bank employees were given a specific set of goals to be achieved within a given time. From their study, it has been concluded that the time pressure does not have a linear effect on performance and decision making quality. They found that the bank employees who performed tasks under reasonable time pressure, worked faster and more accurately

when compared to the employees under no time pressure. However, it has been found that the bank employees who worked under a high time pressure condition showed poor performance in their tasks when compared to the employees who worked under reasonable time pressure. They also found that people choose their effort levels to be appropriate to the tasks at hand and the amount of time available to accomplish the tasks. Hence, it has been noticed that the participants working under the reasonable time pressure condition showed an increased effort in performing the tasks when compared to participants working under no time pressure as the tasks given were of equal importance, which led to an increase in decision quality of the employees. However, when the time pressure induced on the employees became more severe, they were not willing to accept tasks of the same difficulty and a decrease in motivation towards the tasks was observed. The motivational behavior was constrained when time pressure became severe. Hence, it has been concluded in their study, the effect of time pressure on performance is non linear and is in the shape of an inverted U.

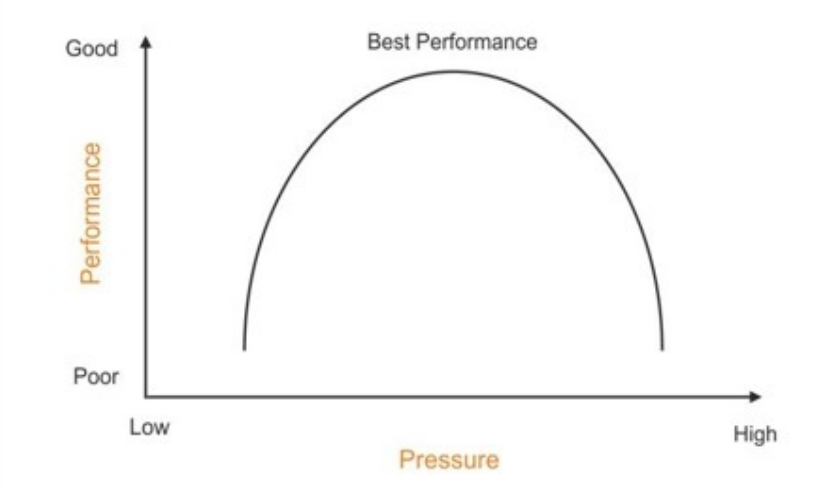

Fig. 2.1. The Inverted U Model

The curvilinear relationship between time pressure and performance has also been observed due to be stress or anxiety experienced by an individual. In an effort to understand the effect of time pressure on stress, which in turn affects decision

performance, Yerkes and Dodson (1908) formulated the Yerkes–Dodson law, which explains the relationship between time pressure and stress, which in turn affects decision quality of an individual. In their experiment it has been noted that as time pressure increased, the stress in an individual increased. It has also been observed that low levels of stress due to low time pressure led to an increase in motivation and thus, an increase in performance, where as high levels of stress lead to decrease in performance levels due to decrease in motivation and cognitive workload. Hence, it can be concluded that a reasonable increase in time pressure leads to lower levels of stress and increased motivation and results in better performance when only drops drastically as time pressure becomes severe causing increase in stress and decreased motivation in an individual.

2.2. COGNITIVE STYLES

Past research revealed that cognitive styles of individuals affect decision making under time pressure. Cognitive styles have mainly been categorized into two, analytical and intuitive [2]. Analysts basically adopt a compensatory strategy to perform extensive analysis and make decisions where as intuitive individuals adopt a non-compensatory strategy to just “glance” through the cues and reach a final decision [1]. People adopting the analytical style believe in detailed, methodical work and tend to study each aspect of a problem in detail to reach a conclusion where as people belonging to the intuitive style believe that too much concern about an issue leads to an inability in making a decision and hence it is better to make “any” decision than make none [29]. The results from various studies which researched the effect of time pressure on decision making have been reported here. Most studies reported that time pressure led to participants using intuitive decision making strategy rather than an analytical decision making strategy. Furthermore, intuitive users performed better than analytical users under time pressure. Kruglanski and Freund (1983) found that time pressure leads to the closure of the mind, i.e., people stop considering all aspects of various available alternatives and they begin believing in their gut for decision-making, which happens to be a characteristic of intuitive individuals. Also, analytical users did not perform better under time pressure when compared to intuitive users. This is believed to be due to the fact that the search pattern adopted by analytical individuals was way more complicated and time consuming

than the pattern used by intuitive individuals. In a similar experiment, Wooler (1984) found that training in analytical methods of decision making failed to improve the quality of decisions when subjects were under time pressure due to the time taken by analytical participants in comparison to intuitive participants while processing the available information. In a study oriented towards researching the effect of cognitive styles on performance under time pressure, Gary Klein (1999), a leader in decision making research found in his study on how people make decisions under certainty, that experts under time pressure used their base of experience to identify similar situations and intuitively choose feasible solutions. They adopt global search patterns rather than local search patterns which leads to better decision quality when the users are given a limited amount of time to scan through the given information and make a quick decision. A questionnaire has also been developed by Allinson and Hayes (2000) which they called the Cognitive Style Index (CSI) test for measuring the analytical and intuitive aspects in an individual. This questionnaire had a total of 38 questions, out of which the first 21 questions measured the analytical aspect of an individual and the other 17 measured the intuitive aspect and were reverse scored. Test scores ranging from 0-38 were considered more intuitive and the scores ranging from 39-76 were considered more analytical. They conducted an experiment to study the effect of cognitive style on performance under time pressure. As a result they found that, in comparison to analytical individuals, intuitive individuals made quicker and better decisions under time pressure as the intuitive individuals based their solution on emotions and they solved problems using accepted paradigms and adopt a global perspective. However, analytical individuals were more autonomous and assessed each alternative in the information given to them. The studies mentioned above, overall, revealed that intuitive users perform better than the analytical users under time pressure.

2.3. DECISION STRATEGY

Decision strategies in line with cognitive styles were studied because this research involves studying the effects of time pressure manipulation on decision strategy chosen by the participants. Hwang (1994) researched the use of decision strategies used to make a decision under time pressure. The research evaluated two types of decision making

strategies, compensatory and non-compensatory. Decision makers using compensatory strategies evaluate each attribute of each alternative separately and then compare all the alternatives to choose the best one. On the other hand, decision makers using non-compensatory strategies were the ones who chose not to perform intensive information processing. They usually made decisions by believing in gut and concentrating on salient information. The characteristics of people choosing a compensatory decision strategy were similar to people whose cognitive style was analytical and the characteristics of people who chose non-compensatory strategy were similar to people whose cognitive style was intuitive. In Hwang's (1994) study, he also proposed a model for decision making under time pressure and hypothesized that under time pressure condition, decision makers will adopt non-compensatory strategies more than compensatory strategies in order to reach a decision. They do not perform intensive information processing and adopt similar and familiar search patterns which are backed up by experience or intuition. Also, when no time pressure exists, individuals choosing compensatory strategy perform better when compared to the ones choosing non-compensatory strategy due to the accurate utilization of all cues and comparing the strengths and weakness of the available alternatives against each other. To research the effect of choice of decision strategies adopted by individuals under time pressure, Weenig and Marleweld (2002) conducted an experiment where the participants were to choose among six refrigerators with the best features, when each of them was described from six different dimensions. The results from the experiment showed that, with time constraint, users who chose non-compensatory decision strategy used their intuition and experience with similar decision making tasks, assessed "few" screened alternatives against one another and reached quick decisions in the experiment. The users who chose a compensatory strategy struggled to reach decisions due to insufficient time and adopting a local search pattern to reach their decisions.

2.4. OTHER VARIABLES THAT ARE AFFECTED BY TIME PRESSURE

Time pressure was also considered to affect preference of information presentation. Early research in this area was concentrated on presenting the user with information using Graphs vs. Tables. The theory of cognitive fit was used to explain the

efficiency and effectiveness of the problem solution depends on a fit between the problem representation and the problem-solving task. Several studies have examined the effects of graphs and tables. Schwartz and Howell (1985) conducted research to study the effect of graphical data vs. numeric data on decision accuracy. They reported that graphical data outperformed numeric data when time was constrained, whereas graphical and numeric data resulted in equivalent performance without time constraints, because graphs were more visually appealing and required less cognition to process when compared to numbers under time pressure. In a similar experiment by Zhang (1996) which was oriented towards evaluating tabular information vs. a software called VIZ planner which generates graphs to represent the same information, he found that the people working with VIZ planner (graphical and visual images) generated more alternatives than the people who used tabular format. They were also more confident and satisfied with the outcomes. Graphs also tended to reduce cognitive load and increase attention when compared to numbers. There were also studies which researched the effects of interruptions on decision accuracy. Hence, it was observed that when time was constrained, graphs outperformed numbers when decision accuracy was the dependent variable.

3. RESEARCH DESIGN

3.1. RESEARCH MODEL AND HYPOTHESIS

This research focuses on addressing two research questions, (i) Does time pressure affect decision quality? (ii) Does time pressure affect decision strategy? There have been significant effects of time pressure on decision accuracy, as mentioned in the literature review section. One of the objectives of this research is to research the effects of time pressure on decision quality. In this experiment, decision quality is measured as decision accuracy. Hence, for this study, it has been hypothesized that the effect of time pressure on decision strategy is curvilinear. The intention is to study the effects of time pressure manipulated at three levels, no time pressure, reasonable time pressure and extreme time pressure on decision accuracy. Considering the concepts being discussed in the literature review section as the foundation, it has been presumed that as time pressure increases from no time pressure to reasonable time pressure, a low stress level is induced in the participants, which causes their motivation to increase. Hence, the effort put into performing the tasks is bound to increase, which in turn leads to better decision quality. However, when time pressure becomes severe, a high stress level is induced in the participants, which causes their motivation to decrease. Hence, effort put into performing tasks is bound to decrease, which in turn leads to a decrease in their decision quality. Thus, the first hypothesis is focused on studying the effect of time pressure on decision quality. The diagrammatic representation of H1 is shown in Fig 3.1. and was theoretically formulated as,

H.1: The effect of time pressure on performance, in this case measured as decision accuracy, is an inverted “U”

1.a) Performance increases with the increase in time pressure when the user is subject to reasonable time pressure.

1.b) Performance decreases when the user is subject to severe/unreasonable time pressure.

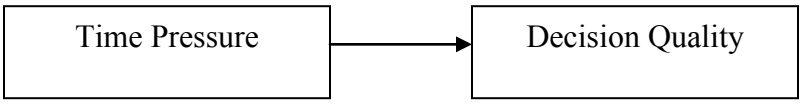

Fig. 3.1. Diagrammatic representation of hypothesis 1

Decision makers using compensatory strategies evaluate each attribute of each alternative separately and then compare all the alternatives to choose the best one. On the other hand, decision makers using non-compensatory strategies are the ones who choose not to perform intensive information processing. One of the objectives of this research is to study the effect of time pressure on choice of Decision Strategy adopted by the participants to make a decision. Adopting a compensatory decision strategy leads to an increase in the cognitive workload of the user as he is bound to evaluate all the cues and choose the best of them. On the other hand, choosing a non-compensatory strategy reduces cognitive workload as the user usually just scans for important information to make his decision. Considering the past literature on cognitive styles as the foundation, it has been hypothesized for this study, that a user subject to time pressure will adopt a non-compensatory strategy and will make use of a global search pattern and base his judgment off his experience with similar tasks. Adopting a non-compensatory strategy under time pressure is hypothesized to be due to the reduced cognitive load and reduced stress levels when compared to choosing a non-compensatory strategy. Hence, the second hypothesis was formulated as,

H.2: Under time pressure condition, the user tends to adopt a non-compensatory decision strategy.

When subject to time pressure, intuitive users have been found to perform better than analytical users due to the processing strategy involving screening fewer alternatives and making decisions based off their gut feeling or experience with similar tasks [1]. Similarly, an individual when subject to time pressure preferably adopts a non-

compensatory decision strategy over a compensatory decision strategy due to the reduced cognitive load and reduced stress. As the amount of information which need to be processed in a non-compensatory strategy is less than when using a compensatory strategy, the users concentrate on just the salient aspects of the information when they are subject to time pressure and hence decision quality is bound to increase. The users who adopt a non-compensatory decision strategy use their intuition or experience with similar tasks to make their decision.

As the characteristics of intuitive and analytical participants have been found to be in line with non compensatory and compensatory decision strategies respectively, it has been presumed that there exists an unexplored fit between cognitive style and decision strategy under time pressure. The fit in this study is defined as the variation between the cognitive style of a person and the decision strategy adopted by a person when he is subject to different time pressure conditions. For this study it has been presumed that when the difference between cognitive style and decision strategy becomes negative, i.e., when the intuitive users tend to choose a non-compensatory strategy, they will perform better when compared to analytical individuals. The diagrammatic representation of Hypothesis 3 is shown in Fig. 3.2. which is focused on studying the interaction effect between decision strategy and cognitive style which in turn affects decision quality.

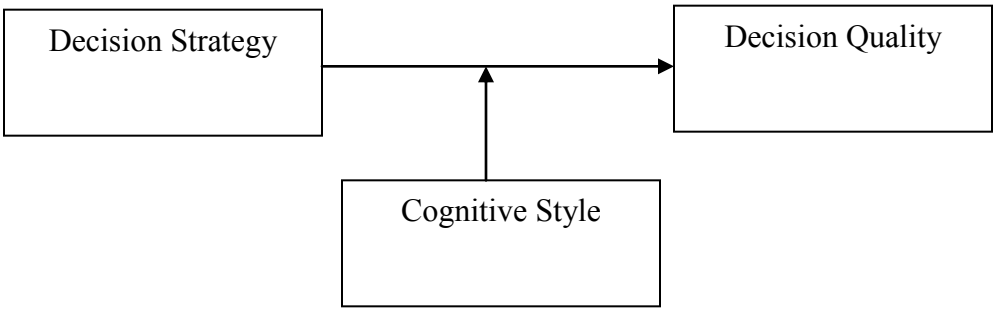

Fig. 3.2. Diagrammatic representation of hypothesis 3

Hence, the third hypothesis was formulated as,

H.3: Intuitive users perform better than the analytical users when they adopt a non-compensatory strategy under time pressure.

Similarly, when users are not subject to time pressure and have the luxury of using as much time as needed to complete a task, performing a detailed and methodical analysis of the cues being given to them before they make a decision can lead them to yield better results i.e. an increase in decision quality. When the users choose a compensatory strategy, it leads to them performing detailed analysis and accurate assessment of all the cues available. This leads to a reduction in the error rate and hence the quality of decision making will be improved. The diagrammatic representation of Hypothesis 4 is shown in Fig. 3.3. and is focused on studying the effects of choice of decision strategy on decision quality under the no time pressure condition.

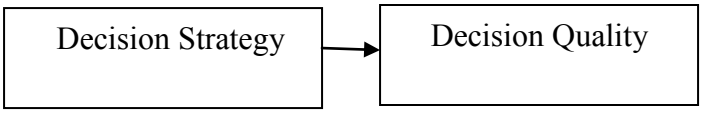

Fig. 3.3. Diagrammatic representation of hypothesis 4

Hence, the fourth hypothesis has been formulated as below to study the effects of choosing compensatory strategy on decision making,

H.4: Under no-time pressure condition, choosing compensatory strategy improves decision quality.

3.2. RESEARCH METHODOLOGY

The research design chosen for the study was a between subject experimental design. The subjects were exposed to three treatments: extreme time-pressure condition, reasonable time-pressure and no time-pressure condition. Hence, Time pressure was the independent variable in this study. The dependent variables were Decision quality and Decision strategy. Cognitive style has been introduced as a moderating variable to study the effect of the fit between cognitive style and decision strategy adopted, on the decision quality. The reason behind choosing a between subject design is to eliminate the learning effect. The subjects were chosen to test the hypotheses by manipulating the independent variable time pressure. A pilot study was conducted with 20 participants to determine the time taken to complete the tasks and to obtain a mean response time for the participants under no time pressure. They were required to perform a financial decision making task. For the actual experiment, 40 participants (20 each) were subject to either a reasonable time pressure or an extreme time pressure condition. They were instructed to make a decision within the given time, making use of all the information possible from the interface presented to them. Though visualization was not manipulated to see the effect of visualization on decision making, the user was presented with financial information in three formats, namely text, tables and graphs.

3.2.1. Task. The participants were asked to assume the role of a financial analyst, working for a premium company and were given financial information corresponding to three companies A, B and C. Values corresponding to the five financial ratios (shown in Appendix A.) of three companies belonging to the same industry, from 2007 through 2011 were provided to the participants in three different information presentation formats namely text, tables and graphs on a dashboard developed using SAP Xcelsius. The financial ratios were Price-to-Earnings Ratio, Price to Sales Ratio, Return on Equity, Earnings growth and Debt to Asset Ratio. The stimuli was presented to the participants on an Intel based computer with a 96 dpi, 17 inch monitor with a resolution 1024*768 pixel and it was 32 bit true color. A screenshot of the dashboard presented as stimulus to the students is shown in Fig. 3.4. It displayed financial information for three companies and allowed the users to view the information for the companies individually and collectively using various types of graphs the displayed the five financial ratios. As a part

of their job, they were told that they were required to analyze the financial performance of three companies namely Company A, Company B and Company C. Their task was to analyze the information presented to them on the dashboard and rank-order the three companies based on their performance and also answer some additional questions on a final survey.

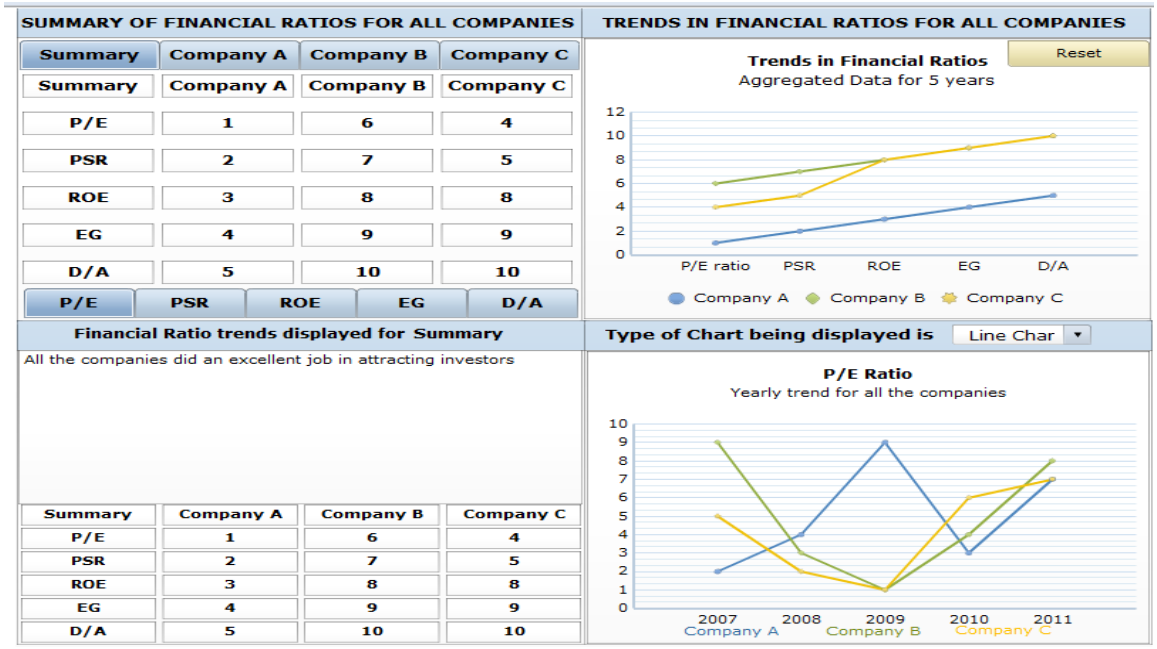

Fig 3.4. Screenshot of the dashboard showing financial information of three companies

3.2.2. Sample. A total of 20 participants took part in the pilot study to determine the time pressure threshold conditions for reasonable time pressure and extreme time pressure treatments. A total of 40, i.e. 20 participants per condition took part in the actual experiment which was performed for reasonable time pressure and extreme time pressure treatment conditions. All the subjects chosen were either under-graduate or graduate students enrolled in a Midwest university. They possessed proficiency in working with information systems and performing decision making tasks using information systems. They were all aged between 18 and 36 years old and were a combination of male and female genders. They possessed expertise in computer usage. Since most of the users

were not familiar with SAP and were not a group of SAP real-time users, the users were provided with a training video which explained how to interact with the dashboard to obtain the necessary information to perform analysis. Also, to eliminate inconsistency in the knowledge on financial ratios, a brief was provided to them in the task background. Demographic statistics are shown below in Table 3.1.

Table 3.1. Demographics of participants

Gender	Responses	Percent(%)
Male	48	80%
Female	12	20%
18 and younger	0	0%
19-24	49	82%
25-36	11	18%
37-45	0	0%
46-55	0	0%
56 or older	0	0%
High School/GED	5	8%
2-Year College Degree (Associates)	3	5%
4-Year College Degree	21	35%
Master's Degree	31	52%
Other	0	0%

3.2.3. Data Collection Procedure. As the participants entered the room, they were given an informed consent form to fill out. They were then seated in a comfortable chair and given a pre-experimental survey which needed to be filled out before they proceeded further. The survey consisted of questions from the Cognitive Style Index test by Allinson and Hayes (1996) and questions to determine their current mood. The Cognitive Style Index (CSI) (Allinson & Hayes, 1996) was chosen for the experiment

mainly because a large-scale study of learning style inventories indicates that it is one of the more reliable and valid learning style instruments among 71 inventories used in research conducted from 1970 to 2000. The CSI test contained 38 trichotomously scored items (true; uncertain; false) in the questionnaire. Nine of the first ten items assess the analytical qualities and nine of the last ten items assess intuitive qualities. 21 items assess analytical orientation scored positively and 17 items assess intuitive dimension with the reverse scoring. Higher score indicates analytical cognitive style and lower score indicates intuitive cognitive style. This survey was used to collect participants' cognitive style and mood.

They were then presented with a task background and task description to read which gave them instructions about their task. They were also presented with a training video which explained how to use the dashboard to perform the necessary analysis and obtain information from it. The participants were then presented with the actual dashboard to perform their analysis which was displayed to them on a Tobii 1750 eye tracker screen/ The Tobii 1750 is designed for eye tracking studies to measure the eye movements and fixation duration of the user while working on the task. Eye tracking works by reflecting invisible infrared light to a user's eye. The reflection pattern is then recorded with a sensor system, calculating the exact point of gaze using a geometrical model. After determining the point of gaze, it can be visualized and displayed overlaying the viewed material. Also a Q sensor which is a wearable, wireless biosensor was wrapped around the palm of the user while working on the task and was used to measure the electro-dermal activity that grows higher during states of excitement and lower during boredom or relaxation. It also measures skin temperature. The EDA is recorded by the Q sensor as it conducts the sweat on users' skin surface. The results from the Q sensor were used to measure stress while the user was working on the task. Last, the participants were given a final survey which consisted of questions they needed to answer based on their analysis using the dashboard for measuring decision quality, decision strategy and some covariates.

The independent variable in this study was time pressure and the dependent variables were decision accuracy and decision strategy on which the effect of time pressure was studied. Cognitive style was introduced as a moderating variable to observe

the interaction effect of the fit on decision accuracy. Also, the effects of covariates such as age, gender, learning style, decisiveness, mood and preference of visualization were studied.

3.2.4. Pilot. A pilot study was conducted to determine the time pressure thresholds for reasonable and extreme time pressure treatment conditions. A total of 20 participants took part in the pilot study. All the students recruited for the pilot were enrolled in a Midwest university. The task administered to them was the same as used for the actual experiment. The participants were not subject to any time pressure and were allowed to work on the dashboard as long as they long wished to, before they reached a decision.

According to Weening and Marleveld (2002), the decision time under low time constraint was calculated as the decision time one Standard Deviation lower than the mean decision time and decision time under high time constraint was the decision time below 50% of the average decision time. The mean decision time of the 20 participants was calculated to be 3.25 min. Calculation of time constraints for different treatment conditions is shown in Table 3.2.

Table 3.2. Calculation of time constraints for different treatment conditions

Average time taken(min)	Std Deviation	Reasonable Time Pressure	Extreme Time Pressure
3.25	1.29	1.95	1.62

The average time taken for the 20 participants under no time pressure condition was 3.253 seconds. Reasonable time pressure was calcuated by subtracting the standard deviation from the mean response time taken for the participants under no time pressure. It was calculated to be 1.954 min (117 seconds). Extreme time pressure was calcuated as 50% of the mean decision time taken by the participants under no time pressure. It was calculated to be 1.626 min (97 seconds).

4. DATA ANALYSIS AND RESULTS

Data Analysis was conducted using SPSS. The results below are presented in the order of the hypotheses and also listed are the statistical analysis methods used to test each hypothesis.

4.1. EFFECT OF TIME PRESSURE ON DECISION QUALITY

Decision Accuracy was calculated as a percentage by dividing the number of correct responses the participants answered by the total responses for the task. 0% was considered the lowest score of decision accuracy and 100% was considered the highest score. Hypothesis 1 stated that the effect of time pressure on performance, in this experiment measured as decision accuracy, is an inverted "U". i.e. the performance improves with increased time pressure up to a reasonable time pressure limit and decreases when the time pressure becomes too severe. In order to test this hypothesis, a one way ANOVA was conducted with the independent variable as time pressure (manipulated for three treatments: no time pressure, reasonable time pressure and extreme time pressure) and the dependent variable as decision accuracy. Pair wise comparisons were conducted to compare the effect of time pressure conditions on the decision accuracy.

4.1.1. No Time Pressure vs. Reasonable Time Pressure. Table 4.1 displays the results from the one way ANOVA conducted with the independent variable as time pressure (manipulated for three treatments: no time pressure, reasonable time pressure and extreme time pressure) and the dependent variable as decision accuracy. The results from the one way ANOVA showed that the mean decision accuracy of the participants under no time pressure condition was 58.3% whereas the mean decision accuracy of the participants under reasonable time pressure condition was 76.6%, which is greater than the mean decision accuracy of the participants under no time pressure condition. However, the results were not significant ($p=0.119$), as shown in Table 4.3 which displays the results of the LSD pair wise comparison. Table 4.2 shows the results of ANOVA.

4.1.2. Reasonable Time Pressure vs. Extreme Time Pressure. The results from the one way ANOVA in table 4.1. show that the mean decision accuracy of the participants under the reasonable time pressure condition was 76.6% whereas the mean decision accuracy of the participants under the extreme time pressure condition was 85%, which is greater than the mean decision accuracy of the participants under reasonable time pressure condition. The results revealed that decision accuracy increased when the time pressure increased from reasonable to extreme limit. This does not support the hypothesis 1.b which stated that time pressure will begin to drop when the time pressure becomes too severe. The results in this case were also not significant as seen in Table 4.3 which displays the results of pair wise comparisons between time pressure conditions ($p=0.475$). Table 4.2 shows the results of ANOVA.

4.1.3. No Time Pressure vs. Extreme Time Pressure. The results from the one way ANOVA in table 4.1 show that the mean decision accuracy of the participants under no time pressure condition was 58.3% whereas the mean decision accuracy of the participants under extreme time pressure condition was 85%, which is greater than the mean decision accuracy of the participants under no time pressure condition. These results revealed that decision accuracy increased when the time pressure increased from no time pressure to extreme time pressure. The results were found significant as seen in Table 4.3 which displays the results of pair wise comparisons between time pressure conditions ($p=0.025$). Table 4.2 shows the results of ANOVA.

Along with the quantitative results obtained from the survey, notes have been made when each participant performed the task. After they performed the analysis using the dashboard, the users were asked to inform the researcher about their opinion on the nature of the task, simplicity of the task and views on the stimulus being presented to them. 30% of the participants stated that the task was very straight forward and very easy to perform. This may be one reason why insignificant results were observed and hypothesis 1.b was not supported. Also, the time difference between reasonable time pressure and extreme time pressure was observed to be very small (i.e. 20 secs) which could be a possible factor for the insignificant results and hypothesis 1.b not being supported. However, the results for the ANOVA conducted between no time pressure and extreme time pressure were significant, which indicated that the time pressure to which

the users were subject to, was reasonable and hence a significant increase in decision accuracy has been observed in that case.

Table 4.1. Descriptives – Effect of time pressure on decision quality

DQ

Descriptives

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					LB	UB		
1	20	58.3333	40.28408	9.00779	39.4798	77.1869	.00	100.00
2	20	76.6667	37.61921	8.41191	59.0603	94.2730	.00	100.00
3	20	85.0000	31.48377	7.03999	70.2651	99.7349	.00	100.00
Total	60	73.3333	37.73233	4.87122	63.5860	83.0806	.00	100.00

Table 4.2. ANOVA- Effect of time pressure on decision quality

DQ

ANOVA

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	7444.444	2	3722.222	2.771	.071
Within Groups	76555.556	57	1343.080		
Total	84000.000	59			

Table 4.3. Pair wise comparison - Effect of time pressure on decision quality

LSD

Multiple Comparisons

(I) 1= NTP 2=RTP 3=ETP	(J) 1= NTP 2=RTP 3=ETP	Mean Diff (I-J)	Std. Error	Sig.	95% Confidence Interval	
					LB	UB
1	2	-18.33333	11.58913	.119	-41.5402	4.8735
	3	-26.66667*	11.58913	.025	-49.8735	-3.4598
2	1	18.33333	11.58913	.119	-4.8735	41.5402
	3	-8.33333	11.58913	.475	-31.5402	14.8735
3	1	26.66667*	11.58913	.025	3.4598	49.8735
	2	8.33333	11.58913	.475	-14.8735	31.5402

*. The mean difference is significant at the 0.05 level.

4.2. EFFECT OF TIME PRESSURE ON DECISION STRATEGY

The final survey administered to the participants judged their decision strategy with 8 questions on a 5 point Likert scale, in which 4 questions were focused on testing if they were more compensatory than non-compensatory and the other 4 to test the vice versa which were reverse scored. Decision strategy of the participants was calculated by taking the average of all the 8 responses. Participants with scores ranging between 1 and 3 were considered to have adopted a non-compensatory strategy and the participants with scores ranging between 3 and 5 were considered to have adopted a compensatory strategy and the participants with score 3 were considered neutral.

Hypothesis 2 was oriented towards studying the effect of time pressure on decision strategy and stated that users under time pressure condition tend to choose a non-compensatory strategy. This has been derived from the fact that as the time being given to the participants is low, the user tends to adapt a strategy that requires less cognitive workload to make quick decisions. In order to test the hypothesis, a one way ANOVA was conducted with time pressure as an independent variable (manipulated as no time pressure, reasonable time pressure and extreme time pressure) and decision strategy as the dependent variable. The results from the one way ANOVA are shown in Table 4.4. and 4.5. The results from the pair wise comparison performed between the three time pressure conditions are shown in Table 4.6.

Table 4.4. Descriptives - Effect of time pressure on decision strategy
1 – No Time pressure, 2- Reasonable Time pressure, 3 – Extreme Time pressure

Descriptives

DS

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					LB	UB		
1	20	3.1313	.42239	.09445	2.9336	3.3289	2.63	4.00
2	20	2.7813	.39917	.08926	2.5944	2.9681	2.13	3.75
Total	40	2.9563	.44267	.06999	2.8147	3.0978	2.13	4.00

Table 4.5. ANOVA – Effect of time pressure on decision strategy

DQ **ANOVA**

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	1.225	1	1.225	7.254	.010
Within Groups	6.417	38	.169		
Total	7.642	39			

Table 4.6. Pair wise comparison – Effect of time pressure on decision strategy

Multiple Comparisons

(I) 1= NTP 2=RTP 3=ETP		(J) 1= NTP 2=RTP 3=ETP		Mean Diff (I-J)	Std. Error	Sig.	95% Confidence Interval	
							LB	UB
—	1	—	2	.35000*	.13537	.012	.0789	.6211
			3	.41250*	.13537	.003	.1414	.6836
	2		1	-.35000*	.13537	.012	-.6211	-.0789
			3	.06250	.13537	.646	-.2086	.3336
	3		1	-.41250*	.13537	.003	-.6836	-.1414
			2	-.06250	.13537	.646	-.3336	.2086

*. The mean difference is significant at the 0.05 level.

The results showed that the mean decision strategy of users who performed the task under time pressure (both reasonable time pressure and extreme time pressure) fall under the range of non-compensatory strategy (i.e. 0-3) which implies that users under time pressure preferred a non-compensatory decision strategy to make their decision. The results of an LSD pair wise comparison performed to study the effect of the three time pressure conditions on decision strategy were significant in the case of no time pressure vs. reasonable time pressure and no time pressure vs. extreme time pressure conditions. However, the results were not significant in the case of reasonable time pressure vs. extreme time pressure. Also, as a whole, 72.5% participants under time pressure used

non-compensatory decision strategy whereas 25% used compensatory decision strategy. The others did not strongly tend to choose either a non-compensatory or a compensatory decision strategy.

4.3. EFFECT OF COGNITIVE STYLE ON DECISION STRATEGY UNDER TIME PRESSURE

The Cognitive Style Index test has been adopted from research on Cognitive styles by Allinson and Hayes (1996) for categorizing the participants into analytical and intuitive cognitive styles. The test contained 38 trichotomously scored items (true; uncertain; false) in the questionnaire. Nine of the first ten items assess the analytical qualities and nine of the last ten items assess intuitive qualities. 21 items assess analytical orientation scored positively and 17 items assess intuitive dimension with the reverse scoring. Scores for each participant were calculated by adding up the participants responses to all 30 items. Higher score indicated analytical cognitive style and lower score indicated intuitive cognitive style. To be more precise, a score of 0-38 indicated strong intuitive orientation and 37-78 indicated a strong analytical orientation. This test was delivered to all the participants in the experiment before they performed the task to determine their cognitive style.

Hypothesis 3 was oriented towards exploring the unexplored relationship or ”fit” between cognitive style and decision strategy adopted by the users when subject to time pressure to verify if it has an effect on decision quality. The hypothesis stated that the intuitive users perform better than the analytical users when they adopt a non-compensatory strategy under time pressure. In order to test the hypothesis, the scores from the cognitive style index test and survey responses on decision strategy have been normalized to be able to represent them in the same scale. It has been observed from previous literature in the literature review section that there exists a three way interaction effect between cognitive styles, decision accuracy and decision quality. Hence, this research studies the combined effect of cognitive style and decision strategy, which is defined as the “fit” in this context, on decision quality. The fit was calculated by obtaining the difference between normalized score of cognitive styles and the normalized score of decision strategy. In order to determine the existence of a relationship between

the fit and decision accuracy, a regression analysis was performed on the difference between normalized cognitive style and decision strategy scores as the independent variable and decision accuracy as the dependent variable. Tables 4.7, 4.8, 4.9 and 4.10 show the results of regression performed between the cognitive fit and decision accuracy to see if the fit affects the decision accuracy.

Table 4.7. Descriptives - Relationship between cognitive fit and decision accuracy

Descriptive Statistics

	Mean	Std. Dev	N
Decision Quality	80.8333	34.49885	40
|NCS-NDS|	-.2587	.27316	40

Table 4.8. Model Summary- Relationship between cognitive fit and decision accuracy

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error
1	.176a	.031	.006	34.40153

Table 4.9. ANOVA - Relationship between the cognitive fit and decision accuracy

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1444.998	1	1444.998	1.221	.276a
	Residual	44971.669	38	1183.465		
	Total	46416.667	39			

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	1444.998	1	1444.998	1.221	.276a
	Residual	44971.669	38	1183.465		
	Total	46416.667	39			

Table 4.10. Co-efficients - Relationship between cognitive fit and decision accuracy

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	75.069	7.536		9.961	.000
	Difftp	-22.284	20.167	.176	-1.105	.276

From the results showing descriptives, it has been observed that, as the value of difference between the normalized cognitive style and the decision strategy falls below zero, i.e. when the users adopt a non-compensatory strategy for decision making, their decision quality is very high (80%). The value of R square is positive (R square = 0.31). However, the results have not been found to be significant (p = .276). This is likely due to an insufficient sample size of intuitive participants.

4.4. EFFECT OF DECISION STRATEGY ON DECISION ACCURACY UNDER NO TIME PRESSURE

According to Hypothesis 4, when the users are not subject to time pressure, participants who choose compensatory strategy are believed to perform better than the participants who choose a non-compensatory decision strategy. This is believed to happen as the users adopting a compensatory strategy evaluate all the available attributes and cues, gauge them carefully before they reach a decision and do not miss out on any detail.

In order to test this hypothesis, a one way ANOVA has been performed with cognitive style as the independent variable (manipulated as 1- Intuitive and 2- Analytical) and decision accuracy as the dependent variable. Tables 4.11 and 4.12 show the results of the ANOVA. The mean decision accuracy of participants who chose a non-compensatory strategy was 53.3% whereas the mean decision accuracy of participants who chose a compensatory strategy was 60%.

Table 4.11. Descriptives - Effect of cognitive style on decision accuracy

DA **Descriptives**

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					LB	UB		
1.00	5	53.3333	44.72136	20.00000	-2.1956	108.8622	.00	100.00
2.00	15	60.0000	40.23739	10.38925	37.7173	82.2827	.00	100.00
Total	20	58.3333	40.28408	9.00779	39.4798	77.1869	.00	100.00

Table 4.12. ANOVA - Effect of cognitive style on decision accuracy

DQ **ANOVA**

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	166.667	1	166.667	.098	.758
Within Groups	30666.667	18	1703.704		
Total	30833.333	19			

However, the results have not found to be significant (p=0.758). One possible explanation for the insignificant results is the disparity between number of participants who chose compensatory strategy (n=15) and a non-compensatory strategy (n=5).

4.5. ANALYSIS ON FIXATION DATA OBTAINED USING EYE TRACKER

The SAP Xcelsius dashboard containing the financial information for the user to assess was presented as stimuli to the user on a Tobii 1750 eye tracker. The SAP dashboard consisted of three types of information presentation formats which are text, tables and graphs. The same information was presented to all the users to observe which information presentation format was chosen the most by participants in each time pressure condition. The eye tracker was used to collect fixation data for each participant from the first stimulus until the end of the task. Data on fixation duration on each area, namely text, tables and charts for all the participants was extracted from the eye tracker. Fixation Duration is defined as the amount of time spent by the participant on each area of the page or the whole page itself. This data was obtained from the eye tracker to perform analysis. A one way ANOVA was conducted to see the effect of time pressure on the preference of information presentation formats. As the size of all information presentation formats namely text, tables and graphs was not the same, the fixation duration on each area was divided by size to obtained the values of total fixation duration on the same scale for all three presentation formats respectively. Hence, the fixation duration was calculated as;

$$\text{Fixation Duration} = \frac{\text{Fixation duration obtained from the eye-tracker}}{\text{Size of information presentation format}}$$

Table 4.13. Descriptives - Effect of time pressure on tables

Tables **Descriptives**

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					LB	UB		
1	20	86.56	35.250	7.882	70.06	103.05	35	175
2	20	127.65	66.155	14.793	96.68	158.61	25	227
3	20	126.26	66.793	14.935	95.00	157.52	11	247
Total	60	113.49	60.128	7.762	97.96	129.02	11	247

Table 4.14. ANOVA - Effect of time pressure on tables

Tables **ANOVA**

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	21780.187	2	10890.093	3.241	.046
Within Groups	191527.361	57	3360.129		
Total	213307.548	59			

Table 4.15. Descriptives - Effect of time pressure on text

Text **Descriptives**

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					LB	UB		
1	20	121.05	99.146	22.170	74.65	167.45	10	405
2	20	64.33	43.968	9.832	43.75	84.90	13	184
3	20	52.57	38.556	8.621	34.53	70.62	9	180
Total	60	79.32	71.944	9.288	60.73	97.90	9	405

Table 4.16. ANOVA - Effect of time pressure on text

Text **ANOVA**

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	53635.777	2	26817.888	6.072	.004
Within Groups	251743.771	57	4416.557		
Total	305379.548	59			

Table 4.17. Descriptives - Effect of time pressure on graphs

Graphs **Descriptives**

	N	Mean	Std. Dev	Std. Error	95% Confidence Interval for Mean		Min	Max
					LB	UB		
1	20	104.8194	34.26894	7.66277	88.7810	120.8577	28.30	152.38
2	20	88.1835	48.52040	10.84949	65.4753	110.8918	21.61	166.76
3	20	92.1580	53.15797	11.88648	67.2793	117.0367	4.68	183.24
Total	60	95.0536	45.79836	5.91254	83.2227	106.8846	4.68	183.24

Table 4.18. ANOVA - Effect of time pressure on graphs

Graphs **ANOVA**

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3019.059	2	1509.529	.713	.495
Within Groups	120732.823	57	2118.120		
Total	123751.881	59			

Graphs were a major part of the dashboard (50%) followed by tables (38%) followed by text (12%). A one way ANOVA conducted on the data with time pressure as an independent variable (manipulated as no time pressure, reasonable time pressure and extreme time pressure) and the dependent variable as fixation duration on each area/information presentation format. The results of the ANOVA are shown in tables 4.13. to 4.18. For the information presented in tables, the fixation duration increased as time pressure increased from no time pressure to reasonable time pressure but it remained almost constant between reasonable time pressure and extreme time pressure. The reason for fixation duration on tables to increase was the summary table which was presented in the first quadrant of the dashboard was that when time pressure increased the user could be seen relying on a trend in the summary table and reaching a decision without looking at any other tables, graphs or text. The results were significant (p=0.46). In the case of text, the total fixation duration decreased as time pressure increased from no time pressure to reasonable time pressure and then to extreme time pressure. The reason for

total fixation duration on text to decrease under time pressure was that it covered a very small area and also text requires a lot of cognitive thinking to process information compared to graphs and tables. The decrease was also significant (p=0.004). In the case of graphs, the total fixation duration dropped when time pressure increased from no time pressure to reasonable time pressure but increased slightly when time pressure became too severe. However, the results were not significant. (p=.495).

However, there were some interesting findings. Under no time pressure, text received the most attention when compared to graphs and tables. Under reasonable time pressure condition, tables received the most attention when compared to graphs and text and under the extreme time pressure condition; tables received the most attention followed by graphs and then text. Overall, when the users were subject to time pressure, they paid most attention to tables in comparison to text and graphs. This is probably due to the summary table being located on the first quadrant which clearly gives the user a summary of all financial ratios from 2007 through 2011 eliminating the necessity of looking at graphs and text for further detail. However, it is very interesting to find that text received the most attention under no time pressure condition as we would have expected the graphs to receive more attention as they were visually appealing and users could clearly see trends from the graphs.

5. DISCUSSION

5.1. EFFECT OF TIME PRESSURE ON DECISION QUALITY

In some studies, Time Pressure is found to have a non-linear effect on performance and decision making quality. As time pressures became reasonably stronger, performance increased as suggested by Parkinson's Law and as such pressures became more severe, the performance decreased. This is called the time-performance inverted "U model" [29]. This research focused on studying decision accuracy as a measure of performance to test the inverted U model. Results show that mean decision accuracy of the participants under the no time pressure condition was 58.3% whereas the mean decision accuracy of the participants under the reasonable time pressure condition was 76.6%, which is greater than the mean decision accuracy of the participants under the no time pressure condition. Also, the mean decision accuracy of the participants under extreme time pressure condition was 85%, which is greater than the mean decision accuracy of the participants under reasonable time pressure condition. However, the results were not significant. The results showed partial support to the hypothesis as the expectation was to see a curvilinear inverted U relationship between performance and time pressure. Comparison between the performance under no time pressure and extreme time pressure revealed that the mean decision accuracy increased from no time pressure to extreme time pressure conditions and the results were significant (58.3% to 85%). The results were significant in this case. Combining these results with the qualitative data from the participant revealed some interesting findings. 30% of the participants stated that the task was very straight forward and very easy to perform. This is likely one cause for the insignificance of the difference in results. Also, the time difference between reasonable time pressure and extreme time pressure was observed to be very small (i.e. 20 secs) which could be considered a possible factor for the insignificant results. The user perception of time pressure did not change much with the 20 second difference between reasonable and extreme time pressure conditions and hence may have failed to impact performance negatively. Increasing the time pressure threshold under an extreme time pressure condition and giving the users a complex set of tasks to perform will give the researchers more trends/relationships to explore in understanding the effect of time pressure.

5.2. EFFECT OF TIME PRESSURE ON DECISION STRATEGY

The effect of time pressure on decision strategy has been studied in the past and the results from those studies showed that users chose a non-compensatory strategy under time pressure [14]. This research focused on studying the effect of time pressure on choice of decision strategy. Results from this research revealed that mean decision strategy of users who performed the task under time pressure (both reasonable time pressure and extreme time pressure) fell under the range of users who adopted a non-compensatory strategy which implies that users under time pressure preferred non-compensatory decision strategy to make their decision. The results were significant in this case. Also, as a whole, it was found that 72.5% of the participants under time pressure used non-compensatory decision strategy whereas 35% used compensatory decision strategy. Hence, the results from this research supported the results from previous studies [14] on choice of decision strategy under time pressure. Thus, hypothesis 2 was supported.

5.3. EFFECT OF COGNITIVE FIT ON DECISION QUALITY

A model was developed to study the effect of the fit between the cognitive style of a user and the decision strategy adopted, to study its effect on decision accuracy. The fit was defined as the variation between cognitive style and decision strategy. The fit was calculated by obtaining the difference between normalized score of cognitive styles to the normalized score of decision strategy. Descriptives from this research revealed that when the value of difference between the normalized cognitive style and decision strategy falls below zero, i.e. became negative, their decision quality was observed to be very high (80%). However, the results were not found to be significant. Hence, hypothesis 3 was not supported. The reason for this is likely an insufficient sample size of the intuitive participants.

5.4. EFFECT OF DECISION STRATEGY ON DECISION QUALITY

The effect of choice of decision strategy on decision accuracy has also been studied under no time pressure. The results revealed that the mean decision accuracy of participants who chose a non-compensatory strategy was 53.3% whereas the mean

decision accuracy of participants who chose a compensatory strategy was 60%. However, the results were not found to be significant. Hence, hypothesis 4 was not supported. This could have happened because of most participants chose compensatory strategy over non-compensatory strategy when they were not subject to time pressure. 15 out of 20 participants chose a compensatory strategy when only 5 chose a compensatory strategy.

5.5. RESULTS FROM THE EYE TRACKER

Fixation Duration data has been collected using the eye tracker. Fixation Duration is defined as the amount of time spent by the participant on each area of the page or the whole page itself. The SAP dashboard presented as a stimulus to the participants consisted of three types of information presentation formats which are text, tables and graphs. An ANOVA was conducted to observe the effect of time pressure on preference of information presentation format. In this case, more preferred meant more fixation duration and less preferred meant lower fixation duration. In the case of tables, the fixation duration increased as time pressure increased (86.5 to 127.65 secs) from no time pressure to reasonable time pressure but it remained almost constant when time pressure became too severe (127.65 to 126.26 secs). The reason for fixation duration on tables to increase was the summary table which was presented in the first quadrant of the dashboard. When time pressure increased the user could easily see a trend in the summary table and reach a decision without looking at any other tables, charts or text. The results were significant ($p=0.46$). In the case of text, the total fixation duration kept dropping as time pressure increased from no time pressure to reasonable time pressure and then to extreme (121.05 secs -> 64.33 secs -> 52.57 secs). One reason for total fixation duration on text to decrease under time pressure was that it covered a very small area and also text takes a lot of cognitive thinking to process information compared to graphs and tables. These results were also significant ($p=0.004$). In the case of graphs, the total fixation duration dropped when time pressure increased from no time pressure to reasonable time pressure (104.81 secs to 88.18 secs) but increased very little when time pressure became too severe (88.18 to 92.15 secs). However, the results were not significant. ($p=.495$). Some interesting findings in this context were: under no time pressure, text received the most attention when compared to graphs and tables. Under

reasonable time pressure condition, tables received the most attention when compared to graphs and text and under the extreme time pressure condition, tables received the most attention followed by graphs and then text. Overall, when the users were subject to time pressure, they paid more attention to tables than either to text and graphs. This is likely due to the summary table present on the first quadrant which clearly gives the user a summary of all financial ratios from 2007 through 2011 eliminating the necessity of looking at graphs and text for further detail.

5.6. ADDITIONAL ANALYSIS ON EYE TRACKER DATA

In psycho-physiological research, people have observed that people switch between two visual attention states namely local attention and global attention, while exploring complex scenes, which leads to distinct scan paths of eye-movements [15]. Local attention state is when the user focuses on specific aspects and details of the scene, and on examining its content with greater visual detail whereas the focus in the global attention state is on exploring the informative and perceptually salient areas of the scene.

Sample gaze plots and heat maps have been obtained from the eye tracker to perform additional analysis. Fig. 5.1 and 5.2 are the sample gaze plot and heat map of an intuitive participant and Fig. 5.3 and 5.4 are the sample gaze plot and heat map of an analytical participant respectively collected from an eye-tracker when the user was performing the analysis using the dashboard. Fig. 5.1 which corresponds to an intuitive participant shows that the participant looked at some cues or just some part of the available information and did not look at all the available cues or information which was available on the dashboard to reach a decision. Hence the gaze-plot is not intense when compared to those of the analytical participant in Fig 5.3.

Talking in terms of local scan path and global scan path, an analytical participant is believed to adopt a local scan path as local attention state is said to be the state when the user focuses on specific aspects and details of the scene, and on examining its content with greater visual detail. An analytical person is said to believe in detailed, methodical work [28] and an analytical person adopts a compensatory strategy which is in line with the analytical style of the user under no time pressure.

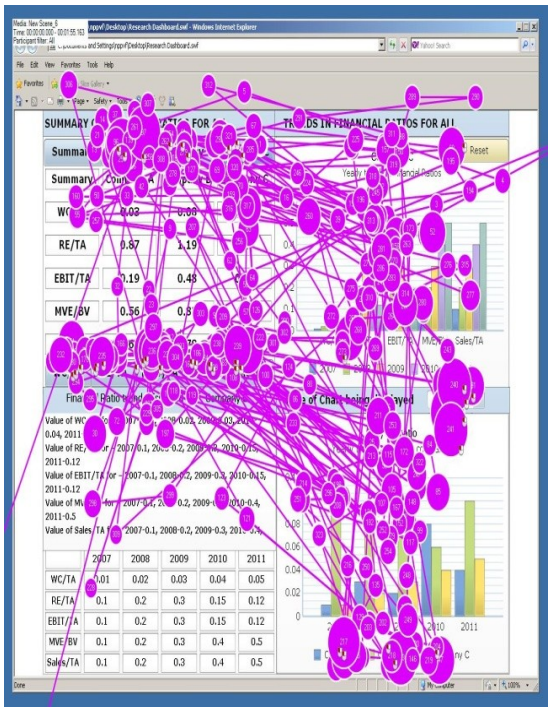

Fig. 5.1 Gaze plot of an intuitive individual

Fig. 5.2. Heat map of an intutive individual

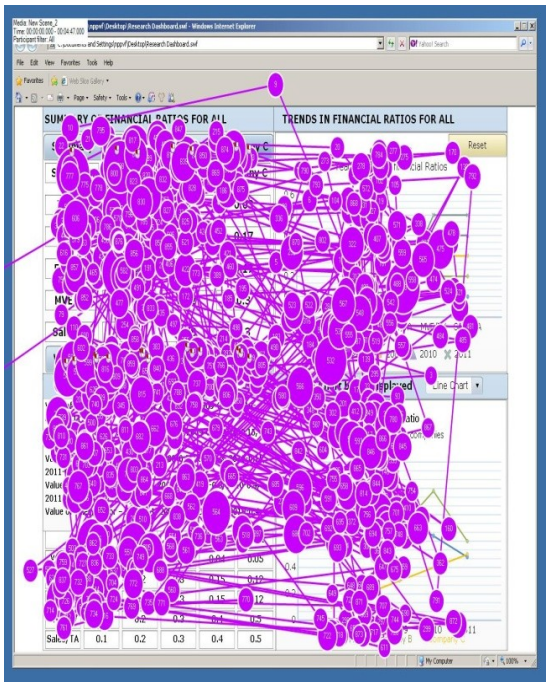

Fig.5.3. Gaze plot of an analytical individual

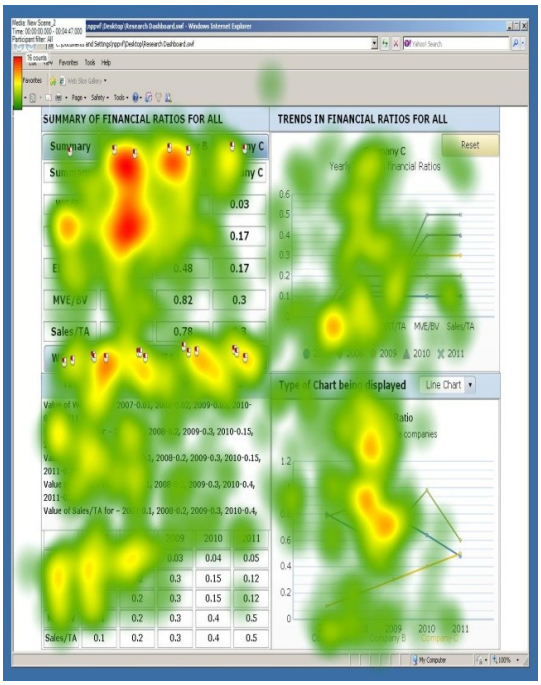

Fig.5.4. Heat map of an analytical individual

An intuitive participant is believed to adopt a global scan path as global attention state is on exploring the informative and perceptually salient areas of the scene and an intuitive person is described as the one who does not perform detailed analysis but scans for important cues to make his decision [28] and an intuitive user usually adopts a non-compensatory strategy under no time pressure. Hence, the intention is to notice a gaze plot with more fixation points in each area in the case of an analytical participant when compared to the intuitive participant.

The gaze plot of an analytical individual who adopted a compensatory strategy is shown in Fig. 5.1. From the gaze plot, the user tends to focus on each quadrant of the dashboard more than compared to Fig. 5.3 which shows the gaze plot of an intuitive individual who adopted a non-compensatory strategy. It is also interesting to note that both the participants focused more on the summary in the first quadrant of the dashboard showing a red area in the heat map. This is in line with the results from the analysis on raw data from the eye tracker which reveals the fact that tables were paid the most attention to, when compared to graphs and text.

6. IMPLICATIONS

Time pressure has become prevalent, not only in professional areas, but also in our day to day lives. A study by ABS in 2006 on time pressure revealed that people belonging to the age group 25 to 34 always/often feel rushed or pressed for time. The majority sample size used in this research belongs to that age group and hence the results are very relatable to most decision making situations under time pressure.

The behavior of users under time pressure when interacting with a decision making system involves a lot of aspects to it such as familiarization with the interface in a limited time, adopting a strategy to process the information being presented to them and finally reaching a decision. The process of decision making as a whole has been studied to observe the effects of time pressure on cognitive styles, decision strategies and performance and some results were observed to be in line with previous studies. Hence, this research adds strength to the studies in the past which concentrated on studying the effects of time pressure on decision making. This study also substantiates the theory that decision making is affected differently under different levels of time pressure.

Decision support systems are raging technology and are being widely used by management personnel in various global organizations to help them improve their process of enterprise decision making, and these decisions often are made under time pressure. The technology used in this research is SAP Xcelsius, which is a product of the SAP Business Objects Suite. The dashboard developed used in this study is a financial dashboard similar to dashboards used in real environments to perform financial analysis. Hence, the results from this study will be useful to future researchers that intend to study the effects of time pressure on decision making using complex decision support systems similar to the SAP Business Objects Suite.

7. LIMITATIONS

The sample used for this study consisted purely of under graduate and graduate students from a Midwest university. But care has been taken to see that the participants were familiar with the technology and the financial terms used as a part of their analysis by providing them the appropriate training. However, for further research, the sample can be a set of financial analysts working for a company in a real environment, so the results can be more relatable to enterprise decision making.

The study focuses on using a financial decision making task and hence the results might not be applicable to general decision making as financial decision making is considered risky when compared to other types of decision making.

The platform used to develop the task for participants to work on, was SAP Xcelsius which is a product of the SAP Business Objects Suite. Hence, there is a possibility that the results this study might be applicable to similar platforms used for decision support but not to all decision support systems.

8. CONCLUSIONS AND FUTURE WORK

This study was focused on studying the effects of time pressure on decision accuracy and decision strategy. The results from this study were very encouraging. It has been observed that decision quality, in this study, measured as decision accuracy increases with an increase in time pressure. Though time pressure has been manipulated on three levels and it was expected that the relationship between time pressure and decision quality was an inverted U, that has not been observed from the results as the difference between reasonable and extreme time pressure was not much and the users did not experience the difference between extreme and reasonable time pressure limits. The results also showed that under time pressure, participants tended to adopt a non-compensatory strategy over compensatory strategy for decision making. The results found when the effect of fit was studied on decision quality were also not significant due to insufficient sample size. However, the responses from the eye tracker revealed some interesting facts on preference of information presentation format under different levels of time pressure. Under a no time pressure condition, participants preferred to read text over graphs and tables. Under reasonable and extreme time pressure limits, participants focused more on tables.

Future plans for this research will be focused on refining extreme time pressure more accurately to re-study the inverted U model and also on developing a more complex set of tasks for the participants to perform analysis on the dashboard in order to elicit stronger trends in decision making under time pressure. The usage of EEG (Electroencephalogram) device is also part of the future plan. The EEG device uses a set of sensors to tune into electric signals produced by the brain to detect player thoughts, feelings and expressions. Using this device in the research can help understand the participants' thoughts and expressions better while performing tasks using the technology. Also, additional analysis will be performed on the pupil dilation data obtained from the eye tracker to measure arousal while analyzing the dashboard and EDA data obtained from Q sensor will be analyzed to measure stress under different time pressure conditions.

APPENDIX

Description of Financial Ratios (Obtained from forbes.com)

1. Working Capital / Total Assets. This ratio measures liquid assets in relation to the size of the company.

2. Retained Earnings / Total Assets. This ratio measures profitability that reflects the company's age and earning power.

3. Earnings Before Interest and Taxes / Total Assets. This ratio measures operating efficiency apart from tax and leveraging factors. It recognizes operating earnings as being important to long-term viability.

4. Market Value of Equity / Book Value of Total Liabilities. This ratio adds market dimension that can show up security price fluctuation as a possible red flag.

5. Sales/ Total Assets. This ratio is a standard measure for total asset turnover (varies greatly from industry to industry).

Note: The greater these ratios are the better the financial health of the company will be.

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