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Risky Decisions And Decision Support: Does Stress Make A Difference?

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Abstract

Studies of human decision making have demonstrated that stress exacerbates risk taking. Since all decisions involve some element of risk, stress has critical impact on decision quality. Decisions are found to improve with stress up to an optimal threshold beyond which deterioration is observed. However, few studies have examined the psychological experiences underlying risk-taking behavior in conjunction with stress creators. In this paper we propose a research framework that integrates pre-conditions of stress (perceptions of high gain/loss, risk, complexity, and organizational pressure) with observed psychological experiences (time pressure, uncertainty, information overload, and dynamism) that potentially result in risky decision making. This framework suggests that decision support systems have the potential of mitigating or enhancing the psychological perceptions of stress and, hence, impacting decision quality. Empirical testing of a component of this framework provided interesting preliminary results. Subjects experiencing high stress indicated the same levels of perceived uncertainty and dynamism as subjects exposed to low stress, suggesting that use of a decision support system mitigated the perceptions of dynamism and uncertainty for the high stress group. Contrary to hypotheses, the use of a decision support system did not mitigate perceptions of information overload.

Keywords: decision making under stress, decision support, information overload, time pressure, decision quality, stress, Yerkes Dodson Law

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Risky Decisions and Decision Support -
Does Stress Make a Difference?

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ABSTRACT

Studies of human decision making have demonstrated that stress exacerbates risk taking. Since all decisions involve some element of risk, stress has critical impact on decision quality. Decisions are found to improve with stress up to an optimal threshold beyond which deterioration is observed. However, few studies have examined the psychological experiences underlying risk-taking behavior in conjunction with stress creators. In this paper we propose a research framework that integrates pre-conditions of stress (perceptions of high gain/loss, risk, complexity, and organizational pressure) with observed psychological experiences (time pressure, uncertainty, information overload, and dynamism) that potentially result in risky decision making. This framework suggests that decision support systems have the potential of mitigating or enhancing the psychological perceptions of stress and, hence, impacting decision quality. Empirical testing of a component of this framework provided interesting preliminary results. Subjects experiencing high stress indicated the same levels of perceived uncertainty and dynamism as subjects exposed to low stress, suggesting that use of a decision support system mitigated the perceptions of dynamism and uncertainty for the high stress group. Contrary to hypotheses, the use of a decision support system did not mitigate perceptions of information overload.

Keywords: decision making under stress, decision support system, information overload, time pressure, decision quality, stress, Yerkes Dodson Law

1.0 INTRODUCTION

Cognitive science has recognized that "psychological stress exceeding a certain intensity affects the quality of decision making" (Keinan, 1987). Proposed aids to decision making under stress (DMUS) have varied with significant emphasis being placed on use of decision support systems (DSS) (Smith, Arnold and Sutton, 1997; Smith, Johnston and Paris, 2004; Sarter and Schroeder, 2001). Although studies have been completed in specific domain areas, the rich and varied theoretical viewpoints emerging from psychology, information systems, and organizational behavior have led to mixed results. Many of these studies concluded that decision making under extremely stressful conditions such as emergency response can only be studied within the specific application domain of interest (Hutchins, 1996) relying on previous training (Klein, 1989; Kowalski-Trakofler, Vaught and Scharf, 2003) and preparatory information (Inzana *et al.*, 1996). Researchers argued that decision aiding in such situations had to be tailored to the specific decision and user group (Klein *et al.*, 1993). Under the more normal conditions encountered in business and managerial situations, decision making has been studied more generally in terms of stressors such as time pressure and information overload (Smith, Arnold and Sutton, 1997; Maule, Hockey and Bdzola, 2000; Marsden, Pakath and Wibowo, 2002; Aminilari and Pakath, 2005). Studies have shown that DSS can assist the user in these situations and improve decision quality. Although some researchers have suggested that "the value of a computer-based decision aid may be most apparent under higher stress conditions" (Grabowski and Sanborn, 2001, p.114), few have conducted an in-depth assessment of decision quality and specific psychological experiences using a DSS under stressful compared to low stress conditions.

In this paper we propose an integrative framework for DMUS that associates pre-conditions of stress (perceptions of high gain/loss, risk, complexity, and organizational pressure) with psychological experiences (time pressure, uncertainty, information overload, and dynamism) that result in potentially risky decisions. The framework relies on the vast body of prior empirical literature to suggest a mitigative role for DSS on psychological perceptions of stress and, thereby, decision performance. We conduct an exploratory investigation of this model with a group of 89 decision makers.

The next section provides an overview of the literature associated with decision making under stress and examines preconditions and manifestation of stress in decision making. An integrating model based on the literature is proposed in Section 3.0 to explain the mitigating effect of DSS. The experimental study is then described in Section 4.0, and data are presented together with analyses. Results are discussed in Section 5.0, and the paper concludes with a summary and contributions to the literature.

2.0 BACKGROUND

2.1 Stress and Decision Making

Cognitive resource theory (Vecchio, 1990) confirms that stress can negatively impact intelligence and decision quality. Harassed decision-makers often make riskier decisions (Lehner *et al.*, 1997). Baradell and Klein (1993) reported that stress, perceived as time pressure, low self-esteem, and threats of punishment for poor performance, resulted in more errors on cognitive tasks, use of stereotypes when making judgments, and a greater tendency to ignore situational norms in reaching decisions. In group settings, Smith, Arnott, and Sutton (1997) found that the quality of group decisions declines under conditions of stress. Stressed decision makers usually demonstrate impaired performance (Ahituv, Igbaria and Sella, 1998) and generate fewer alternatives in the decision process because these alternatives appear less attractive under conditions of stress (Mann and Tan, 1993; Svenson, Edland and Karlsson, 1985). In sum, numerous studies have confirmed deleterious effect of stress on decision quality.

Diverse explanations have been proposed for demonstration of deleterious behavior under stress. Decision makers seek rational solutions which may not be accessible under the circumstances (Fiedler, 1986). They ignore crucial information, use simplifying and often inefficient strategies (Lehner *et al.*, 1997; Svenson and Edland, 1987), and become extremely alert to discrediting evidence (Wright, 1974). Janis (1993) proposed decision conflict theory as a coping behavior that decision makers use to respond to stress by becoming hyper vigilant in their search for information. In this state they frantically search for a solution, fail to consider all alternatives, process information in a disorganized manner, and rapidly shift among possible solutions. Furthermore, stress can interfere with a fair evaluation of appropriateness of responses (Baumann, Sniezek and Buerkle, 2001). Typifying recency and availability bias (Tversky and Kahneman, 1974), under stressful conditions decision makers can revert to familiar responses from prior experiences which may be inadequate for the challenging situation at hand (Kaemph *et al.,* 1996).Since rationality is bound by ability of the human mind to process complex information (Simon, 1997), demands of stressful conditions are often beyond the capabilities of human short term memory (Smith, Johnston and Paris, 2004). Physiological explanations (de Quervain *et al.* 2000) suggest that stress can cause the release of steroids that can interfere with short term memory. Under such circumstances, decisions are more likely to be faulty than decisions resulting from rational, organized decision making.

Much research effort in DMUS has focused on decision making under extreme emergency situations as those experienced by emergency personnel. Such studies exist in the area of emergency management (Kowalski, 1995), air and military warfare (Morrison *et al.*, 1997; Angelborg-Thanderz, 1997; Hutchins, 1996), commercial aviation (Poulton, 1976), and nuclear emergencies (Papamichail and French, 2005). Managerial DMUS has focused largely on the impact of stress induced by time pressure with significant focus in the auditing and accounting areas (Smith *et al.*, 1997; Arnold *et al.*, 1998; Sutton *et al.*, 1998; Arnold *et al.*, 2000). Our work falls within this domain of management decision making.

2.2 Pre-conditions to and Psychological Manifestation of Stress

What causes stress i.e. what are its pre-conditions? While much has been written in the context of job and organizational stress, for purposes of this paper, we examine stress as experienced in individual decision settings, with the acknowledgement that general work stress can impact the decision maker's response to individual settings. In this narrower domain, we found four key factors that led to stressful decision situations. First, perceptions of high gain or loss in the decision can result in increased stress while taking that decision (Frisch and Clemen, 1994). When combined with the riskiness of outcome (a probability measure), high gain/loss can enhance the perception of stress. Third, when the decision environment is complex and highly unstructured, individuals can feel increased stress (Johnston, Driskell and Salas, 1997; Hollnagel, 1987, 1993) since there are fewer past experiences to revert to. Finally, as there is increased organizational/internal pressure to achieve success from this decision (Kirby and Davis, 1998), individuals may encounter greater perceptions of stress. Although on some scale, most semi-structured decisions would qualify as stressful decisions, we do emphasize that the intensity of these conditions will be higher in order to create stress (Keinan, 1987).

Under conditions described above, the decision-maker will undergo several negative psychological experiences that can impact decision quality. These perceptions of negative experiences have been termed more broadly as stress. In current literature, stress has been measured as perceptions of increased time pressure (Smith, Arnold and Sutton, 1997; Arnold *et al*., 1998; Sutton *et al*., 1998; Arnold *et al*., 2000), perceptions of increased information overload (Smith *et al*., 1997; Marsden *et al.*, 2002), increased perceived dynamism of the decision situation, and increased uncertainty in the decision environment(Field *et al*., 2006).

A common trigger for stress is perception of increased time pressure. Although this perception can positively impact the focus required for task completion (Karau and Kelly, 1992), it is most often associated with reduced decision quality (Hwang and Lin, 1999; Kelly and McGrath, 1985; Karau and Kelly, 1992; Stokes and Raby, 1989).

Stress measured as information overload is also found to be detrimental to decision quality (Smith *et al.* (1997), Marsden *et al.* (2002), Hahn *et al*. (1992). Information overload is exhibited when the decision maker is receiving more information than he/she can process for effective decision making. Often this decline in decision quality is evidenced by inconsistent decision-making, disagreement with composite judgment, and lower consensus (Chewning and Harrel, 1990). Lamb (1991) indicates that information processing capability is limited in humans and animals and when the level of information exceeds that capacity selective attention is used to process some information at the expense of other information. Vugdelija and Aguirre (2004) point out that information overload has a paralyzing effect in crisis situations, and it becomes increasingly difficult to distinguish vital information from secondary information. Other studies such as those by Schultze and Vandenbosch (1998), Chewning and Harrel (1990), and Kim (1998) have also examined the impact of information overload on decision quality, though not necessarily under conditions of stress.

Stressful decision situations increase in intensity as the element of dynamism, such as constantly changing criteria or environment for the decision, is introduced. The decision environment becomes particularly intense when the decision maker has to make rapid, independent decisions under changing conditions such as those associated with threat assessment (Phillips-Wren and Forgionne, 2002). In Kersthot(1994), subjects were required to monitor an athlete running a race and determine if the athlete needed treatment to restore her fitness level. Subjects tended to use a judgmental approach even though an action-oriented strategy would have given the best return. They waited longer to intervene when the probability of false alarms increased, but maintained the same intervention level across time pressure conditions. Waiting longer to take action under conditions of uncertainty has been called 'action-postponement' and explained as thinking that a decision maker can postpone action until after nature moves (Pomerol, 2001). Executive decisions are inherently dynamic since decision makers need more than minimal information, layered advice, fast conflict resolution, and integration between decisions and tactical plans to make rapid decisions (Eisenhardt, 1989).

Uncertainty, the lack of complete knowledge about a situation, is known to negatively impact a decision maker's ability to process data and information in a decision situation (Simon 1980, Nutt, 1990; Landsbergen *et al*., 1997). It creates fear and/or indecisiveness (Covey, Merrill and Merrill, 1994) and causes bias that interferes with rational decision making (Hey, 1993). Mahan *et al.* (1999) suggested that when faced with irreducible levels of uncertainty, decision makers often use expert judgment, and that decision support can drive the decision maker toward a particular type of cognition. Field *et al*. (2006) found that uncertainty reduction strategies were associated with improved performance. Hey, Loloto and Maffioletti (2008) found that subjects simplify in uncertain situations instead of using more sophisticated decision rules.

Business and emergency decisions share similar preconditions, although at varying levels. We suggest that stressful managerial decision environments require at least one of four pre-conditions: (1) a situation of high/gain or loss; (2) a risky outcome; (3) a complex decision environment; and, (4) organizational pressure to minimize the negatives of a decision. These preconditions then result in a manifestation of stress, often represented as (1) time pressure; (2) information overload; (3) uncertainty of decision parameters; and/or (4) perception of dynamic decision environment.

2.3 Decision Support for Decision Making

Several studies have provided evidence toward the positive role of DSS on improved decision quality. For instance, Haubl and Trifts (2000) found that online buyers make more efficient and better quality decisions when interactive decision aids are provided to them in early phases of their decision process. Benbasat, Dexter and Todd (1986) investigated the influence of different information representations, color, and information presentation on user perceptions and decision performance under varying time constraints. Color led to improvements in decision making under time pressure. Zeleznikow and Nolan (2001) found that soft computing methods could be integrated with statistical methods, reasoning from imprecise data, and knowledge discovery from databases to provide effective decision support in uncertain environments. Vugdelija and Aguirre (2004) developed an expert system for a power plant to analyze incoming information in real-time and verbally announce recommendations for operation. Such organized information feeds resulted in quick response time, identification of relevant information, emotionless reasoning, enhanced knowledge, and expert advice. Similarly, Lee (2004) proposed a multi-agent system to deal with information overload in electronic commerce and Turetken and Sharda (2004) utilized fisheye-based clustering and visualization to mitigate adverse effects of information overload from Web searches. Recently, Aminilari and Pakath (2005) examined the effectiveness of written text and images on decision makers under time pressured financial situations. Image users earned more in this simulation but utilized less accurate search strategies as compared to text users.Multimedia (Metha, Webb and Bitter1995), volumetric displays using laser technologies to view 3D images (Wild and Griggs, 1998), and decision-centered screen displays (Thordsen, 1998) have all been proposed as improved decision support solutions.

Despite these initiatives, the use of decision aids has largely focused on system design and human-computer interaction issues. Furthermore, results on the beneficial use of decision technologies have been equivocal. Other studies we encountered, such as that by Akbari and Menhaj (2000), focused largely on design of decision aids and overlooked performance degrading issues such as stress and workload. Furthermore, where decision aids were implemented, few studies adequately reported their impact on psychological experiences such as time pressure and information overload (Xia and Rao, 1999; Negnevitsky, 1996). This equivocality is manifested in our limited understanding of how decision making is impacted by psychological stress and the mitigating effect of decision aids (Kontogiannis, 1996).

3.0 AN INTEGRATED MODEL OF DECISION MAKING UNDER STRESS

Discussion in the previous section highlights the need to assimilate the disjointed but potentially complementary pieces of research in DMUS support. In our proposed model, we aim to integrate the two parts of previous research on DMUS – pre-conditions to stress, i.e. the stress creators, and perceptions of stress i.e. the psychological manifestation of stress. Figure 1 presents this integrative framework. The model presents factors that both create a stressful decision situation and those that are experienced once the decision maker is involved in a stressful situation.

The framework further proposes the intervening role of DSS on perceptions of stress. Specifically, the use of DSS can potentially mitigate the negative psychological experiences associated with stress and thereby improve decision quality. On the other hand, for certain psychological factors, DSS may have the opposite effect – that of worsening the perception of the stressor. The DMUS Framework in Figure 1 further suggests that DSS will have little effect in mitigating pre-conditions to stress since these are defined by organizational and decision environment. Consistent with all existing literature, any mitigation of psychological perceptions will improve decision quality. In contrast, if the DSS has deleterious effects on psychological perceptions of the decision maker, decision quality will be appropriately harmed.

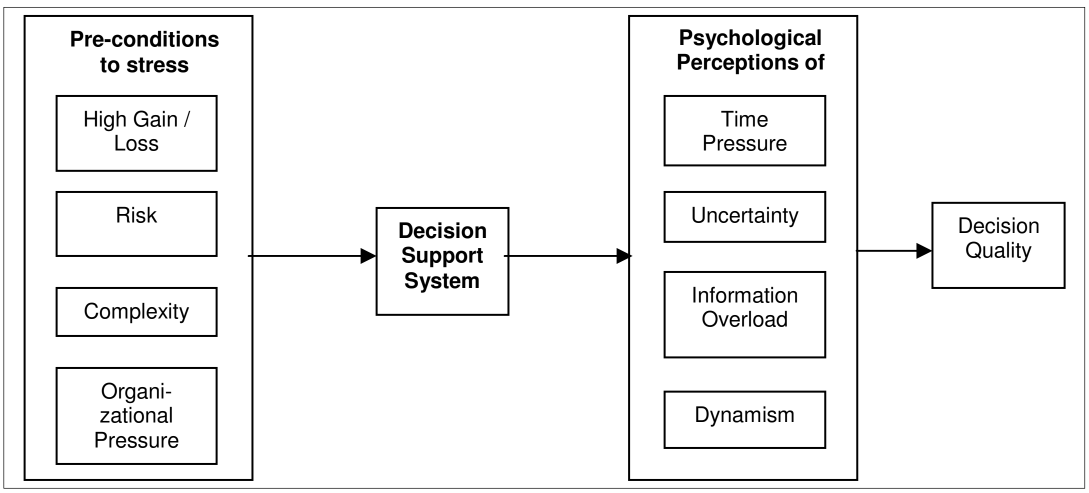

Figure 1. The DMUS Framework - Proposed model to characterize stressful decision situations, decision quality, and the mitigating role of decision support systems.

The framework makes several suggestions, all of which can benefit from further research:

Proposition 1(a): Individuals who experience high gain or loss situations will perceive greater stress manifested as dynamism and uncertainty as compared to individuals who do not perceive such a risk.

Proposition 1(b): Individuals who perceive high gain or loss situations and use DSS for decision making will experience lower levels of dynamism and uncertainty as compared to individuals who do not use such a decision aid.

Proposition 2(a): Individuals who perceive high risk in their decision environment will perceive greater stress manifested as dynamism and uncertainty as compared to individuals who do not perceive such a risk.

Proposition 2(b): Individuals who perceive high risk situations and use DSS for decision making will perceive lower levels of dynamism and uncertainty as compared to individuals who do not use such a decision aid.

Proposition 3(a): Individuals who perceive complexity in their decision environment will perceive greater stress manifested as time pressure, information overload, dynamism, and uncertainty as compared to individuals who do not perceive such a risk.

Proposition 3(b): Individuals who percieve complexity in their decision environment and use DSS for decision making will experience lower levels of time pressure, information overload, dynamism, and uncertainty as compared to individuals who do not use such a decision aid.

Proposition 4(a): Individuals who perceive organizational pressure in their decision environment will perceive greater stress manifested as time pressure and dynamism as compared to individuals who do not perceive such a risk.

Proposition 4(b): Individuals who perceive organizational pressure in their decision environment and use DSS for decision making will experience lower levels of time pressure and dynamism as compared to individuals who do not use such a decision aid.

We examine some of these propositions in this paper.

4.0 EXPERIMENTAL STUDY

To conduct a preliminary test of our model we executed a research study with 123 undergraduate business students enrolled in a business information systems course. Student subjects have been widely used to study decision making and risk-taking situations (Valacich *et al.*, 2009). Valacich et al. (2009) pointed out that there are numerous studies comparing student decision making with managers in real organizations indicating that "there are few differences in the costs, erraticism, or patterns of biases in decisions made by these two groups" (p. 905). In addition, student subjects are often preferable to practicing managers when studying decision making due to organizational influences that are difficult to control.

The subjects in the study were divided into low and high stress groups based on the treatment that was administered to them. The pre-conditions of stress proposed in the DMUS framework were used to create conditions of high and low stress. A DSS was made available to both the high and low stress groups. The decision task was to invest $50,000 in a portfolio of stocks for a company with the intent of maximizing return. Motivating factors were incentives of $10 gift certificates for food, at least one in each class, and a $100 grand prize for the overall best decision.

Demographics of the subject group were fairly homogeneous. All subjects were enrolled in a university in the same introductory business course with a common syllabus across all sections, were in the 19-20 year old age group, had been admitted based on similar characteristics such as grades and high SAT scores, and were in class sizes of about 25 students each with four instructors with equivalent educations and experience. Four class sections were taught by two different instructors so that each instructor had two different treatment scenarios, one under stress and one not under stress. All subjects used a DSS as shown in Figure 2. Participation was voluntary, and the experiment was held during class in a controlled computer lab.

4.1 The Decision Task and Stress Conditions

Subjects were given the scenario of a first job in which they have $50,000 to invest in a portfolio of stocks for their company. The decision problem was to choose a stock portfolio for investing their funds to optimize value while minimizing risk. The portfolio consisted of 37 stocks divided into sectors as shown in Appendix 1 and drawn from actual historical data.

Subjects were told to invest at least $10,000 in each of 3 different areas such as technology, energy, etc. They did not have to invest all of the money and any remainder was left as cash with no interest. Data were provided for the share price for each of the last 4 quarters, the current share price (the purchase price), and the historical return rate. Subjects were informed that:

*Expected Return = (Avg. share price over 5 data points) * (# of shares purchased) * (historic annual rate of return)*

Instructions were presented in writing and verbally in the same manner in each class. Subjects were provided opportunities through a follow-up Q&A session to obtain clarification on the task.

Risk was described as the variability of the share price, that is, the more variable the stock price has been, and the more money put into it, the more risky the portfolio. On the other hand, more risk usually translates into higher potential earnings. The decision question was posed as: How should you invest up to $50,000 in a stock portfolio (3 different areas, at least $10,000 per stock, do not have to invest all your money) so that you maximize your portfolio value while minimizing your risk? Maule and Svenson (1993) define risky decisions as those "characterized by coupling between alternatives and outcomes that are probabilistic and therefore cannot be predicted with certainty" (p. 9), and this scenario is consistent with their definition.

Following our proposed model in Figure 1, preconditions to stress were introduced. High gain/loss was simulated using the $50,000 investment amount with potentially high return or high loss. Risk was directly calculated as described later in section 4.2 and stocks with high variability were included. Complexity was captured through the large number of stocks, multiple constraints on investing, necessity of balancing return and risk, and lack of experience on the part of the users. Organizational pressure was introduced by posting class competition scores and giving one grand prize to the entire winning class. Individual scores were also posted with the permission of each person to increase stress and all results were announced publicly as was known ahead of time.

The treatment conditions varied stress in one of two experimental conditions. The psychological manifestations of stress were time pressure, uncertainty, information overload, and dynamism. Time was specifically manipulated. The large number of choices and complexity of the decision provided an environment where we expected subjects to experience the other three stressors. In the low stress conditions subjects were given unlimited time to make their decisions, and in the high stress conditions subjects were given 10 minutes. The variability in the stock prices and large amount of information presented many possibilities, and subjects were not able to investigate all scenarios within the allocated 10 minutes.

A DSS must be matched to the decision problem and to the decision maker (Howard, 1988). The DSS was written specifically for the experiment and consisted of an interface for investment, drill-down into the stock past performance with tables and graphs, user input for various portfolio choices, and output of the expected return and the associated risk. The interface is shown in Figure 2. There is large variability possible with the design of the DSS, and in order to remove the DSS as a variable in the study, we chose to vary stressors in the experiment.

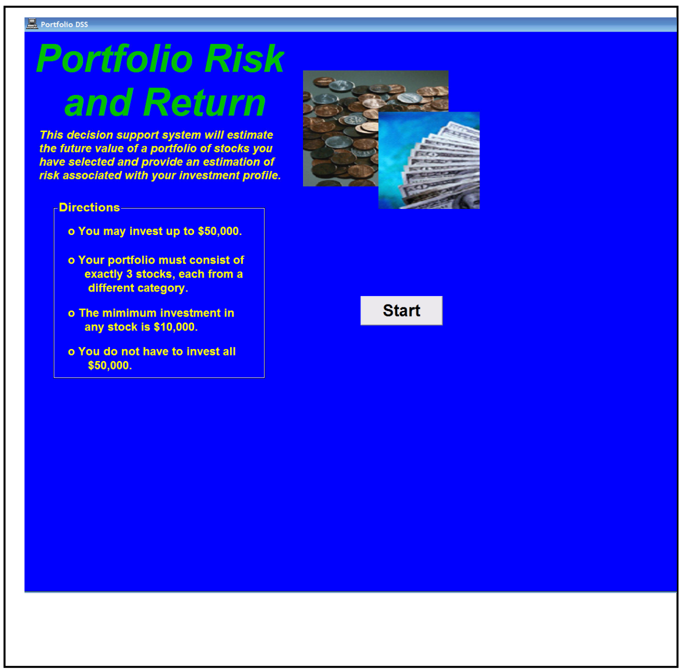

Figure 2. Screen print of the interface for the DSS.

4.2 The Decision Environment - Portfolio Risk, Return, and Optimization

Investors seek to maximize return on investments while maintaining an acceptable level of risk. Risk and return are related, with higher return usually associated with higher risk. A portion of the risk associated with an individual stock can be diversified away by balancing it with less risky stocks for a given level of investment. The Expected Return on a portfolio was computed as the weighted average of the expected returns on the stocks that make up the portfolio, with the weights reflecting the proportion of funds invested in each stock (Ballestero and Pla-Santamaria, 2004). That is, for n stocks, i = 1 to n,

$$E[R_p] = \sum w_i E[R_i]$$

where $E[R_p]$ is the expected return on the portfolio, n is the number of stocks in the portfolio, w_i is the proportion of funds invested in stock i, and $E[R_i]$ is the expected return on stock i.

The variance (or standard deviation) of a portfolio reflects the variance (or standard deviation) of the stocks that make up the portfolio as well as how they vary together, measured as the covariance or correlation coefficient. Risk was calculated as the weighted average of the variances of individual stocks, with the weight based on the amount of funds invested in each stock in the portfolio. That is, for n stocks, i = 1 to n,

$$Risk = \sum w_i s$$

where $E[R_p]$ is the expected return on the portfolio, n is the number of stocks in the portfolio, w_i is the proportion of funds invested in stock i, and $E[R_i]$ is the expected return on stock i.

An optimal portfolio can be defined in one of two equivalent ways:

(1) For any level of volatility (or risk), select the portfolio that has the highest return.

(2) For any expected return, select the portfolio with the lowest volatility (or risk).

Either definition can be satisfied with a portfolio from the stock options called the *efficient frontier* with the set of portfolios obtained from one definition the same as those from the other definition. The efficient frontier for our stock options is shown in Figure 3.

The graph has the normal bullet nose shape, with the region in the center between the branches being other portfolios that can be formed from the stock options. The top branch or positively sloped portion of the graph is the efficient frontier. We defined the optimal portfolio under the constraints in our experiment as the point at the top of the efficient frontier; that is, it is the point at which we have maximum return for minimum risk.

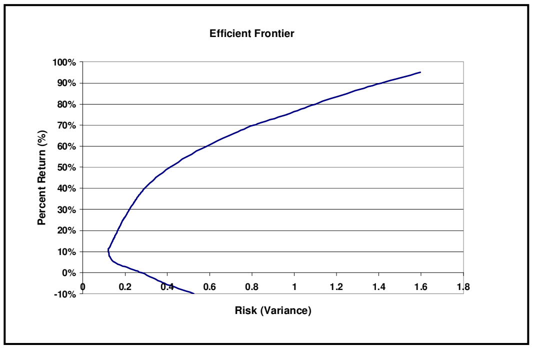

Figure 3. Efficient Frontier for portfolios in experiment.

4.3 Experimental Result

Subjects in each of the two experimental conditions reported portfolio selections under our constraints and experimental conditions. A review of portfolio selection results (HSDSS=59, LSDSS=64) resulted in the elimination of data from subjects who did not adhere to the guidelines, i.e. invest at least $10,000 in each of 3 different areas any remainder left as cash with no interest. This resulted in a final sample of n=53 for HSDSS cases and n=55 for LSDSS cases for portfolio results. The mean return, standard deviation, and mean risk are reported in Table 1.

Table 1. Experimental Return and Risk of Portfolio Compared to Treatment Condition

	Number Subjects (n)	Mean Return	Std. Dev. Return	Mean Risk (Variance)	Std. Dev. of Risk
HSDSS	53	$62258.39	$13374.95	3.720	8.943
LSDSS	55	$73918.71	$17409.49	2.201	2.759

Normality of the samples was checked using the Anderson-Darling goodness-of-fit test statistic at a significance level of 0.05. This indicates whether a data sample comes from a population with a specific distribution. It makes use of the specific distribution in calculating critical values. Anderson-Darling is a one-sided test wherein the hypothesis that the distribution is a particular form is rejected at the chosen significance level if the test statistic is greater than the critical value for the normal distribution. The adjusted Anderson-Darling statistic is multiplied by a constant that depends on the sample size (Trujillo-Ortiz, 2007). The results of the Anderson-Darling test is shown in Table 2. As can be seen, none of the distributions are normal, and therefore we could not use statistical tests assuming normality.

Table 2. Results of the Anderson-Darling test for the samples at alpha=0.050.

	Sample size	Anderson-Darling statistic	Anderson-Darling adjusted statistic	Probability associated to the Anderson-Darling statistic	Distribution
HSDSS	53	3.4465	3.4980	0.0000	Not normal
LSDSS	55	2.9846	3.0275	0.0000	Not normal

Next, we tested the hypothesis of equal medians for the two independent unequal-sized samples using the Wilcoxon rank sum test with a significance level of 0.05. The test is used when populations are not normal in place of the two sample t-test. The test consists of combining the samples into one sample, sorting the result, assigning ranks to the sorted values, and then finding the sum of the ranks. If the two populations have the same distribution then the sum of the ranks in each sample should be close to the same value. Comparing the LSDSS case with the HSDSS case, the Wilcoxon rank sum test yields p=2.8111e-004, and we reject the null hypothesis that the medians are equal. We are 95% confident that the two samples are drawn from different populations.

4.4 Psychological Responses

At the participant level, the outcome of a stressful situation can be driven by several personality and environmental factors. Some that particularly concerned us were individual ability to handle stress, prior experience in both task and use of technology for the task, and differential perceptions of high gain or loss. Choosing subjects with similar backgrounds and experiences minimized this difference in such experiences and abilities. Where an occasional subject does demonstrate high experience in these areas, we expect that a statistically acceptable sample size would mitigate the effects of such confounding factors. Possibly measures such as those suggested by Pratt (1964) and inventories such as Coping Resources Inventory can be used to measure risk aversion in future studies.

Each subject who participated in the experiment completed a questionnaire with a Likert scale of 1 to 5 measuring their perception of time pressure, uncertainty, information overload and dynamism. The specific statements posed to the subjects, means of the responses, and standard deviations are shown in Table 3. The number of subjects in the sample reflect all those that participated in the study, and the sample sizes are larger than those shown in Table 1 since several portfolio results were eliminated as discussed previously.

Table 3. Reported psychological experiences in two experimental conditions.

	HSDSS n=59		LSDSS n=64	
	Mean	Standard Deviation	Mean	Standard deviation
Time Pressure: The time assigned to this task was sufficient.				
	2.9153	1.1932	4.0161	1.1234
Uncertainty: It was clear what choice was best for me.				
	2.5254	1.0725	2.8413	1.0657
Information Overload: I felt overwhelmed with the amount of information provided to me for this task.				
	2.1186	0.8727	1.7937	0.7220
Dynamism: I did not have to change my decisions again and again.				
	2.4237	0.9685	2.3651	1.0519

The Wilcoxon rank sum test for hypothesis of equal medians for two independent unequal-sized samples at significance level of 0.05 was used to determine if the sample means are significantly different. The results are shown in Table 4. We reject the null hypothesis that the medians of the two groups are equal for time pressure and information overload. We do not reject the null hypothesis for uncertainty and dynamism.

Table 4: Wilcoxon Test for Hypothesis of Equal Medians for Reported Psychological Experiences

	Time Pressure	Uncertainty	Information Overload	Dynamism
HSDSS compared to LSDSS	p=0.000 Reject	p=0.1203 Do not reject	p=0.0269 Reject	p=0.5709 Do not reject

4.5 Discussion of Results

In terms of performance, the results are consistent with the literature. The Yerkes-Dodson curve suggests that stress will decrease performance after some point, all else being equal, and this effect is seen our experiment. We reject the null hypothesis of equal means in terms of performance for the two groups. Since the LSDSS mean return is $73,918.71 with mean risk = 2.20 and the HSDSS mean return is $62,258.39 with mean risk = 3.720, we conclude that subjects made better decisions under low stress conditions compared to high stress. The low stress group has both a higher mean return and a lower risk that the higher stress group.

The psychological responses of the two groups are different for some variables. Since time was specifically manipulated, we expected the high stress group to recognize time pressure, and they did. The HSDSS group also reported a difference in their perception of information overload compared to the LSDSS group, and this result was not expected since the DSS was hypothesized to mitigate this response. The results indicate that there is no difference in the reported psychological experiences under the two experimental conditions in terms of uncertainty and dynamism. We suggest that this is support for the hypothesis that the DSS mitigated the effect of stress in terms of these two variables.

5.0 IMPLICATIONS FOR RESEARCH

The results from our preliminary application of the DMUS framework indicate potential for future research in this domain. First, this model may be further enhanced by examining other pre-conditions and decision stressors. More specifically, we have not examined or attempted to distinguish various features of the DSS to determine what aspect of the DSS has greater impact on the psychological stressors. Researchers engaged in DSS design research may benefit from keeping the pre-conditions and psychological factors constant while examining effectiveness of specific DSS characteristics such as color and information presentation across experimental groups.

Secondly, the evidence regarding effectiveness of DSS on decision quality has been somewhat contradictory. For instance, Joslyn and Hunt (1998) focused on individual differences of the decision maker in time-pressured situations and found that some people handle time pressure better than others. This ability may result in better decision-making under stressful situations. As a result, the effectiveness of DSS may or may not be relevant in this case. Dora *et al.* (2001) evaluated a decision support system for treatment of severe head injury patients by comparing physician expert opinions with results generated by the decision support system. The study concluded that the tool was not accurate enough to support complex decisions in high-stress environments. Lerch and Harter (2001) found that providing certain types of cognitive support for real-time dynamic decision making can degrade performance and designing systems for such tasks is challenging. This contradictory evidence leads to the question – is there a threshold beyond which DSS begin to lose their effectiveness in mitigating psychological experiences? Yerkes and Dodson (1908) have proposed that there is an "inverted U" shaped relationship between the levels of arousal or stress and the efficiency of memory (see Fig 4.). A certain amount of arousal can be a motivator toward change (with change in this discussion being learning). Too much or too little change will certainly work against the learner. Too little arousal has an inert effect on the learner while too much has a hyperactive affect. Furthermore, for each task optimal levels of arousal have to be discovered. This optimal level is (a) lower for more difficult or intellectually (cognitive) tasks since learners need to concentrate on the material, and (b) higher for tasks requiring endurance and persistence since learners need more motivation. Subsequent research has confirmed that the correlation suggested by Yerkes and Dodson exists (Broadhurst, 1959; Telegdy and Cohen 1971; Anderson, 1994; Dickman, 2002) and many psychological and physiological factors have been developed to explain the phenomenon. The Yerkes-Dodson Law can be extended to the use of DSS for stressful decision making. If stimulation beyond an optimal level serves to degrade performance, how does the use of DSS for supporting DMUS change the psychological experiences and stress at which a decision maker operates? Based on this research, we make the following proposition:

> *Proposition 5*: DSS will mitigate psychological effects of stress to a point beyond which its effectiveness in such mitigation and, subsequently, decision quality will decline.

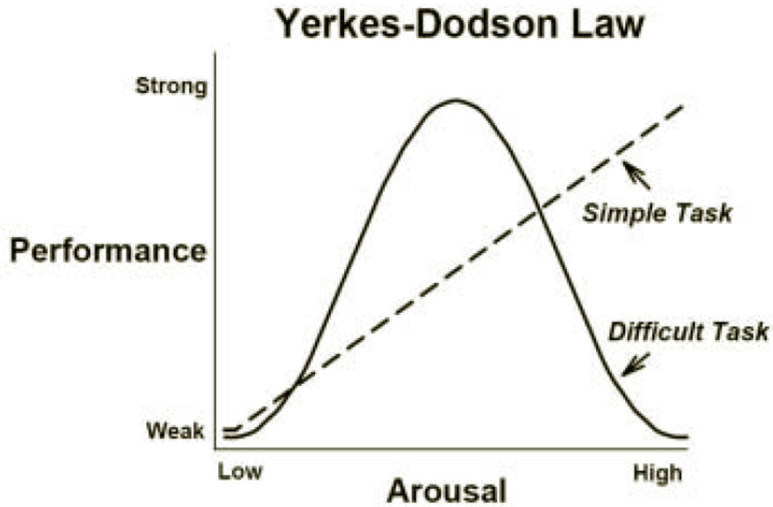

Figure 4: The Inverted 'U' Curve representing Yerkes-Dodson Law.
Adapted from Diamond (2005).

Finally, the above argument has interesting implications for both researchers who study DSS design and those who study related decision making. For DSS designers, determining DSS features that extend the point of decreasing returns will be a productive investment of time and research efforts. For organizational behaviorists and psychologists, understanding and leveraging individual factors that can result in better utilization of these DSS features will be worthwhile direction to enhance our understanding of human decision making and information processing abilities.

6.0 SUMMARY AND CONCLUSIONS

While prior research initiatives have provided deep understanding of particular aspects of decision support technology and have explored specific benefits to decision making under time pressure, we propose a broader framework that focuses on multiple gains from decision aids: reduction of negative psychological experiences of time pressure, information overload, uncertainty, and dynamism as well as improving decision quality. In this paper we explored the effect of stress on decision making with a DSS. We hypothesized that using a DSS would mitigate the reported psychological experiences under stress. Our experimental data only partially support the model. We found support for mitigation of uncertainly and dynamism as reported psychological experiences in high and low stress conditions with a DSS.

The contributions of this paper to the literature are:

(1) providing a thorough review and synthesis of the literature on decision making under stress as related to decision support systems;
(2) proposing an integrated model based on the literature that separates preconditions to stress from psychological perceptions of stress;
(3) separating variables so that the potential mitigating role of decision support systems in stressful decision making can be studied;
(4) characterizing the role of decision support systems in improving decision quality under stress;
(5) providing experimental data to demonstrate that decision support systems can mitigate some reported psychological experiences under stress.

Further research is needed to validate or refute the hypotheses and results of this study. Our data are limited, and the stressful decision making is better studied in real environments. Based on our study, however, we suggest that decision support systems could be specifically designed to mitigate the negative effects of stress on human decision making in terms of the variables we have identified, and that this is a fruitful area of future research.

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APPENDIX 1 Stock choices for the portfolio.

	Company Name	Category
1	Intel	Tech
2	Dell	Tech
3	MSFT	Tech
4	Toshiba	Tech
5	Compaq	Tech
6	Gas Inc.	Energy
7	BP	Energy
8	Nuclear Inc	Energy
9	Exxon	Energy
10	Mobile	Energy
11	Hydro Inc.	Energy
12	Citgo	Energy
13	Chevron	Energy
14	Ford	Auto
15	Saturn	Auto
16	Toyota	Auto
17	Honda	Auto
18	Isuzu	Auto
19	Mercedes	Auto
20	Aflac	Insurance
21	Nationwide	Insurance
22	Verizon	Communication
23	Tmobile	Communication
24	ATT	Communication
25	Cingular	Communication
26	MCI	Communication
27	GRU	Utilities
28	FLPowerLt	Utilities
29	Banana Rep	Retail
30	Ann Taylor	Retail
31	Sears	Retail
32	Gap	Retail
33	Old Navy	Retail
34	Ross	Retail
35	Burdines	Retail
36	JC Penny	Retail
37	Dillards	Retail