Using Aggregated Data Under Time Pressure: A Mechanism for Coping with Information Overload

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Abstract

Decision makers have become accustomed to making decisions using summarized or aggregate data through the use of financial and accounting reports. The use of aggregate data minimizes the effects of information overload on a decision maker; however it may not provide a decision maker all the details he or she would like to have. The effects of aggregated versus detailed information presentation on decision making has been previously examined. However, these earlier studies have ignored the impact of limited time availability on the decision maker. A laboratory experiment using a 2x2x2 factorial design was conducted to investigate the influence of limited time availability, data aggregation, and decision task on decision making. Results from the experiment indicate a main effect for each of the three factors and an interaction effect between the level of data aggregation and time availability.

I. INTRODUCTION

Decision makers require quantitative data to support both routine and one-time decisions. This type of data includes monthly sales forecasts to facilitate production scheduling, labor availability and cost of living indexes to support facility location decisions, and company sales and compensation history when evaluating candidates for job openings. However, the need for and processing of information must be balanced with both the cognitive limits of human information processing and the available time an individual has to make a decision.

In many instances, the available data to support decision makers investigating a problem is overwhelming. In today's computerized business environment, more information than necessary is often available. Decision makers must determine which information is relevant for a given problem, locate the information, and then process it. Information overload is likely to occur when the amount of information available exceeds a decision maker's cognitive capacity or when the amount of information to be processed exceeds the available processing time. Previous literature suggests that a condition of information overload encourages decision makers to use heuristics instead of an optimal decision making strategy [18],[36], decreases decision performance [25], and reduces the confidence in the decision [35].

As a means of minimizing information overload and facilitating effective decision making, much of the data presented to a decision maker is in a summarized form. Summarized or aggregated data is used in many accounting and financial reports to convey corporate information. Aggregating data reduces the information overload a decision maker may feel when processing the information as there are fewer pieces of information to examine. However, it may decrease overall decision quality as the information selected and processed is not as precise as the detailed information [1],[4]. Therefore, it would appear that providing decision makers with detailed information results in more accurate decision-making. However, past studies have not examined the effects of limited time availability on processing detailed and aggregate information.

When time is limited, decision makers have less time to examine and process the information available. In these situations, more aggregated data would result in fewer discrete data elements to process as compared to detailed data. Aggregate data, though less precise, could be fully examined and processed while some of the detailed data is likely to be ignored or processed incorrectly due to the limited time. Therefore, does aggregate data alleviate information overload under conditions of limited time availability? In what manner does processing of information change when decision makers are faced with limited time?

This paper will lay the groundwork to answer these questions. Section II presents prior research related to human information processing and decision making, information overload, and data aggregation. Research propositions are also presented. Section III describes a laboratory experiment designed to investigate these proposotions while Section IV presents statistical results. Finally, Section V provides a discussion of results and describes limitations and contributions associated with this research.

II. LITERATURE REVIEW

2.1 Human Information Processing and Decision Making

It is well understood that decision makers have limited cognitive ability and therefore, are only able to store and process limited amounts of information [20],[22]. When faced with more information that can be processed effectively, decision makers choose to minimize cognitive effort by limiting the amount of information processed [24]. Decision-making performance can be severely inhibited when information is in abundance as the quantity of available information may encourage the decision maker to focus on information that is irrelevant instead of attending to the information that is necessary for effective problem solving [34].

The processing of information becomes even more complex when decision makers are solving multi-criteria decision problems. Multi-criteria decisions have more than one alternative as a potential outcome and have multiple criteria or attributes from which to evaluate each alternative [23],[41]. Given the possibility of multiple outcomes and multiple attributes, these types of decisions are more complex than single criteria decisions. Furthermore, decision makers experience this increased complexity as increased cognitive effort required to process the information. Therefore, it is expected that when solving multi-criteria problems, decision makers are more likely to reduce their information intake in order to balance their information processing and cognitive effort requirements.

Decision Processing Strategies

A number of strategies have been identified explaining the precise manner in which decision makers process information. These types of decision making strategies are often broken up into optimal and heuristic or satisficing decision making [33]. Using an optimal decision processing strategy, every possible decision outcome must be enumerated in order to identify and select the optimal solution. Specific strategies have been identified (e.g., additive decision strategy, additive difference decision strategy) where a decision maker places an importance value or weight on each of the attributes associated with a potential outcome [26]. The attribute weight is then multiplied by the value associated with that attribute to obtain an attribute score for a specific alternative. Each of the importance weight/attribute pairs are added together for each attribute of an alternative generating an overall rating. Using these optimal strategies, the alternative with the highest rating is the "best" decision.

This type of decision strategy has been labeled "compensatory" as a decision maker uses all of the available information when processing the decision [27]. Furthermore, a compensatory decision strategy enables a decision maker to compensate for relatively low values on one attribute with relatively high values on a second attribute since all attributes are combined to form an overall score.

Although there are many strategies for obtaining an optimal solution to a problem, significant cognitive processing loads often lead to the use of heuristic strategies (e.g., elimination by aspects, conjunctive) [17]. This type of strategy yields a satisficing, not an optimal solution [33]. Satisficing corresponds to a trade-off between accuracy and effort, where a decrease in effort required yields a satisfactory, yet not necessarily optimal solution [17].

Heuristic strategies are considered to be non-compensatory as decision makers use only a portion of the available information when obtaining a solution and therefore, require less cognitive effort [17]. Decision makers select minimum criteria values for some or all attributes. Should a specific attribute not reach this minimum criterion, that alternative is no longer considered as a potential outcome. Furthermore, this potential outcome is not evaluated further even though the remaining attributes might have relatively high values.

When completing low complexity tasks, compensatory decision making strategies are often used while non-compensatory strategies are used with highly complex tasks [27]. Therefore, non-compensatory decision strategies are a mechanism to help decision makers deal with cognitive overload.

2.2 Information Overload

Information overload has been defined as a condition in which the amount of input to a system exceeds its processing capacity [21]. More specifically, overload occurs when there is more information available than necessary for processing a task and where this extraneous information has a detrimental effect on decision quality.

In explaining information overload, [37] developed the concept of an information saturation point, beyond which, information is detrimental. More specifically, information processing increases as the amount of available information increases. As more information is made available, information processing increases until a saturation point is reached. Up to this point, all of the information has the potential to be used by the decision maker. Beyond the saturation point, information processing actually decreases as decision makers can no longer process all of the information available.

Empirical examination of the information overload phenomena has extended across a number of disciplines including finance and accounting [1],[10],[31],[35] and consumer behavior [14],[15],[19]. Results from these studies indicate that information overload results in decreased decision quality, increased decision time, and increased confusion.

Information overload has been operationalized in a number of ways across various studies. The definitions of information overload primarily focus on the amount or volume of information. Therefore, the corresponding operationalization has also been based on the amount of information as measured by number of pieces of information a decision maker must examine [6],[8],[25],[35] or by increasing the number of alternative solutions or attributes describing these alternatives [31],[32],[36].

While the amount of information has been well established as a factor influencing information overload, it appears that the content of the information also affects information overload. Specifically,[13] extends the operationalization of information overload to explicitly include the number of repeated dimensions and the number of unique dimensions across all the information attributes. He suggests that it is the diversity of the information that generates the most significant influence on perceptions of information load. Empirical results indicate that aggregating information across dimensions should be considered when constructing reports that contain a large number of different dimensions in order to maximize decision accuracy.

In addition to features of the information, more recent research emphasizes the need to incorporate the aspect of time when examining information overload [30]. Time, it is suggested, is critical to the concept of information overload as with sufficient time, all information could ultimately be processed. Therefore, information overload occurs when the time required to meet a decision makers processing requirements exceeds the available supply of time. The concept of time includes all aspects of decision processing, including the time required to acquire information, processing time between the decision maker and other information providers, and time to internally process the information and reach a decision. Finally, the prior discussion focused on information load as it influenced decision outcomes. Information overload also influences information processing as demonstrated by the empirical support for the [37] concept of saturation point [31],[32]. Other research investigating effects on decision processing under increased information load report the use of non-compensatory (e.g., heuristic) decision strategies for large tasks when compensatory strategies were used for the same, but smaller tasks [6],[18],36].

Limited Time Availability

As [30] suggest, it is critical to include the aspect of time when examining decision-making processes under conditions of information overload. In prior work examining overload, time was used as a dependent outcome measure. However, the research associated with time pressure uses time as an independent variable influencing decision outcomes.

Similar to the saturation point in information overload, an inverted U-shape curve is also used to explain decision performance when experiencing time pressure[1] [12],[16],[28]. Moderate levels of time pressure result in accelerated information processing where the decision maker often makes high quality decisions in less time than when time is unlimited. However, when time constraints become more severe, decision accuracy deteriorates as decision makers either reduce their examination of information or consciously choose not to use some information [7],[38].

In addition to deteriorating decision accuracy, more severe time pressure influences decision processing in other ways. For example, decision makers search for and process information in order from most salient to least salient, regardless of the validity of the information for the specific decision task [40]. Finally, people respond to time constraints in different ways [7] indicating that feelings of time pressure are subjective, generating different effects based on the individual, task importance, and information load.

2.3 Data Aggregation

[1] Time pressure is a psychological state that occurs when time is too limited for completing a task. Manipulating the amount of time available may create a feeling of time pressure in some people but not others. Therefore, time pressure will be used to indicate a measured psychological state while limited time availability will refer to manipulating time with the explicit intention of inducing time pressure in individuals.

Data aggregation has been defined as "the combining of information according to some type of integration rules" (e.g., over people, time, geography) [3]. Research in the accounting and financial literatures define data aggregation as condensed or summarized data, such as data found on traditional accounting reports [1],[4]. Detailed data will be used here to discuss the counterpart to aggregate data.

Data aggregation is an integral aspect of information presentation that is often used to facilitate managerial decision making. The over-abundance of data generated by information systems [2] often requires that some data be aggregated in order to present decision makers some meaningful information as opposed to hundreds of data points. Many accounting and financial reports have been designed to summarize operations activities, company sales, etc. [29]. However, empirical examinations of differences in decision performance when using detailed versus aggregate information indicate that detailed data results in more accurate decisions [1],[4].

In addition to financial reports, other managerial decisions are dependent on the way in which data are presented. For example, different levels of data aggregation can influence facility location decisions [39]. In this research, the quality of the facility location decisions improved with more detailed customer location information. It appears that up to a certain (undefined) point, increased customer location detail provides a visual pattern of activity to the decision maker that facilitates the decision making process. However, human decision making capabilities radically degrade in performance if too much detail is provided. On the other hand, [9] discovered that decision makers using aggregate data performed better than those using detailed information when processing manufacturing-related decisions. Interestingly, it appears that decision makers prefer using aggregate data [5], however, those using detailed data are more confident in their decisions [9].

2.4 Research Propositions

The impact of information overload on decision making has received a great deal of attention. Unfortunately, few studies examining information overload have included the aspect of time (which might lead to time pressure) as an independent variable. Prior research suggests that limited time availability can result in more efficient decision making when there is limited information processing. However, when tasks are complex (e.g., multicriteria) or the amount of information processing necessary increases, limited time availability results in decreased decision-making effectiveness. Therefore,

P1: As the available time becomes more limited, decision accuracy decreases.

Prior examinations of decision effectiveness when using aggregate versus detailed information have been equivocal. When decision makers have ample time to process information, all of the detailed information available can be used to support decision making. Although this detailed information may need to be manipulated (e.g., added together, etc.) it is in the most precise form available. Once information has been aggregated, it has lost some of its precision and a decision maker might have to make assumptions (valid or invalid) about how the aggregated number was calculated. Therefore, Proposition 2 is stated as:

P2: As data is more highly aggregated, decision accuracy decreases.

The decision strategy implemented can also influence decision accuracy. Compensatory decision strategies result in more accurate decisions then non-compensatory decision strategies. Although the overall task processing between these two strategies is similar, the use of a non-compensatory strategy should result in the processing of fewer alternatives. On the one hand, this lessens the processing load. On the other hand, it is possible that one of the alternatives not processed is really the optimal solution. Therefore, Proposition 3 is stated as:

P3: As more non-compensatory decision strategies are implemented, decision accuracy decreases.

Two mechanisms decision makers can use to deal with limited time availability are 1) using aggregate data and 2) applying non-compensatory decision strategies. Therefore, the more interesting questions relate to the influence of these factors “in combination” on decision accuracy. It is expected that there will be differences in decision-making performance when time is limited and different levels of information detail are presented to the decision maker. For example, more detailed information allows a decision maker to use more precise data when selecting and processing the necessary information. However, this decision maker is likely to require additional time to find and process the relevant information (e.g., finding the relevant information amongst the irrelevant) and may need to manipulate the information (e.g., adding information values together) to obtain the needed value. When time is limited, a decision maker may not be able to effectively locate and process this detailed information. Additionally, prior research suggests that decision makers often process the most salient information when time is limited instead of the most relevant information. This is also likely to result in decreased decision accuracy. On the other hand, aggregated information has been summarized so there is less information to search. Although this aggregated data is less precise than detailed data, ti will be easier to locate. In addition, the decision maker is less likely to make manipulation errors with this data as it has already been processed. Therefore Proposition 4 states:

P4: As available time decreases, decision accuracy decreases when using more detailed information.

Finally, the normative perspective on decision making suggests that decision makers use a compensatory decision making strategy when trying to maximize decision accuracy. This perspective also suggests that as the amount of information increases, decision makers consciously or unconsciously switch to non-compensatory strategies. This switch in processing strategy provides a decision maker an effective means to screen alternatives and to reduce the amount of information to be processed. It is likely that a decision maker using aggregate information can process that information even when time is limited. However, those processing detailed information when there are constraints on time are likely to find non-compensatory strategies more effective. Therefore we state the following three-way interaction:

P5: Decision makers using detailed information under highly limited time will have higher decision accuracy using a non-compensatory strategy than a compensatory one.

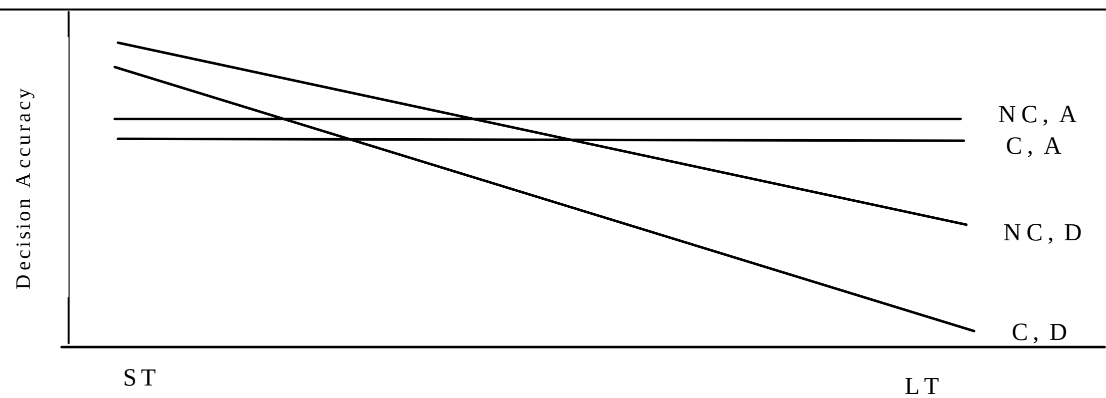
Figure 1 presents a graphical representation of the expected differences between conditions as described in Proposition 5.

III. RESEARCH METHOD

A laboratory experiment was conducted to investigate these propositions as illustrated in Figure 2. A 2 X 2 X 2 full factorial design was implemented where there were two levels of Time Availability (limited and sufficient), two levels of Information Presentation (detailed and aggregate), and two levels of Decision Strategy (compensatory and non-compensatory).

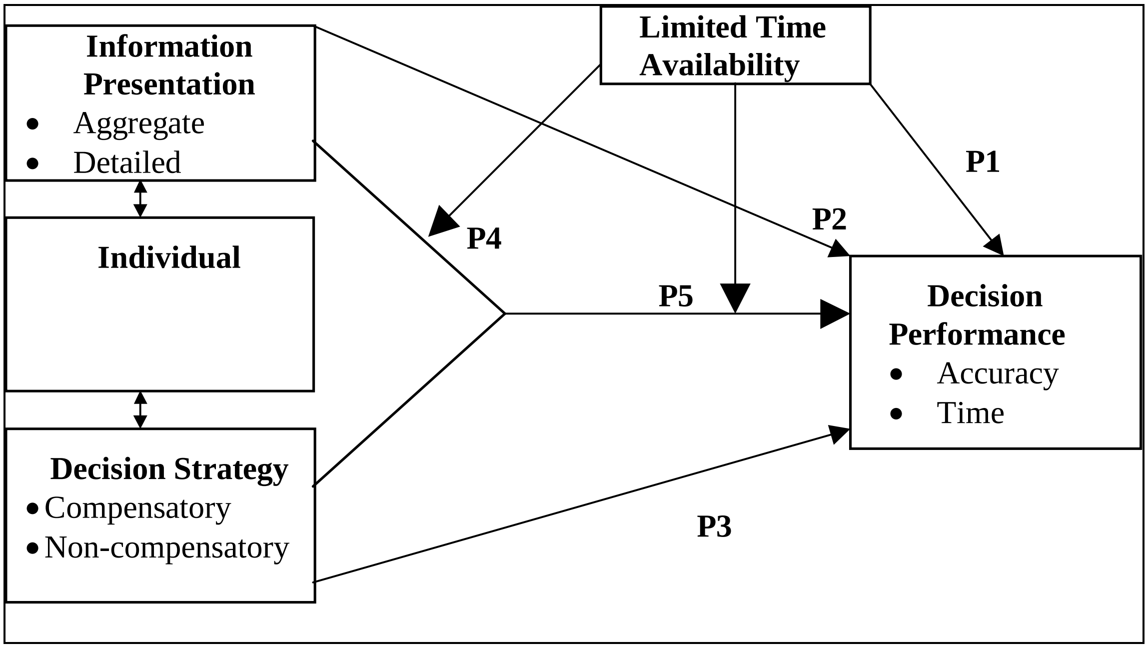
Figure 1:

Graphical Representation of Proposition 5



NC=Non-compensatory A=Aggregate ST= Sufficient Time
C=Compensatory D=Detailed LT= Limited Time

Figure 2
Research Model



3.1 Subjects

Data was collected from 188 undergraduate students enrolled in an introductory computer course at a large Midwestern university. All subjects were randomly assigned to one of the eight treatments. There were no significant differences across treatments with respect to gender, age, year in school, and major. Subjects received class credit for participating in the experiment.

3.2 Task

Subjects participated in a structured decision making task in which they were asked to act as an executive recruiter evaluating nine job candidates for two potential job positions. Subjects were given explicit decision making criteria on which to evaluate the different candidates and were asked to select the top three candidates for each job. Each candidate was described using ten different attributes characterized by numeric information (e.g., number of people supervised, current salary). Subjects were also given a predefined set of attribute rankings for each job position. These attributes were ranked by the researchers to ensure the same optimal answer for each decision task. Subjects were asked to multiply the attribute rank times the value for the attribute to obtain an attribute weight for each candidate. Each attribute weight for a candidate was added together to obtain an overall candidate rating where

Candidate rating = (Value of attribute 1 X rank of attribute 1 + Value of attribute 2 X rank of attribute 2+…).

Once all candidates had been rated, subjects then selected the top three candidates for each job position. Prior to performing the decision task, subjects were given an initial training session to demonstrate the decision rules.

3.3 Independent Variables

There were three independent variables manipulated in this experiment: time availability, information presentation, and decision strategy.

Time Availability

Pilot testing provided an initial base line time to be used for both the compensatory and non-compensatory tasks. This baseline time was designated as 90% of the average time it took all subjects to complete the task. To determine the level for low time availability, a pilot study was run using 50% of the baseline time. This manipulation was found to be too severe in that subjects in this condition were unable to complete the task. A second series of pilot studies were run at 75% of the baseline. Subjects in these conditions indicated they felt rushed to get through the material, however, in most cases were able to complete the task. In post-experimental interviews, most of the subjects indicated that they would like to have had "a little more time". Thus, 75% of baseline was used as the limited time availability manipulation based on subjects ability to complete the task yet at the same time feeling pressured by the available time.

Information Presentation

Information in the aggregate condition appeared as a single number for each attribute while the detailed condition contained multiple values for each attribute. The aggregate value provided might be composed of more summarized information than necessary to complete the evaluation of a candidate. For example, the subject might be requested to enter candidate sales for the last quarter. If the only information related to sales encompassed the past year, the subject would need to approximate the appropriate quarterly figure. Therefore, subjects using aggregate data could either directly extract values from the candidate data into the calculation form or were required to approximate the appropriate value. On the other hand, subjects using detailed data were able to directly extract values from the candidate data into the calculation form or were required to add detailed numbers together to obtain a summary value.

Decision Strategy

Subjects in the compensatory condition were asked to rate and evaluate all nine candidates by calculating the candidate rating for each candidate and then selecting the top three individuals for each job. In the non-compensatory condition, subjects were given minimum criteria for each job position. These minimum criteria allowed the candidate pool to be reduced to three candidates for each job position prior to calculating candidate rankings. Therefore, the subjects were able to perform the rating and ranking procedure on a subset of the original candidates. The top three candidates were identical regardless of the strategy treatment assigned.

3.4 Dependent Variable

The dependent variable examined in this study was decision accuracy. Decision accuracy was measured as the number of correct calculations and candidate decisions divided by the total number of calculations and candidate decisions. Therefore, decision accuracy represents the percentage of optimal obtained.

RESULTS

Analysis of variance was used to test the propositions. As the theory predicted both main and interaction effects, all three independent variables were included in the statistical model when testing each proposition to provide a more rigorous test. The means and standard deviations for the measures associated for all tests are presented in Table 1. Results from the statistical analysis indicate that there were significant main effects for all three independent variables as well as a two-way interaction between information presentation and decision task (see Table 1).

Proposition 1 examined the effect of time on decision accuracy. Results from the ANOVA indicate that less available time results in significantly lower decision accuracy (.88) than when ample time is available (.94) for the decision maker ($F=9.125$, $p=.003$). Therefore, Proposition 1 was supported.

Proposition 2 investigated the influence of information presentation on decision accuracy. Results from the ANOVA indicate a significant difference between the use of aggregate and detailed information on decision-making accuracy ($F=7.362$, $p=.007$). Decision makers using detailed information had greater decision accuracy (.94) than those using aggregate information (.89). Therefore, Proposition 2 was supported.

Proposition 3 examined the relationship between decision strategy and decision accuracy. Results of the ANOVA indicate a significant main effect for decision strategy ($F=5.04$, $p=.026$). As predicted, decision makers using a compensatory strategy had greater decision accuracy (.94) than those using a non-compensatory strategy (.89). Therefore, Proposition 3 is supported.

Proposition 4 suggested that there would be a two-way interaction between information presentation and time availability. Results from the ANOVA indicate a significant effect (F= 4.31, p=.039) where subjects using detailed data with limited time (mean =.86) performed significantly worse than the remaining groups (aggregate/limited time=.91, detailed/sufficient time=.95, and aggregate/sufficient time = .94). Therefore, Proposition 4 was supported.

Finally, Proposition 5 suggested a three-way interaction between time availability, information presentation, and decision strategy. Results from the ANOVA indicate a non-significant result (F=.28, p=.599). Therefore, Proposition 5 was not supported.

Table 1
Results of the Statistical Analysis

Prop.	**Effect**	**Decision Accuracy**	**F (df)**	**p-value**
		Mean (s.d)		
1	**Time Availability**		9.125 (1, 179)	.003
	Limited Time	.88 (.163)		
	Sufficient Time	.94 (.078)		
2	**Information Presentation**		7.362 (1,179)	.007
	Aggregate	.89 (.138)		
	Detailed	.94 (.128)		
3	**Decision Strategy**		5.043 (1, 179)	.026
	Compensatory	.94 (.143)		
	Non-Compensatory	.89 (.072)		
4	**Information x Time**		4.31 (2, 179)	.039
	Limited time/Aggregate	.91 (.155)		
	Limited time/Detailed	.86 (.166)		
	Sufficient time/Aggregate	.94 (.088)		
	Sufficient time/Detailed	.95 (.065)		
5	**Information x Time x Strategy**		.28 (3, 179)	.599

V. DISCUSSION

As expected, limited time availability, information presentation, and decision strategy all individually influenced decision accuracy. Limited time availability, the use of aggregate information, and non-compensatory decision strategies all independently resulted in decreased decision accuracy.

The results of the study also indicate a significant interaction effect for information presentation and time availability. As anticipated, the use of aggregate data enhances decision quality only when there is limited time. When ample time is available, detailed data results in the most accurate decisions.

Therefore, the results of this study indicate that are "traditional" aggregated accounting reports may not be the most effective way to present information. Likewise, leaving data in more raw, detailed formats does not automatically lead to increased decision accuracy. The optimal information presentation structure would appear to involve aggregate data to support the ongoing time pressure many decision makers experience supplemented by detailed data when more precision and/or additional time is available.

As information systems designers, there are many dimensions associated with information presentation (e.g., the graphical representation of data, use of color and font, and the level of aggregation) that must be attended to. The results of this study provides the designers of decision support systems and executive information systems a better understanding of the impact of different levels of detailed information in a decision making process. It appears that both detailed and aggregated data might be effective to best support decision-maker processing. Similar to the concepts embedded in data warehousing, decision makers could be provided with aggregated data to minimize the chances of information overload given the “time pressured” contexts of many organizations. In addition, supporting detailed data could be “hyperlinked” or available in “appendix” format for decision makers to drill down into when needed.

Furthermore, system design features should be examined more globally with the influence of limited time in mind. Systems could be constructed so that the decision maker could visually see (using color, shading, etc) which information has already been examined and which has not. Likewise, an intelligent agent could track what information and how much was used and report this to the decision maker upon task completion. This tracking data could provide the decision maker a benchmark from which his/her existing knowledge of task information needs could be compared to the benchmark.

The meaningfulness of any research can only be assessed in light of its limitations. For this study, the increased control afforded by the laboratory experiment must be traded-off against inherent limitations of the approach, primarily that of generalizability. Specific to this research, limitations in generalizability involve the use of student subjects, the nature of the task. These subjects may not be as motivated as knowledge workers in a business context nor did they have extensive experience performing the type of task involved in the experiment.

This research study provides a contribution to the MIS community along two dimensions. On one hand, it provides some additional empirical understanding regarding the influence of time on decision making. Although time pressure is a concept we can all relate to, we have a limited theoretical understanding of how limited time availability affects the decision-making process. This study adds to the growing body of literature that will enable a theory to be developed and tested concerning decision making under time pressure.

The results of this study provided support for the idea that limited time not only influences decision outcomes, but the manner in which information is processed. It is important to better understand this moderating influence of time as it may require systems designers to alter interfaces, intelligent agents used to support problem solving, etc.

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