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Input Information Complexity and Information Processing in GSS-Based Virtual Work Groups: An Experimental Investigation

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Abstract

The issue of information overload in group decision making settings has not received sufficient attention in the past. In particular, information processing and information complexity have not been addressed in the context of GSS research. This paper discusses a study that examined whether information overload occurs in group decision making settings, using a combination of measures for information processing and information complexity. The relationship between information complexity measures, information diversity and information volume, and information processing measures, decision time and information flow, suggest that overload occurs in a group setting involving cognitive conflict tasks. The study also showed that adding an appropriate decision aid alleviated the overload, permitting groups to process larger and more complex information. The initial results are promising and provide a basis for future exploratory research.

1. Introduction

Globalization of business, enhanced market competition, and the increased need to respond quickly to customer needs have led to distribution of business processes in locations where expertise is available, thus relying increasingly on virtual work groups whose members communicate using collaboration systems. Collaboration systems facilitate sharing and flow of information. When coupled with Intranet, these systems allow group members to access high volume of information within short period of time. The technology can boost the work of distributed groups provided that the members can process the large volume of information that is accessed and shared within a short period of time. The productivity of individuals and groups, depends strongly on their information-processing characteristics (Driver and Streufert, 1969). Although information processing is a well established area of research in cognitive science and psychology and more recently, group support system (GSS), with the exception of the work by Grise and Gallupe (1999-2000), no major IS study has specifically focused on the information characteristics of collaboration technology supported work groups. What happens when these work groups access high volume of information within a short period of time? How can the adverse effects, if any, of information be overcome? These are some of the critical issues that will determine the efficacy of the collaborative systems and will perhaps shed light on change/enhancements of functionalities that may have to be incorporated in the existing collaborating systems. In this paper, we attempt to address some of these research questions through a laboratory experiment that involved collaborative technology supported virtual work groups. In conducting our research, we rely on prior studies on information processing and extend the relevant issues in the context of group research.

Prior studies suggest that an increase in the number of information cues provided to decision makers can have an adverse impact on their decision making performance (Miller, 1956; Streufert, 1973; Iselin, 1988; Schroder, Driver, and Streufert, 1967; Streufert, 1970). Schroder et al. (1967) modeled input information cues in terms of information load, information diversity, and rate of information exchange and depicted its relationship with information processing in the form of inverted U-curve. Later empirical studies on information processing of individuals did demonstrate the importance of volume or load and diversity of information as two major elements of input information complexity (Chewning and Harrell, 1990; Iselin, 1988; Iselin, 1989; Hwang and Lin, 1999). We focus on both these dimensions of input information and conduct an experiment to explore their impact on the information processing of GSS-based virtual work groups. In addition, we assess if the use of a schema that offer a frame of reference for acquiring input information, can alleviate the adverse effects of information overload. We report the findings of a laboratory experiment in which groups used a GSS to access a large pool of information that were necessary to complete a group task. Half of these groups were allowed to use a hypermedia based schema that depicted the relative importance that some input cues had over others. The performance of both groups are compared and reported in this paper.

We start with a review of some relevant studies on information processing and prior GSS research in related areas and propose our research questions. Next, we elaborate the design of our research and report the findings of the study. We end the paper with discussion of our findings and their implications for practice and future research.

2. Theoretical Background

2.1 Information Processing and Integrative Complexity

In cognitive psychology, there exist different views regarding how human beings process information. Generalists view is simple and it posits that all human beings are more or less similar in processing information (Miller, 1956; Streufert, Suedfeld, and Driver, 1965). In stark contrast, researchers like Newell and Simon (1972) propose the uniqueness of information processing of each individual. This is classified as "unique" school of thought regarding information processing by Driver and Mock (1975). According to them the middle path is "differential" school of thought which recognizes the differences in individuals' information processing capacity. Human beings process uncertain and complex information differently (Driver and Mock, 1975). Researchers (Schroder et al., 1967; Driver and Streuffert, 1969) explain information complexity in terms of two major factors: *diversity* and *repetitiveness*. *Diversity* relates to the extent different dimensions exist in the input information that a human being processes and *repetitiveness* is the quantity of repeated dimensions (Iselin, 1988). Schroder et al. (1967) further proposed a nonlinear (inverted U-shaped) relationship between the complexity of input information and the level of information processing (Figure 1). The level of information processing is the maximum when the input complexity is moderate (i.e., neither too high nor too low). Further, Driver and Streufert (1969) suggest that the inverted U-shaped relationship also holds for the behavior, perception, and decision making of the individuals or groups engaged in information processing. They propose the concept of *integrative complexity*. While processing information individuals or groups sort the input information into different dimensions or points of view which is referred to as *differentiation.* The interconnections among these dimensions are collectively referred to as *integration.* The extent of differentiation and integration is the *integrative complexity* in the information processing. While *integrative complexity* is viewed as a cognitive style of individuals, the nature of relationship between input information complexity and the level of information processing is generally considered to be nonlinear whose exact nature is determined by the characteristics of the system processing information (Schroder et al., 1967; Driver and Struefert, 1969). As shown in Figure 1, the system (individual or group) with higher information processing capability will have the nonlinear curve positioned above that with lower capacity. Driver and Streufert (1969) also imply that an individual's information seeking behavior is consistent with its information processing capability. Driver and Streufert (1969) suggested that the integrative complexity model is valid for groups as well. Studies on information processing and integrative complexity in groups can be found in the literature on small group research. Gruenfeld and Hollingshead (1993) studied 22 work groups over a period of 12 weeks and found that the relationship between integrative complexity and quality of decision outcomes of groups was dependent on the nature of the task. As the focus of this paper is on GSS-based virtual work groups, we discuss research on information processing in GSS in the next section.

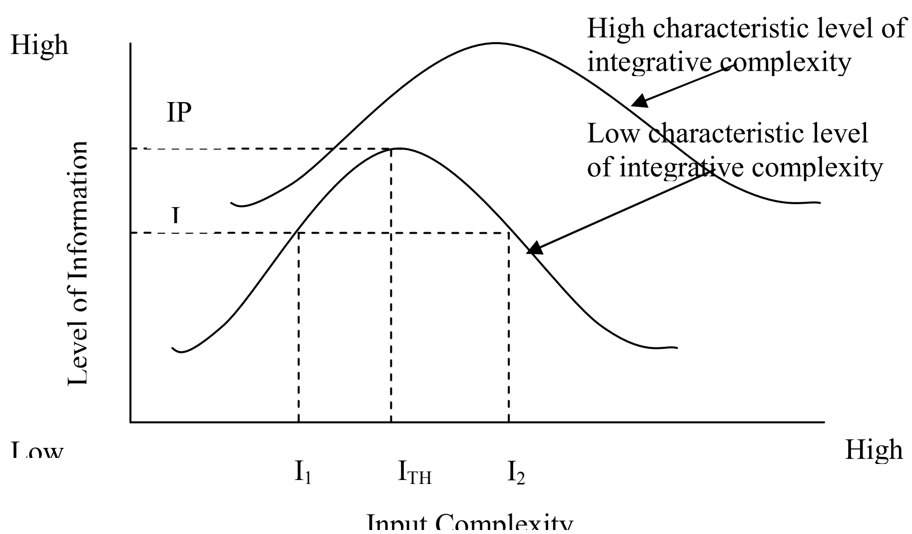

Figure 1: Relationship between Input Complexity and Level of Information Processing

2.2 Information Processing in GSS-based Groups and the Use of Decision Schema

While information processing of individuals and groups has been studied extensively, the related research on GSS-based virtual work groups is almost non-existent with the exception of the work by Grise and Gallupe (1999-2000) who demonstrated that GSS tools that can regulate the flow of information can help its users to process ideas of high level of complexity. Other researchers have acknowledged the importance of information processing in GSS research. Zigurs and Buckland (1998) suggest the necessity of information processing support in GSS. Dennis (1996) demonstrated that GSS-based groups excelled non-GSS groups in both exchange of information and use of exchanged information. Researchers acknowledge that sharing and processing of information are important aspects of GSS (Mennecke and Valacich, 1998; Chidambaram and Bostrom, 2004). Jones, Ravad, and Rafaeli (2004) found the dynamic interplay between volume and complexity of information exchanged in online groups; users of online communities responded to simpler messages in overloaded interactions. Thus, we expect that in GSS-based virtual work groups, the complexity of information accessed by group members will impact their information processing. Following on the nonlinear relationship between input complexity and information processing proposed by Schroeder et al. (1967), we expect that group members will increase their information processing to resolve the complexity of information till their information processing capability reaches a limiting situation (which is the information overload) after which the members will fail to resolve the complexity of the information and will attempt to simplify the information processing. Therefore, we propose:

> *Proposition 1: In GSS-based virtual work groups, group members' input information complexity is nonlinearly (inverted U-shaped) related to their level of information processing.*

The effect of information complexity in GSS-based group work can be overcome, at least to some extent, by providing additional information processing support. Zigurs and Buckland (1998) discussed about several types of information processing support that a GSS application can have, such as tools to gather, aggregate, evaluate, and structure information. Sometimes, aggregation of information provides decision makers with a broad overview of the fact that is hidden in an information system. Senior level executives almost always analyze the aggregate information first and then drill down the dimensions where further analyses are necessary. A similar approach can be followed in GSS applications. Decision makers can be provided with aggregate level information of prior decisions, which can consist of preferences, preference structures, policies, and norms of groups engaged in similar decisions in the past. The aggregate decision can have a drill-down facility that enable the decision makers to conduct in-depth analyses of any specific aspect of prior decisions, such as the details of a particular choice made by the majority of the prior decision makers. This aggregate level information together with the drill-down facility, in fact, can serve as a decision n schema. The utility of schema in processing decision information has been discussed in organizational literature (Starbuck, 1983; Weick, 1979). The decision incorporates the details of prior decisions can referred to as a memory-based decision schema. The use of the schema is expected to help the decision makers to identify and focus on the critical dimensions when input information is voluminous and diverse. The groups that use the decision schema will have enhanced capability to process information and will experience information overload at a much higher level than those not using it. Thus, we propose:

> *Proposition 2: In GSS-based virtual work groups, group members supported with decision schema will experience information overload at a level of input information complexity which is higher than the corresponding level for the groups not using the schema.*

3. Research Methodology

In order to test the propositions, we used the data that was collected from a controlled experiment at a large public university in the mid-western part of the USA. Fifty-four five-member groups were drawn from undergraduate business students in introductory information system classes. They used a group decision support system (GDSS) integrated with a web-based Intranet application that presented the information on the decision situation to the subjects. Each study participant received a waiver for one assignment in a mandatory introductory information systems course. Participation in the experiment was voluntary. Subject to the time constraints indicated by the students, participants were randomly assigned to one of the fifty-four groups in the experiment. One member of each group served as a coordinator, fully participating in the decision making and performing other tasks as well. Face-to-face communication among the group members was discouraged. However, communication between the coordinator and other members of the group was allowed at specific transition points from one activity to another. The experiments were conducted in a group decision room equipped with VisionQuest. Each experiment session could extend up to two hours. Pilot sessions were held before conducting the actual experiment sessions to ensure that sufficient time was available to complete the decision process satisfactorily. The participants in the pilot sessions did not report any difficulty in working with the system.

The descriptions of the decision situation and the decision schema are presented below.

3.1 Decision Situation

The decision situation addressed the evaluation of alternative MBA programs. The participants developed a group level preference structure for attributes of MBA programs in order to produce a ranked list of programs. Undergraduate business students have an interest in admission to MBA programs and were chosen as the decision makers in this experiment. Evaluation of MBA programs is not trivial, though. Each program can be assessed on multiple attributes, such as acceptance rates, percentage of admitted students receiving financial aid, and so on. Each applicant has his/her own preference among attributes to evaluate programs. Consequently, arriving at a collective preference structure for attributes to evaluate MBA programs involves examining information that is diverse (i.e. multiple and varied attributes) and voluminous (i.e. large data sets to describe each MBA program), presents a challenging task, more so given the differences in individual preference structure. This type of decision situation is categorized as cognitive conflict task in the literature (McGrath, 1984). The group could retain the combination of attribute weights and rank-ordered list of schools and terminate the session. Alternatively, attribute weights could be revised to generate a new rank-ordered list of schools. Turban and Aronson (2001) discuss a somewhat similar group task where the students were engaged in group work to identify the criteria for college selection.

The meeting consisted of the following activities:

1. The participants completed a consent form. They were shown a video presentation about the experiment.
2. Using a standard browser, each participant browsed the Intranet on MBA programs and attributes (for school selection). A fixed set of attributes for MBA admission was presented to the groups. In addition, the groups using the decision schema had access to aggregate level information gleaned from the work of prior groups engaged in similar decision situation.
3. With the help of the "allocating tool" within VisionQuest software, each participant assigned 100 points among one or more attributes. Once all team members had allocated weights, the coordinator instructed the system to display group results. Each member could view both their own and their group weights. The system also displayed the dispersion in weights submitted by group members. After viewing the dispersion and mean weights for each attribute, the member(s) could change their allocation of weights. This process of readjustment of weights would go on till group members agreed upon the group level weights that could be submitted to the system. The decision task chosen for this research has significant similarity with the techniques followed in social judgment theory (SJT) paradigm (McGrath, 1984).
4. At this point, the coordinator exported these average weights to a database in Microsoft Access and instructed the database program to compute rankings of the schools. Based on the attribute weights allocated by a group, the computer generated a rank-ordered list of schools following the principle of the "simple additive weighting" method (Churchman and Ackoff, 1954; Hwang and Yoon, 1981; MacCrimmon, 1968). A score for each school was computed by multiplying the weight on each attribute by a predetermined normalized rating of the MBA program on that attribute. Finally, the rank ordered list of schools was imported back to VisionQuest from the database.
5. Participants viewed the rankings of the schools emerging from their attribute ratings.
6. Participants electronically voted using VisionQuest to confirm that the judgment policy expressed in terms of selected attributes and their weights was final.
7. If four or more group members voted in favor of the judgment policy, the group moved to end the experiment, otherwise, they reassessed weights till a consensus was reached. In order to prevent groups from thrashing around endlessly, a maximum of seven iterations was permitted. None of the groups ran into this constraint.

The participants were not allowed to take the instruction sheet with them after the experiment, appropriately debriefed, and were advised not to discuss the study with their classmates.

3.2 Operationalization of Constructs

The level of information processing and input information complexity are the two major constructs in this study. In prior research on integrative complexity, the level of information processing has been operationalized as decision time, time spanned to integrate information, the number of integrations in a period (Schroder et al., 1967; Streufert, 1970; Chervany and Dickson, 1974; Iselin, 1989). In electronic brainstorming the level of information was measured as ideas organized, categories organized, and ideas repeated (Grise and Gallupe, 19990-2000). We chose to consider decision time and the flow of information as two operationalization of the level of information processing. Input complexity has been measured in terms of number informational inputs (Schroder et al., 1967; Streufert, 1970; Einhorn, 1971; Shields, 1983; Iselin, 1988; Iselin, 1989; Iselin, 1991; Hwang and Lin, 1999), the number of dimensions in input information (Iselin, 1988; Iselin, 1989; Iselin, 1991; Hwang and Lin, 1999), and the number of repeated dimensions (Iselin, 1988; Hwang and Lin, 1999). We chose to operationalize input information complexity in terms of the number of informational inputs (herein referred to as input information volume) and the number of dimensions of input information (referred to as information diversity). The operationalizations of the variables are presented in Table 1.

Table 1: Operationalized Variables and their Measurements

Variable	Measurement	Source of data
Information volume	Total number of information bits accessed across all pages during the experiment	Intranet server log file
Information diversity	Computed as: $\frac{\text{Number of unique pages accessed}}{\text{Number of unique pages available}}$	Intranet server log file
Decision time	Elapsed time between start and end of decision activity, measured in minutes	Intranet server log file
Flow of information	Computed as: $\frac{\text{Number of total pages accessed}}{\text{Decision time}}$	Intranet server log file

4. Results

We conducted polynomial regressions to test our hypotheses. Since the relationship hypothesized was that of an inverted U-curve, a quadratic model was selected.

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \varepsilon$$

The standard precautions associated with polynomial regression were adopted (Montgomery and Peck 1982). These included keeping the order of the model as low as possible, progressive introduction of polynomial terms, and proscriptions about extrapolating beyond the observed data range. SAS was used to develop the General Linear Models (GLM) for the regression analyses. For each polynomial regression, we also conducted linear regressions to ensure that polynomial model is a significant improvement over the linear one in terms of adjusted R^2. In order to test proposition 1, we used the entire data set, i.e. all 54 teams. We used group type (with or without decision schema) as a control variable in the regression model. Proposition 2 was tested by conduction regression analyses for each type of group separately and then comparing the nature of nonlinear plots for each group. The results of the analyses are presented in the next few pages. Table 2 explores the relationship between information complexity and information processing across all groups. Table 3 breaks down this analysis between control and treatment groups. The nonlinear plots appear in Figures 2 and 3, for different groups.

Table 2a. Regression Results for Decision Time and Information Flow [all groups] (Input Information Complexity Operationalized as Information Volume)

Variable	Decision Time	Information Flow
Information Volume	1.203 (4.587)	0.001*** (0.0002)
Information Volume^2	-0.005* (0.006)	-6.644** (2.358)
R^2	0.264	0.600
F	5.97	9.59
Pr>F	0.002	<0.0001
N	54	54
Hypothesis Supported?	***H1: Yes***	***H1: Yes***

* p<0.10 ** p<0.05 *** p<0.01 **** p<0.001 Standard errors in parentheses

Table 2b. Regression Results for Decision Time and Information Flow [all groups] (Input Information Complexity Operationalized as Information Diversity)		
Variable	**Decision Time**	**Information Flow**
Information Diversity	-125.706 (77.338)	6.002*** (3.057)
Information Diversity^2	132.076** (62.046)	-2.982 (2.453)
R^2	0.204	0.622
F	4.26	7.71
Pr>F	0.009	0.0002
N	54	54
Hypothesis Supported?	***H1: No***	***H1: Yes***
* p<0.10 ** p<0.05 *** p<0.01 **** p<0.001 Standard errors in parentheses		

Support for Proposition 1 is indicated by a negative coefficient for the quadratic term in the polynomial regression model. Table 2 indicates support for Proposition 1 reconfirming the nonlinear (inverted U-shaped) relationship between information complexity and information processing.

Table 3a. Regression Results for Decision Time and Information Flow [separate analyses] (Input Information Complexity Operationalized as Information Volume)				
Variable	**Decision Time**		**Information Flow**	
	Without decision schema	**With decision schema**	**Without decision schema**	**With decision schema**
Information Volume	0.0132 (0.008)	-0.010 (0.0076)	-8.873E-6 (0.0003)	0.001**** (0.0003)
Information Volume^2	-1.015E-6 (8.6486E-7)	1.646E-6** (8.118E-7)	2.085E-8*** (3.399E-8)	-9.367E-8**** (3.203E-8)
R^2	0.268	0.338	0.325	0.446
F	4.38	6.13	5.77	9.66
Pr>F	0.0238	0.007	0.009	0.0008
N	27	27	27	27
* p<0.10 ** p<0.05 *** p<0.01 **** p<0.001 Standard errors in parentheses				

Table 3b. Regression Results for Decision Time and Information Flow [separate analyses] (Input Information Complexity Operationalized as Information Diversity)				
Variable	**Decision Time**		**Information Flow**	
	Without decision schema	**With decision schema**	**Without decision schema**	**With decision schema**
Information Diversity	87.221* (164.854)	-155.689 (100.743)	-3.669* (6.176)	7.283* (4.044)
Information Diversity^2	-40.787** (130.014)	158.429* (81.423)	4.462 (4.871)	-3.939 (3.269)
R^2	0.152	0.244	0.290	0.345
F	2.15	3.88	4.90	6.32
Pr>F	0.13	0.035	0.016	0.0062
N	27	27	27	27
* p<0.10 ** p<0.05 *** p<0.01 **** p<0.001 Standard errors in parentheses				

Support for Proposition 2 hinges on whether the observed peak processing ability occurs at different points for the control and treatment groups. The lack of consistent coefficients for the quadratic term suggests other forces at play. A review of the plots in Figures 2 and 3 provides some insight into this.

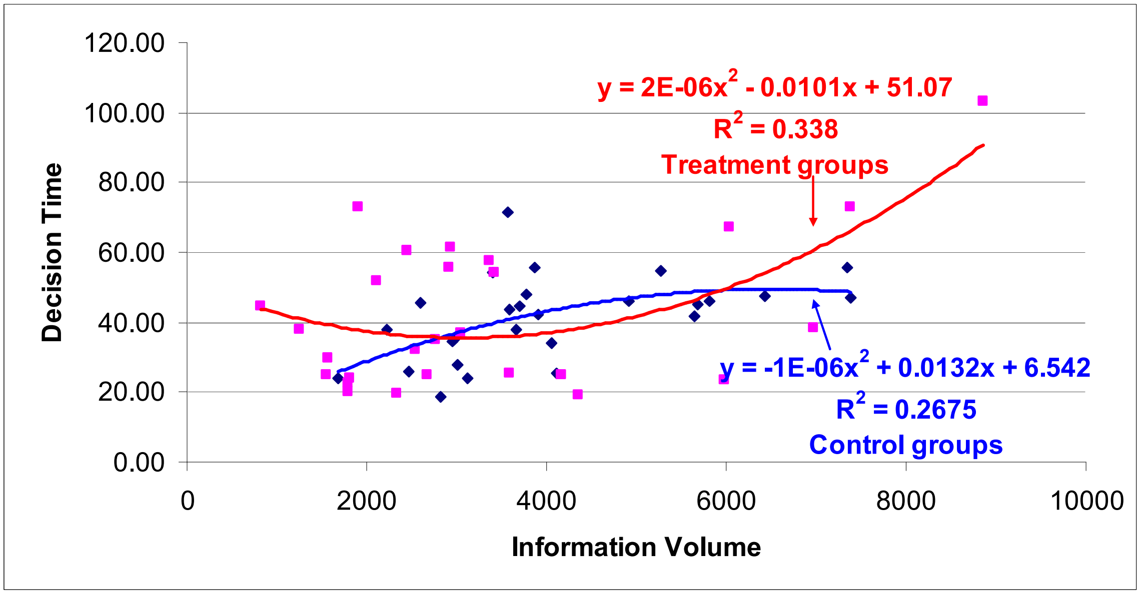

Figure 2a. Decision Time vs. Information Volume

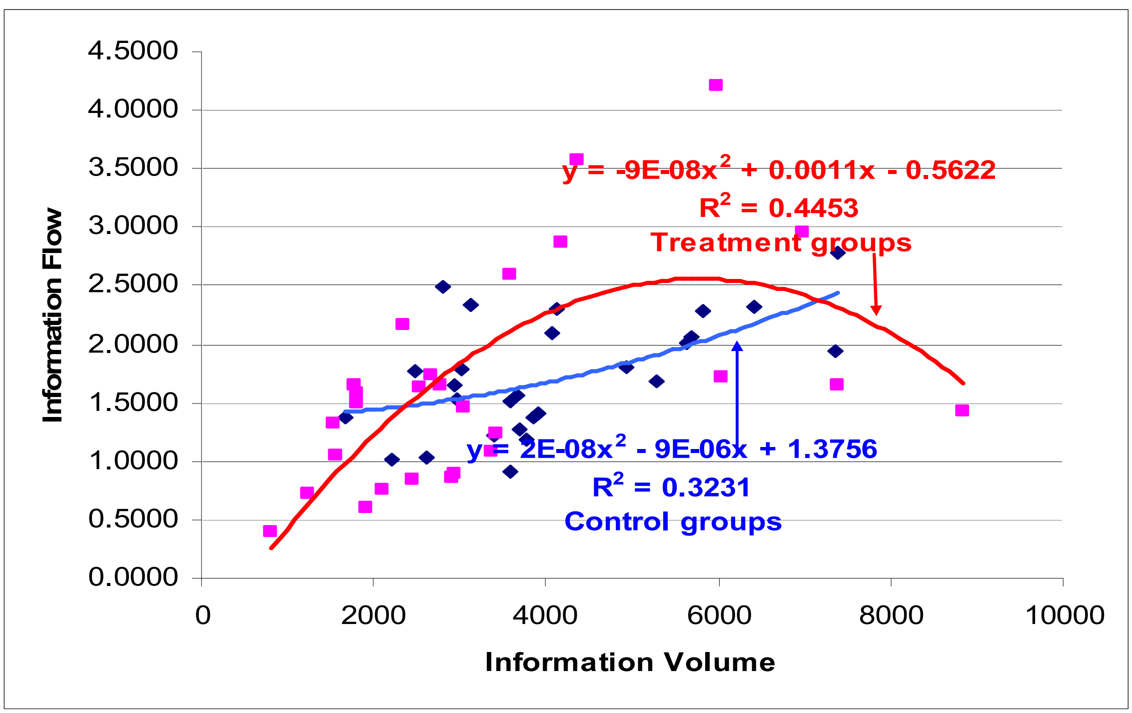

Figure 2b. Information Flow vs. Information Volume

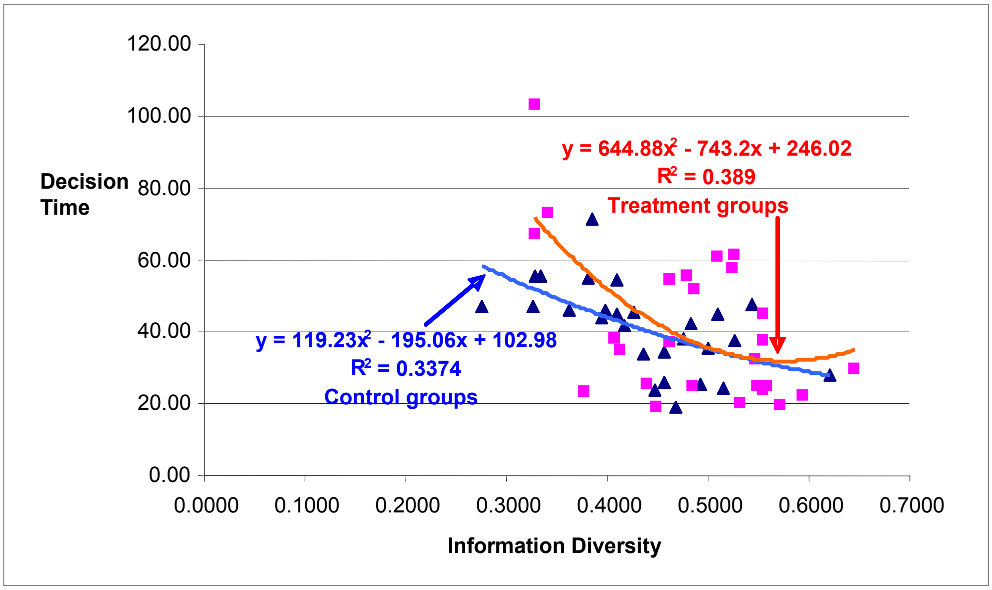

Figure 3a. Decision Time vs. Information Diversity

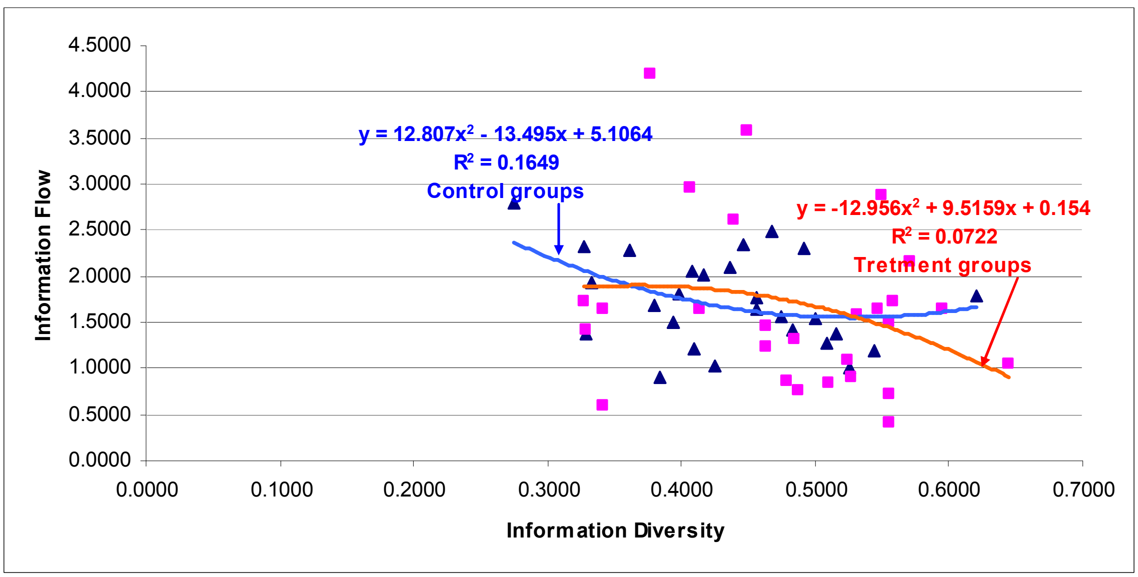

Figure 3b. Information Flow vs. Information Diversity

An examination of Figure 2a reveals that groups that do not use the decision schema (control groups) reach a state of information overload, and any additional information accessed is not processed, leading to shorter decisions. By contrast, groups using the schema (treatment groups) are able to process more information, and continue to work at the decision using larger volumes of information. In examining Figure 3a we find that the groups that do not use the schema exhibit monotonically declining decision time with increase in information diversity whereas the groups that use the schema have declining decision time up to a limiting level of information diversity after which the decision time starts increasing. This implies that the groups without using any schema reach information overload condition as diversity increases whereas the groups using the schema are able to recover from the overload effect perhaps learning from the schema about the pattern of the diversity.

As information flow is inversely proportional to the decision time, Figures 2b and 3b depict the reverse effects of what was observed with the decision time.

5. Discussion

The study extends prior research on information processing and integrative complexity to the GSS-based virtual groups. The findings of the study suggest that information complexity does exhibit a nonlinear relationship (inverted U-shaped) with the level of information processing. This effect was observed for two measures of complexity – information volume and information diversity. Information processing was measured in two forms – decision time and information flow. These findings suggest that information overload applies equally to group as it does to individual decision makers. Group process gains and losses may affect the rate at which the maximum processing capability is attained, but the overload problem is encountered nonetheless. The implication for group activity is that simplifying the group process is necessary. This can be accomplished in a variety of ways. Reducing the number of tasks involved is an obvious option. Reducing the amount of information to be processed at any stage is another possibility. However, both of these entail changes to the group process that may curtail the group's ability to accomplish its objective. Employing appropriate decision aids represents a possibility when the group process and task complexity cannot be altered.

The effects of information overload may be alleviated through the use of a decision schema that helps group members understand the nature of information, so as to enable greater processing capability. This study examined the use of prior weights in the preference structure for selecting among attributes. The results indicate that the groups using the schema had increased information processing capability, at least in some cases. More importantly, in many cases, the nature of the relationship between information complexity and information processing capability was revered between the control and the experimental groups. This strongly suggests that the presence of appropriate decision aids can improve the ability to process information. It is expected that the ability to process additional information will have an impact on decision quality. Future research can examine this aspect of the group decision process. Likewise, an evaluation of different decision schema, as appropriate to the task at hand, represents additional areas for research.

6. Conclusion

This research has examined the problem of information overload in a group decision making setting. It established that the overload does occur and can have an impact on the group process and outcomes. Multiple measures for information processing and information complexity were used to establish this. It also demonstrated that the use of appropriate decision aids, in this case a schema that synthesized prior decisions, can alleviate the problem of overload. More research is needed to assess the impact of overload on group decision quality, and the effectiveness of alternative decision aids in offsetting this.

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