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ABSTRACT

Globalization has increased competition and dynamic nature of business environment, and formation of work groups that collaborate electronically has become common. Electronic brainstorming and polling can be useful for these groups. However, groups that use electronic brainstorming tools can generate a large number of diverse ideas, which can make the input environment complex for the members. Input complexity influences the level of information processing, hence affects the outcome of group work. We report the findings of a laboratory experiment involving a group support system (GSS) in an electronic discussion task. We found that input complexity influenced the level of information processing, group members' participation, and the number of unique solutions generated. Additionally, we demonstrated the inter-relationship that group members' participation and their output have with their satisfaction. We believe that our findings will be useful for practitioners managing virtual work groups and researchers studying performance of these groups.

INTRODUCTION

Individuals, groups, and organizations can be viewed as information-processing systems that have certain general characteristics in common, and productivity is viewed as strongly dependent on information-processing characteristics of these systems. The difficulty of processing information depends heavily on the load and diversity of input information (Driver and Streufert, 1969). Several researchers have discussed input complexity to the functioning of human information-processing systems (Miller, 1956; Anderson and Fitts, 1958). Even though input complexity has been explored in the context of individual human information processing, it is a less explored area in the Group Support Systems (GSS) field. With the exception of the work by Grise and Gallupe (1999-2000), there have not been any major study on input complexity in the GSS context and we believe this is an area that should be further explored in the GSS realm.

LITERATURE REVIEW

Information Processing

Prior studies on information processing suggested how an increase in the number of input information cues can impact performance of individual decision makers (Miller, 1956; Iselin, 1988). Schroder, Driver, and Streufert (1967) hypothesized an inverted U-shaped relationship between the complexity of input environment and the level of information processing complexity (Figure 1). The level of information processing is the maximum when the input complexity is moderate (i.e., neither too high nor too low).

Individuals or groups sort the input information into different dimensions or points of view which is referred to as *differentiation*. *Integration* is the interconnection among these dimensions. The amount of integration among different dimensions is known as integrative complexity and it reflects the level of information processing complexity.

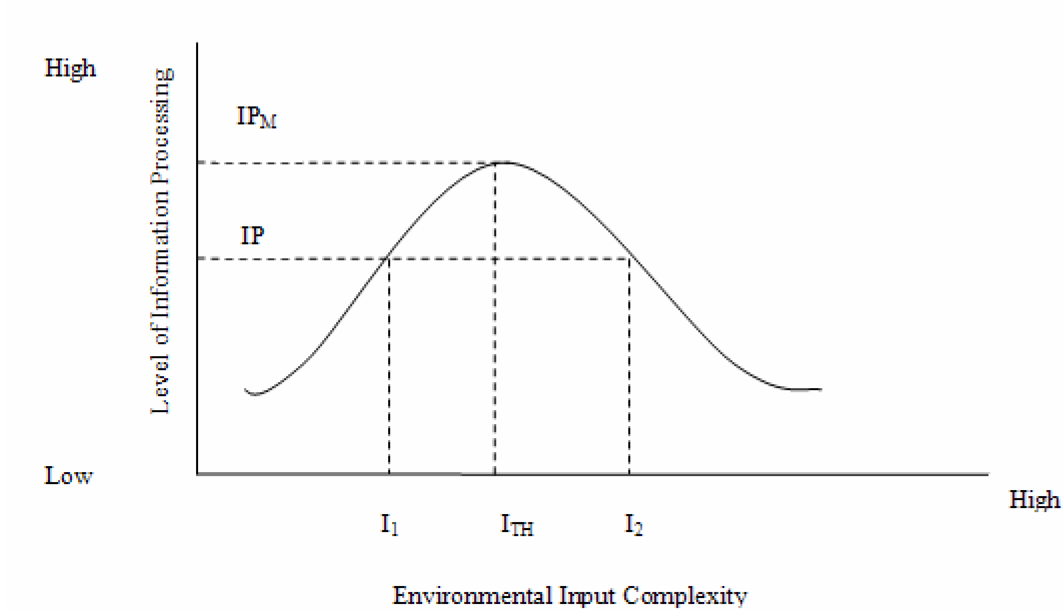

Figure 1: Relationship between Environmental Input Complexity and Level of Information Processing (Schroeder et al., 1967)

Input Complexity and Integrative Complexity

Integrative complexity theory purports that individuals and groups can themselves be regarded as information processing systems. Driver and Streufert (1969) explain that input complexity consists of a number of information cues to be processed, cue diversity, and the flow of cues in a unit of time. As input complexity increases, systems increase information handling capacity linearly up to an upper limit, after which the information processing systems begin to omit inputs or accumulate them in a delayed action "list," and the processing of information begins to decline in quality and quantity. Input complexity is the central factor in respect to integrative complexity (Schroder et al, 1967).

Input complexity

Input complexity is defined as the number of utility or probability changes that an input can potentially evoke in a maximally open system as a result of the informational content of the input. The primary properties of input complexity include information load, information diversity, and information change. Information load and diversity have been studied several times (Iselin, 1988; Hwang and Lin, 1999). These studies focused on information diversity and repetitiveness and demonstrated how these dimensions can influence decision quality and decision time in structured and unstructured tasks.

The task context in our study is an electronic discussion, where input information complexity comprises of the number of ideas discussed and the diversity of these ideas. Research has presumed that input complexity may happen in consequence of too many ideas being created. When too many ideas are generated, some group members may become frustrated by the effort required to edit, select, and evaluate those ideas (Gallupe and Cooper, 1993). Additionally, idea diversity can create information overload, and high diversity can increase the general complexity of problem solving (Sethi, Smith, and Park, 2001). Thus, we examine these two aspects of input complexity.

Number of ideas

Discussion tasks involve the generation of different ideas pertaining to the issues discussed. As such, the number of ideas discussed is a crucial aspect of the complexity of the input environment. When generated ideas are organized, only relevant ideas are retained. Identifying relevant ideas from a large pool involves considerable information processing which increases as the number of input ideas increase.

Idea diversity

Idea diversity can benefit organizations by allowing them to suspend preconceived beliefs and utilize team learning to innovate, thus idea diversity can provide organizations with a long-term competitive advantage (Black and Prudente, 1998; Welbourne and De Cieri, 2001). Nevertheless, idea diversity can increase the general complexity of team problem solving (Sethi et al., 2001). Idea diversity involves a higher level of differentiation and integration of issues in the minds of group members who process the ideas. This constitutes a higher level of information processing.

The number of ideas and idea diversity are related to the human mind's ability to recall what is remembered (Svensson and Angelborg-Thanderz, 1997). The increased input complexity, caused by this increased number and diversity of ideas puts a severe limitation on the ability of the mind to recall what is heard or learned. Human information processing abilities can be deterred by increases in input complexity (Wu and Yuan, 2003).

Information Processing and GSS-based Groups

Prior studies of the performance of GSS-based groups have included variables such as decision time, member satisfaction, participation, consensus, and quality of group work (Fjermestad and Hiltz, 1998-99). We focus primarily on the effectiveness of the GSS-based groups and exclude consensus and decision time from our research questions. Thus, the performance variables in our study are quality of group work, group members' perceptions of participation in group work, and satisfaction with the group work. All of which are important and well-studied variables in GSS research.

Quality of group work

In discussion tasks, group members discuss different issues and reach agreement on solutions that are acceptable to the majority of the group. The unique solutions identified by the group during the discussion reflect the creativity or the quality of the group work. However, we acknowledge that even though the notion that there is a positive correlation between idea quantity and idea quality has not yet been theoretically supported or empirically examined, researchers have suggested this correlation (Potter and Balthazard, 2004).

Perceived participation

Fjermestad and Hiltz (1999) believe that the task type impacts perception of participation, and that decision tasks resulted in a greater perception of participation. Observed participation equality—one's perception of whether participation is equitable—is a mathematical function of the distribution of participation input among group members. Perceived participation equality seeks group members' opinions of how participation input was distributed within their group discussion, and examines whether they believed they were heard and given equitable consideration. This factor indicates how great is their overall perception of participation.

The use of GSS increases the equality of the participative process in project teams, and the storage of comments by use of GSS may impact group members' perceived participation (Dennis and Garfield, 2003). Threaded discussions also enhances members' perception of participation in group work (Paul, Seetharaman, Samarah, and Mykytyn, 2004).

Satisfaction

Practitioners and researchers have made the implicit assumption that satisfied users perform better than users with poor or neutral attitudes toward a system. Theoretically, satisfied users will make better decisions and thus achieve a higher level of performance for an organization (Gatian, 1994).

Reinig (2003) presents a causal model of meeting satisfaction derived from goal setting theory, and distinguishes satisfaction with meeting outcome from satisfaction with meeting process. The distinction between outcome and process is necessary because it is possible that an individual could be satisfied with a meeting outcome and not satisfied with a meeting process, and vice versa.

Process satisfaction

A meeting process refers to the procedures, deliberations, and methods used by a group throughout the duration of a meeting Reinig, 2003). Researchers (Briggs, Vreede, and Reinig, 2003; Connolly, Jessup, and Valacich, 1990) have emphasized the importance of satisfaction with the GSS-supported meeting process. A study by Mejias, Shepherd, Vogel, and Lazaneo (1997) argues that GSS technology should contribute to group achievement by eliminating communication barriers associated with face-to-face discussion; therefore, GSS-based groups can experience more process gains—including satisfaction—and fewer process losses. Similarly, Reinig, Briggs, Shepherd, Yen and Nunamaker (1996) illustrate the importance of process satisfaction and indicate that a low process satisfaction may cause users to abandon GSS technologies, even if performance is improved.

Outcome satisfaction

In GSS-supported group meetings, outcomes vary according to the meeting's purpose. Meeting outcomes could include products or deliverables, decisions, recommendations, or courses of actions, and could be characterized as the absence of any specific accomplishment, which may or may not be consistent with an individual's goals. Satisfaction with that outcome can be a goal itself in meetings that are held to accomplish a specific outcome. For instance, individuals faced with a difficult decision to make often have the specific goal of being satisfied with their final decision. When such an outcome is obtained, a goal is fulfilled (Reinig, 2003). When outcomes are aligned with preferences, they are perceived as more favorable (Hunton and Price, 1997).

Outcome satisfaction provides a valuable indicator of the group's success since group members' satisfaction is likely to influence their confidence in the decision and their commitment to its successful implementation (Miranda and Bostrom, 1999). The data-generation and data-retrieval features of GSS technology can reduce uncertainty and thus evoke a feeling of comfort and outcome satisfaction (Mejias et al., 1997). The exchange of useful data can lead to a better quality outcome, which in turn leads to a groups' outcome satisfaction (Huang, Wei, and Tan, 1999).

THEORETICAL FRAMEWORK

A system's internal integrative complexity varies in a curvilinear pattern as input complexity changes and the amount of information that must be processed increases. As discussed above, Miller (1956) explained that as information input complexity increased, both individuals and groups increased information-handling capacity linearly up to an upper limit or asymptotic level, after which the systems began to omit inputs or decrease processing. Similar curvilinear function between input complexity and output quality in information-processing systems were observed or suggested by other researchers (Anderson and Fitts, 1958).

Svensson and Angelborg-Thanderz (1997) determined that it is crucial to pay attention to human limitations for information processing, as the human mind has severe limitations regarding what can be received, what can be processed, and what can be remembered. Up until a certain point, as input complexity increases, processing of information increases, but as input complexity increases further, information processing begins a descent due to increase in integrative complexity. Therefore:

Hypotheses 1: *In discussion tasks, input complexity is curvilinearly (∩) related to the level of information processing.*

As input complexity increases, the complexity of problem solving will increase (Sethi et al., 2001). It may involve a higher level of differentiation and integration of issues in the minds of group members who process the input information. As input complexity increases, individual members will remain busy understanding the complexity of the problem, and responding to each comment will not be easy. Responding to too many messages may create psychological tension for the group members, especially for those who are passive in the group, and their natural pattern of participation may be altered (DeSanctis and Gallupe, 1987). They may filter information or pay less attention to the ideas submitted by other members. This will have an adverse effect on group members' perception of participation in the discussion. Therefore:

Hypothesis 2: *In discussion tasks, input information complexity negatively impacts perceived participation.*

Conversely, we believe that input complexity has a positive impact on the number of unique ideas generated in the group discussion. The more diverse are the input ideas, the greater is the possibility of generating large number of ideas in the discussion session. A study by Black and Prudente (1998) points out that idea diversity can benefit organizations by allowing them to suspend preconceived beliefs and utilize team learning to be more innovative. Welbourne and De Cieri (2001) discussed how idea diversity can in some cases provide organizations with a long-term competitive advantage. When the number of input ideas increases, the group has a wide pool of ideas from which the final selection can be made. Even if the members filter some of the ideas when encountering information overload, the availability of a wide pool of ideas will enhance the likelihood of including more unique ideas in the outcome of group discussion. Therefore:

Hypothesis 3: *In discussion tasks, input complexity positively impacts the number of unique ideas generated in the session.*

Thoroughness or comprehensiveness of analyses underlying the final decision is a measure of group decision effectiveness and performance (Fjermestad and Hiltz, 1998-1999). When group members evaluate a wide range of issues and identify many unique solutions, they are likely to perceive that the outcome solution is comprehensive. Additionally, if group members perceive that the discussion is well-participated, they consider that the final outcome includes views of a majority of members and is, thus, relevant to them. As a result, group members' satisfaction with discussion outcome increases. Hence:

Hypotheis 4a: *In discussion tasks, the higher the perceived participation of the group members, the higher will be their satisfaction with the outcome of the group work.*

Hypotheis 4b: *In discussion tasks, the higher the number of unique ideas generated by a group, the higher will be its members' satisfaction with the outcome of the group work.*

When individuals perceive that they are fully participating in a meaningful manner, they are more satisfied with the process. Bailey and Pearson (1983) called this "feelings of participation," and found it was an important factor in participation and in satisfaction. Additionally, as the number of unique solutions generated as an outcome of the discussion increases, the participants realize that the group is successful in reaching consensus on many issues. Increased participation and consensus improve satisfaction with process (Olaniran, 1996). Hence:

Hypothesis 5a: *In discussion tasks, the higher the perceived participation, the higher will be the satisfaction with the process of group work.*

Hypothesis 5a: *In discussion tasks, the higher the number of unique solutions generated in the session, the higher will be the satisfaction with the process of group work.*

RESEARCH METHOD

We conducted a laboratory experiment to test our hypotheses. Volunteer subjects enrolled in BBA (junior/senior levels) and MBA programs at a major Midwestern university participated in this experiment. All subjects were experienced with information technology, including Internet/Web skills. Thirteen groups had three persons; ten groups had four.

Once the availability of the students was known, students were randomly assigned to the three- or four-member groups. Each subject participated in a detailed training session in which each command of the GSS software package was demonstrated.

Task Identification and Description

The task chosen was to make a recommendation for about five options for technology fee usage to the administrators of a university. This task involved the following activities:

- Group members discussed and generated as many ideas as possible on usage of technology fees.
- Group members summarized the unique ideas discussed. Although the members could revisit the ideas generated and filter out the redundant ones, it would involve considerable time unless the members had already read and understood all ideas generated in the discussion. Thus the group members listed the non-redundant ideas that could be recalled from the discussion.
- When prompted by the facilitator, each member voted on each unique idea using the polling tool of Lotus Sametime, and the system showed the results. The ideas selected by the majority were proposed to the university administration.

These activities were implemented using Lotus Sametime. Each group was under the control of a facilitator who monitored the discussions and dealt with any technical software questions; the facilitator did not interject anything into the discussion regarding the use of technology fees. The facilitator was assisted by a support personnel who addressed the technical/process related problems that the subjects might encounter in the meeting.

Variable Identification

In this research, the independent variables are input complexity. The dependent variables are the level of information processing, the number of unique solutions proposed, perceived participation, and satisfaction. The control variable is size of groups.

Information load and information diversity are two primary properties of input complexity (Schroder et al., 1967). Thus, input complexity was measured in terms of the number of input ideas discussed and the diversity of input ideas. A surrogate measure of the level of information processing is output information complexity resulted in number of ideas recalled. The GSS software captured a record of the groups' communications and discussions. The group discussions were analyzed to identify the total number of input ideas and the number of diverse dimensions to which these ideas belong; the number of ideas recalled. Two coders independently analyzed the group discussions. The inter-coder correlations, listed below, are acceptable considering the exploratory nature of the study in the context of virtual teams.

- Number of input ideas: 0.977 ($n=23$, $p<0.0001$)
- Number of diverse dimensions to which the input ideas belong (i.e. diversity of ideas): 0.835 ($n=23$, $p<0.0001$)
- Number of ideas recalled: 0.934 ($n=23$, $p<0.0001$)

The other dependent variables were measured using 5-point Likert-type scales: perceived participation, outcome and process satisfaction.

RESULTS

Reliability and Validity

Reliability assessments were calculated for the self-reported variables of perceived participation, process and outcome satisfaction. Our instruments were adapted from similar instruments in prior research (Paul, Haseman, and Ramamurthy, 2004; Paul et al., 2004; Paul, Samarah, Seetharaman, and Mykytyn, 2005). Two experts on group decision-making and attitude measurement conducted an initial review of these measures to establish their face validity. Subsequently, Cronbach Alpha coefficients were calculated. Although the measurement scales were tested and validated in prior studies, in view of the exploratory nature of this research, a cut-off value 0.70 was considered acceptable (Nunnally, 1978). An alpha of 0.69 was found for "perceived participation," 0.81 for "process satisfaction;" and 0.81 for "outcome satisfaction."

We conducted factor analysis employing VARIMAX orthogonal rotation for perceived participation, process and outcome satisfaction. The factor analysis of the five items representing "perceived participation" produced a single-factor structure with factor loadings ranging from 0.607 to 0.725. The factor analysis of the eight items representing "process satisfaction" loaded on three factors representing three dimensions of decision-making process. These dimensions are "completeness," "harmony and pace," and "contribution" aspects of decision making process. The items of the factor "completeness of decision making" had loadings between 0.698 and 0.906; those for factor "harmony and pace of decision making" had factor loadings ranging from 0.683 and 0.821; and the items of the factor "contribution in decision making process" had factor loadings of 0.811 and 0.862. These three dimensions jointly constitute the satisfaction with decision making process. In order to confirm the validity of the "process satisfaction" instrument, we attempted to load all eight items on a single factor. The factor loading ranged between 0.536 and 0.767 and most of the loadings were above 0.600. The factor analysis of the five items representing "outcome satisfaction" produced a single-factor structure with factor loadings ranging from 0.659 to 0.821.

Hypothesis Testing

To test the relationship between input complexity and the level of information processing, a curvilinear regression analysis was performed with each measure of information complexity (see Tables 1 and 2). The analyses demonstrate a statistically significant curvilinear relationship between input information load and the level of information processing. The result supports hypothesis 1. However, we did not find any support for the curvilinear relationship between idea diversity and the level of information processing. As such, hypothesis 1 was supported for only one measure of input complexity (which is input information load).

To test whether a curvilinear model is the best predictor of the relationship between input complexity and level of information processing, we compared linear and curvilinear regression models involving the variables. An F-test comparison of the regression coefficients of the two models was carried out. The curvilinear regression model was found to be significantly different and had higher R^2 when input information load was used as a measure of input complexity. This confirmed the inverted U relationship between input information complexity (measured as input information load) and the level of information processing.

We regressed perceived participation on the number and diversity of ideas generated in the initial phase of the group work. The results revealed that the diversity of input ideas negatively impacts group members' perception of participation in the idea generation session (see Table 2), thus providing weak support for hypothesis 2.

We also regressed the number of unique solutions generated in the session on the number and diversity of ideas generated. The regression results demonstrated that both diversity and total number of input ideas has positive relationship with the generation of unique ideas in a session (see Tables 1 and 2). The result provides strong support for hypothesis 3.

In order to test hypotheses 4 and 5, we regressed outcome and process satisfaction separately on the number of unique solutions generated in a session and perceived participation of each group. The results of the regression analysis, presented in table 3, show support for hypotheses 4a, 5a, and 5b. Thus, perceived participation has positive relationship with both outcome and process satisfaction. However, the number of unique solutions generated by each group has positive relationship with only its process satisfaction.

Dependent Variable / **Independent Variable**	**Number of Recalled Ideas**	**Perceived Participation**	**Number of Unique Solutions Generated**
Input information load	1.074**** (0.2679)	-0.013 (0085)	0.290**** (0.0422)
Input information load ^{2} – Quadratic Term	-0.011* (0.0043)		
R^2	0.6907	0.1077	0.6937
F	22.34	2.54	47.55
N	23	23	23
Hypothesis Supported?	***H1: Yes***	***H2:No***	***H3: Yes***
* p<0.10 ** p<0.05 *** p<0.01 *** p<0.001 Standard errors in parentheses			

Table 1. Regression Results [Input Complexity Measured as Input Information Load]

Dependent Variable / Independent Variable	Number of Recalled Ideas	Perceived Participation	Number of Unique Solutions Generated
Diversity of input information	0.374 (0.8170)	-0.048* (0.0254)	0.809**** (0.1497)
Diversity of input information^2 – Quadratic Term	0.046 (0.0427)		
R^2	0.6553	0.1436	0.5819
F	19.01	3.52	29.23
N	23	23	23
Hypothesis Supported?	***H1: No***	***H2:Weak***	***H3: Yes***
* p<0.10 ** p<0.05 *** p<0.01 *** p<0.001 Standard errors in parentheses			

Table 2. Regression Results [Input Complexity Measured as Diversity of Input Information]

Dependent Variable / Independent Variable	Outcome Satisfaction		Process Satisfaction	
Perceived participation	0.571** (0.2092)		0.480**** (0.1077)	
Number of unique solutions generated		0.024 (0.0225)		0.034** (0.0127)
R^2	0.2959		0.5102	
F	3.78		10.42	
N	21		23	
Hypothesis Supported?	***H4a: Yes***	***H4b: No***	***H5a: Yes***	***H5b: Yes***
* p<0.10 ** p<0.05 *** p<0.01 *** p<0.001 Standard errors in parentheses				

Table 3. Regression Results

DISCUSSION

The study revealed that the complexity of input environment impacts the level of information processing of the virtual work groups, engaged in discussion tasks. We measured the level of information processing in terms of the information that the group members could recall after ideas were generated. We found that the input information load had a curvilinear relationship with the recalled information. However, the diversity of information was found to have a linear relationship with the recalled information ($\beta=1.226$, $R^2=0.6353$, $p<0.0001$). The findings indicate that the groups might have generated many ideas in the beginning of the discussion, but the ideas lacked sufficient diversity. Thus, the input complexity consisted primarily of the input information load. This implies that unless group members are encouraged to generate diverse ideas, the purpose of engaging virtual work groups in idea generation activities will be defeated. To overcome this problem, some form of content facilitation may be introduced in the electronic meetings.

The study also revealed that the complexity of the input environment did not have any major impact on group members' perception of participation in the group work. Interestingly, input load did not have any significant effect on perceived participation. An explanation could be the possibility that when many ideas were submitted, group members filtered the inputs and thus failed to realize that others participated heavily in the meeting. Interestingly, the diversity of input ideas had a negative impact on the perceived participation (β=-0.048, R^2=0.1436, p=0.075). This lends credence to our assumption that when faced with diverse ideas from others in the meeting, some members may refrain from participating vigorously in the group work. However, as the statistical significance of our finding is not very strong, we intend to explore this issue more carefully in future research.

As proposed, we found a positive relationship between the input complexity and the number of unique solutions proposed by the groups. We also found that both perceived participation and the number of unique solutions generated by the groups had positive relationships with the process satisfaction. However, contrary to our expectations, the number of unique solutions generated in the meeting did not have any impact on the satisfaction with the meeting outcome. The group members' satisfaction was influenced only by the perceived participation. This finding is somewhat confusing and needs in depth investigation in the future. Overall, the findings of this preliminary study on the information processing of the virtual work groups are quite interesting and provide motivation for in further research in this area.

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