Discrimination of Structure and Technology in a Group Support System: The Role of Process Complexity

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DISCRIMINATION OF STRUCTURE AND TECHNOLOGY IN A GROUP SUPPORT SYSTEM: THE ROLE OF PROCESS COMPLEXITY

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ABSTRACT

It is not clear whether improvements found with group technology are due to the structure embedded in the technology or the added benefit of the technology in managing information complexity. Process complexity is proposed as the explanatory factor in previous conflicting results. Task complexity is clarified and a Process Complexity Model is proposed and tested. The principal factors manipulated are task complexity (complex and less complex) and technology (present or absent). Ill-structured policy tasks are employed and, in addition to other outcome variables measured, task outcome quality is quantified by comparing the reported results of policy experts in these tasks. Since small group size (three to four) may be the reason that previous experiments have not shown significant differences, group size is controlled using larger groups of seven or more members.

The experimental results broadly support the hypotheses except for user satisfaction and confirm that when there is sufficient process complexity the benefits of the technology are unmistakable. In other words, the results demonstrate that process complexity differentiates technology and structure.

1. INTRODUCTION

For organizations to adopt group technology, the proven efficacy of information technology to support group work is essential. The use of aids to structure group decision making has its critics and proponents (Applegate 1991). It has been found that structured processes improve decision outcome when compared to unstructured process treatments (Easton 1988; Watson, DeSanctis and Poole 1988). However, what is not clear is whether improvements found with group technology treatments are due to the structure embedded in the technology or the added benefit of the technology in managing complexity (Easton 1988). In their discussion of major limitations which weaken the validity of previous GDSS studies, Pinsonneault and Kraemer (1990) emphasize

> Firstly, *there is a lack of control for the effect of greater structure on group processes resulting from the technological support* in most GDSS studies. This is particularly important because greater structure of the processes might cause changes in the group process variables and in the outcome variables, rather than the GDSS.

The goal of this research is to discover if Electronic Meeting Systems/Group Decision Support Systems (EMS/GDSS) provide benefits beyond the mere structure of the process. Process complexity is proposed as the explanatory factor in previous conflicting results, and task complexity, a major component of group process complexity, is clarified.

2. BACKGROUND

EMS research results to date reveal sharp differences between field and laboratory studies (Nunamaker et al. 1990), and significant inconsistencies among laboratory experiments (for example, Applegate 1986; Easton 1988; Gallupe 1985; George et al. 1990; Ruble 1984; Turoff and

Hiltz 1982; Watson 1987; Zigurs 1987). Four key differences between field and laboratory outcomes are (Nunamaker et al. 1990): (1) task characteristics, especially complexity, (2) group size, (3) irregularity or asymmetry of information, and (4) congruence between the EMS system and contextual factors. Nunamaker et al. suggest that to demonstrate the value of an EMS, some minimum level of task complexity must be present to just overcome system impedance (productivity losses attributable to the system itself). Group size in reported field studies range from 16 to 31 (Nunamaker et al. 1990; Tyran et al. 1990).

Analysis of laboratory research reveals inconsistencies, but certain conclusions are possible. The level of task complexity and difficulty in most laboratory studies is relatively simple. Also, group sizes are rather small — usually only three or four. In addition, structured processes are shown to be beneficial whether provided manually or through a computer system. Further, these laboratory studies consistently indicated that structured support, however provided, is superior to no support at all. A continuing issue in laboratory research is the demonstration of a difference between manual support and computer-aided support. The divergence between laboratory research and field studies suggest manipulation of complexity as a means of discriminating between manual support and computer-aided support.

3. CLARIFYING TASK COMPLEXITY

Task complexity is a key component of group process complexity and important to development of a research model. Problematically, tasks are variously and interchangeably described in the literature as both complex and difficult (for example, see Shaw 1964, 1973, 1981). There are far more similarities than differences among conceptualizations of task complexity and task difficulty. However, group and process characteristics are often included in these conceptualizations. This has confounded selection of appropriate tasks of varying complexity and comparison of experimental results.

Gallupe, DeSanctis and Dickson (1988) made use of Payne's (1976) discussion of task difficulty which refers to the relative degree of cognitive load, or mental effort, required to identify a problem solution. Hackman (1968) also uses the term "difficulty" and employs a difficulty definition from Shaw, "the amount of effort required to complete the task" (p. 164), which includes factors such as solution time, number of errors or failures to complete, etc. Gallupe, DeSanctis and Dickson further state that objective evidence of difficulty is implied by decision makers' relative performance and ability to complete a task and the amount of time spent in completing a task. In these discussions, one dimension of task difficulty depends on the relevant experience of those performing the task and the collective characteristics of individuals in the group. That is, a given task can require different cognitive loads on groups depending on the qualifications of the group.

Definitions also incorporate process characteristics which are a consequence of the task and/or related to the size of the group. Tushman (1978, 1979) partially describes complex tasks as more difficult to solve and more complicated to coordinate. Shaw (1964) relates task complexity to communication saturation, i.e., the more communication channels and messages, the more complex the task. One aspect of Shaw's communication perspective and Tushman's description thus correlates with group size: larger groups bring about process complication due to more inputs and sources of information.

Tushman (1978, 1979) and Wood and his colleagues (1986; Wood, Mento and Locke 1987) also differentiate task according to mental effort and cognitive load. However, they relate such cognitive effort to the nature of the task, rather than to the capabilities of the problem solvers, the number of problem solvers, or process characteristics. Tushman describes complex tasks as non-routine with more uncertainty and which require new knowledge and unique solutions while Wood and his colleagues (1986; Wood, Mento and Locke 1987) rates complex tasks according to the number of acts or information cues, and according to relationships among acts and information cues, as well as changes among them.

Payne uses nearly the same description for both task complexity and task difficulty. Payne, citing Newell and Simon (1972), points out that information processing varies with complex tasks and complexity is determined by the number of alternatives and the number of dimensions of information available per alternative, or, the amount of information available per alternative. Payne's description of complex tasks is in line with Wood's characterization and appears to directly compare with "the number of issues and alternatives that must be considered" from Dennis et al. (1988), but apparently not a source of Dennis et al.'s interpretation of complexity.

These definitions incorporate the dimensions of complexity and difficulty found in the literature which concern the task itself, and do not intermix group and the process characteristics.

They are consistent with Campbell's (1988) discussion of task complexity for information processing activities, and more easily operationalized than his attempt at a general model of task complexity which he proposes is good for distinguishing among different classes of tasks as well as within a single class. Therefore, for a given class of information-processing related problems, measuring the number of issues and alternatives associated with a task provides a reasonable metric to distinguish between the relative complexity of two tasks.

4. RESEARCH MODEL

The EMS/GDSS attributes of interest to theorists and researchers are rather consistent. The key parameters they have identified and explored are group characteristics, the nature of the task, the properties of the technology employed, process qualities, and outcomes or results. Applegate (1991), for example, draws from previous studies in developing her CSCW Alignment model which incorporates these parameters. The research framework of Dennis et al., although more detailed, keys on these same parameters. Other work directly or indirectly includes these parameters (George et al. 1990), and considers underlying, explanatory micro-theory (Rao and Jarvenpaa 1991).

The theoretical models and frameworks developed can be described as additive and parameters influence each other culminating in outcomes. Applegate's (1991) CSCW alignment model establishes linkages and influences between model parameters and mentions a profusion of potential characteristics, but the combination effects of these features are not considered. Dennis et al. describe successive effects of group, task, context and technology on process and outcomes. The work of George et al. can be similarly described. Again, numerous potential characteristics of these parameters are described, but combination effects of particular characteristics are not considered. Rao and Jarvenpaa's examination of underlying micro theory also develops models in terms of additive effects.

The joint or interactive effects of model parameters are not often considered directly and, in particular, the combination of features which influence group process characteristics are usually not taken into account. Subsets of antecedent models and frameworks can be merged into a general group process model (see Figure 1). Previous EMS research presents the view that group, task and process support characteristics operating in a particular environment generate a group process which yields outcomes.

The precise nature of the group process is not fully understood. In testing the affects of such parameters as group size, task complexity, and process support, the group process can usefully be viewed as a "black box" with numerous sub-processes at work, some known and many not known. Group process complexity, as affected by group size and task complexity, is the question of interest in this research, and a specific implementation of the group process model is appropriate. (See Figure 2.)

As Nunamaker et al. point out, there are process losses associated with the utilization of information technology, but these losses are mitigated and justified if there is sufficient task complexity. Likewise, large groups complicate the process, but the addition of expertise may mitigate and justify the larger group.

In effect, the simplified model used for this investigation is a retrogression, or a retreat Figure 2 from the trend in EMS research to increasingly complex models. The main purpose of this experimentation is to explore a very basic question: Does technology mitigate process losses and improve process outcomes for increasing levels of complexity, or not?

4.1 Summary of Research Model Parameters

4.1.1 Group Size

Group size in the research model affects productivity both positively and negatively (Applegate 1991; Nunamaker et al. 1990). Larger groups increase process complexity with more inputs, viewpoints and expertise to be processed (Nunamaker et al. 1990). At the same time, the greater expertise of larger groups should be beneficial to outcomes.

Of course, there are other group characteristics which affect the process and subsequent outcomes, but those effects are not being tested or manipulated and are controlled in the design of the experiment. For example, individual member characteristics may also complicate the process when personality, job status or political agenda introduce conflict (Dennis et al. 1988) and greater numbers of participants multiply these individual effects. Also, some group attributes can reduce process complexity, such as cohesiveness and positive previous work experience as a group (Nunamaker et al. 1990).

4.1.2 Task Complexity

Task Complexity directly increases process complexity. In particular, a more complex task demands a more complex problem solving process (Dennis et al. 1988; Gallupe 1985). Task complexity is a key variable and is manipulated in this research. Other task characteristics are controlled in these experiments and principally operate to alter the nature of the process required rather than the complexity of the process, as for example the type of task (George et al. 1990; McGrath 1984) and the balance of rational/political perspectives involved (Dennis et al. 1988).

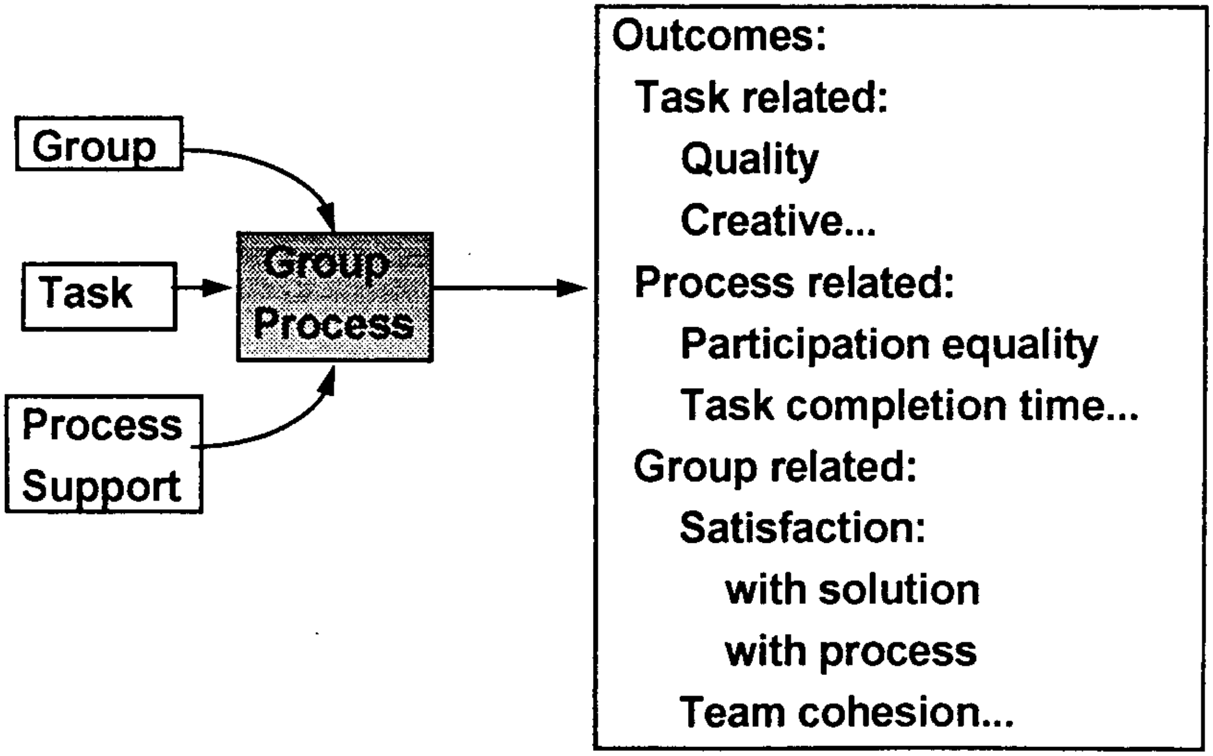
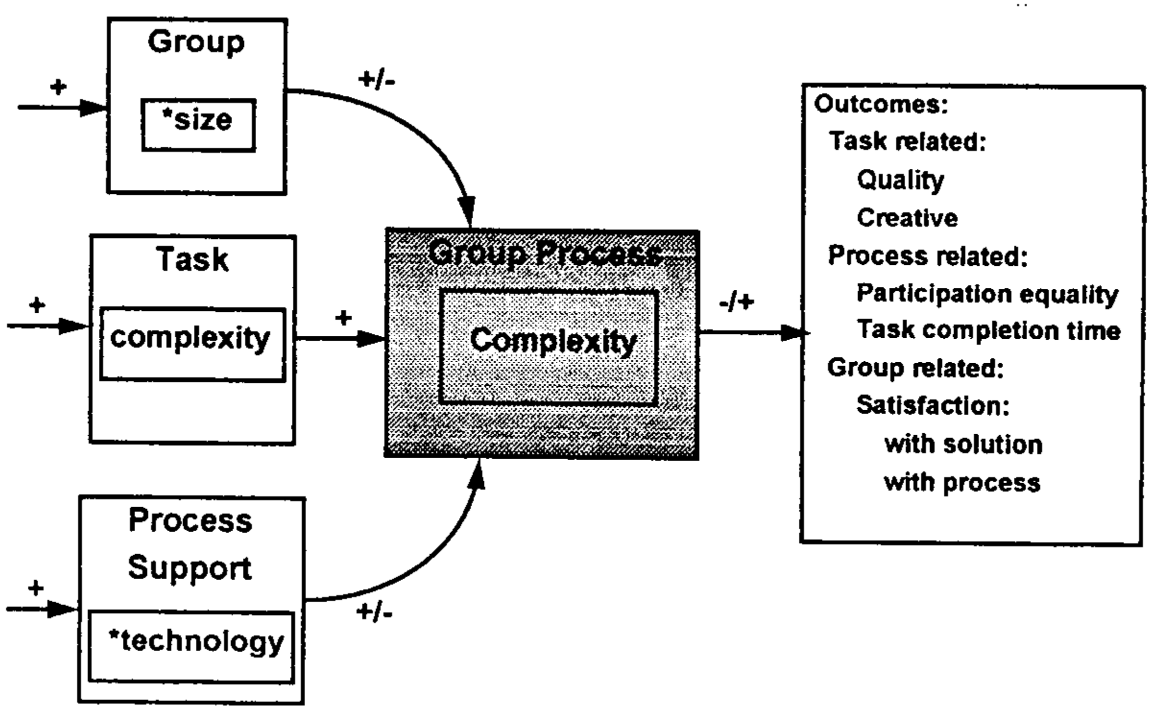


Figure 1. Group Process Model



* For complex tasks, mitigates the negative effect of increased process complexity

Figure 2. Group Process Model
Research Model: Group Process Complexity

4.1.3 Technology

Technology is directly manipulated, but simply through the presence or absence of a single EMS. The characteristics of technology employed have both positive and negative consequences (Dennis et al. 1988; George et al. 1990). There is some loss of productivity due to the need to learn and understand the technology, and because of individual experience or personality characteristics which result in a negative attitude toward technology (Nunamaker et al. 1990). But overall, if EMS tools are present, productivity gains are expected to outweigh losses (Dennis et al. 1988; George et al. 1990; Nunamaker et al. 1990; Rao and Jarvenpaa 1991).

4.1.4 Group Process Complexity: Combinatory Effect of Group Size, Task Complexity and Technology

Other research results suggest that with small groups (less than seven) and tasks with relatively few inputs, the EMS/GDSS may impart "technological impedance" with productivity losses from the software tools outweighing the gains (George et al. 1990; Nunamaker et al. 1990). That is, for simple problems where inputs can be easily retained in participant memory and the number of participants minimizes viewpoints, a manual approach is satisfactory and less cumbersome than a computer-aided one. Therefore, larger groups and the use of technology operate to both increase the complexity of the process and benefit the outcomes.

4.1.5 Process Outcomes

For consistency and comparison, previously identified outcome characteristics of interest (Dennis et al. 1988; Easton 1988; George et al. 1990; Nunamaker et al. 1990) are adopted in the research model. The same outcome characteristics predicted, but not always confirmed, by previous researchers are appropriate to the model for this research since the intent is to identify the cause of previous conflicting results, and to clearly test the value of EMS technology.

5. PROPOSITIONS

Previous EMS research is conflicting but helpful in framing propositions. The theory, models and predictions developed have validity for this work since we hope to explain previous conflicting results.

1. TASK OUTCOME QUALITY

> Task outcome quality will be higher for more complex tasks when groups are supported by technology.

Productivity gains are expected to surpass losses experienced using a computer-aided tool when the task and group size produce more numerous inputs (George et al. 1990; Nunamaker et al. 1990; Watson, DeSanctis and Poole 1988). Easton (1988) found no significant difference between GDSS supported groups and manual structured groups. She did not evaluate task complexity or difficulty but it was apparently of a low order; a premise of this research is that a higher order of difficulty or complexity will reveal differences.

Task complexity adds to the magnitude of the task (Mason and Mitroff 1981; Payne 1976; Shaw 1964, 1981; Tushman 1978, 1979). Larger groups are often formed to bring greater expertise or the needed skills to build sufficient resources to deal with more complex tasks. However, more participants mean more competition to contribute, more viewpoints and variability to resolve (Nunamaker et al. 1990; Shaw 1981), and therefore greater process complexity. In addition, larger groups result in more inputs to be processed (Nunamaker et al. 1990). Group size increases process complexity, but adds to group capability to produce more process gains than losses and higher task outcome quality.

2. IDEATION

> There will be greater creativity for more complex tasks when groups are supported by technology.

The creativity and ideation important to group deliberation, decision making and problem solving are enhanced by process structure (Easton 1988; Van de Ven, Delbecq and Koenig 1976). It has been shown that creativity is reinforced when participants work independently and pool results (McGrath 1984; Shaw 1981), especially in larger groups (Valacich, Dennis and Connolly 1992). Larger groups are enabled by computer-aided tools which allow more alternatives to be recorded than manual structure because parallel communication is supported and productivity losses are minimized (Dennis et al. 1988; Gallupe 1985; George et al. 1990; Nunamaker et al. 1990; Steeb and Johnston 1981).

3. PARTICIPATION EQUALITY

> Participation will be more equal for more complex tasks when groups are supported by technology.

Although Easton did not find more even distribution of participation for computer supported than manually supported groups, increased task complexity and larger groups may clarify the impact of computer support. A structured process is expected to result in more even participation consistent with previous studies (Easton 1988; Lewis 1982; Watson, DeSanctis and Poole 1988). However, sufficient process complexity is necessary for computer supported group productivity gains to offset and exceed losses (Nunamaker et al. 1990) and for the effects of the technology to be seen. Computer-aided support encourages reluctant participants to contribute and supported groups have more equal influence (Watson, DeSanctis and Poole 1988). Computer-aided support results in parallel communication, which avoids the need for turn taking, reduces interruption of thought processes, provides greater opportunity to express opinions and results in greater cognitive effort (Dennis et al. 1988; George et al. 1990; Nunamaker et al. 1990; Rao and Jarvenpaa 1991). Participation is expected to be more equal with greater process complexity which allows a productivity differentiation (Dennis et al. 1988; Gallupe 1985; George et al. 1990; Nunamaker et al. 1990; Steeb and Johnston 1981).

4. TASK COMPLETION TIME

> Task completion time will be shorter for more complex tasks when groups are supported by technology.

There is conflicting evidence concerning task completion or decision time, especially in laboratory studies (Beauclair 1987; Easton 1988; Gallupe, DeSanctis and Dickson 1988; George et al. 1990; Steeb and Johnston 1981; Watson, DeSanctis and Poole 1988) where groups are small and tasks are less complex. Greater information processing capability and more alternatives to consider could lead to longer processing time (Nunamaker et al. 1990; Rao and Jarvenpaa 1991). Another possible explanation, particularly in the case of laboratory studies, is that less complex tasks require less cognitive effort while the EMS/GDSS involves additional time to learn a system which is of little assistance in a straightforward task. Thus, the time benefit when using technology support would not appear except when the group process required is relatively complex.

At greater levels of complexity where technology results in a net productivity gain, group processes should be more efficient and require less time. Task completion time is reduced by group memory aids, support for parallel communication, and tools which help ease management of the problem solving process. Group memory support reduces time spent in information search by facilitating access to and review of group deliberation (Rao and Jarvenpaa 1991; Tyran et al. 1990). Parallel communication facilities preclude the need for turn taking and reduced "process noise" enhances individual concentration on the task (George et al. 1990; Rao and Jarvenpaa 1991). Tools which help manage the process should help the group stay focused on the task and avoid time wasted on extraneous discussion (Kiesler 1978; Shaw 1981). Easton found that manually structured groups took somewhat longer than computer-aided groups, even with a relatively simple task.

5. USER SATISFACTION

> User satisfaction with outcomes will be higher in groups supported by technology.

Mixed user satisfaction results include studies indicating that groups using a structured process are more satisfied than those using traditional interaction (Applegate 1986; Steeb and Johnston 1981; Van de Ven, Delbecq and Koenig 1976), as well as research not supporting the thesis (Gallupe 1985; Gallupe, DeSanctis and Dickson 1988; Watson, DeSanctis and Poole 1988). The benefits of free expression of ideas in computer supported processes appear to explain satisfaction with computer supported versus manual supported processes in accomplishing relatively simple tasks (Applegate 1986; Easton 1988; Rao and Jarvenpaa 1991; Steeb and Johnston 1981). Tools which support process structure contribute to satisfaction (George et al. 1990; Nunamaker et al. 1990).

> User satisfaction with the problem solving process will be higher in groups supported by technology.

Reasoning similar to the User Satisfaction with Outcomes Proposition applies here; as member participation increases, satisfaction with the group and its problem solving process also rises. Van De Ven, Delbecq and Koenig (1976) found more satisfaction among groups supported by the Nominal Group Technique than unsupported interacting groups. Both Beauclair (1987) and Applegate (1986) found that computer supported groups expressed high satisfaction with the decision or problem solving process. Easton found higher decision process satisfaction in computer-aided groups over manually structured groups.

6. EXPERIMENTAL DESIGN

As previously discussed, the task dimension is the primary interest of our current work while the group dimension is indirectly involved. We therefore manipulated task complexity while holding group size at seven or more. This group size is large compared to other laboratory research to date. As previously noted, there appears to be some minimum threshold level of group size necessary where the benefits of the technology (a) outweigh the learning costs of using the technology and (b) manifest in managing the complexity of a "large" number of inputs and interactions. We also manipulated process support by dividing groups into those using group support technology and those using a similarly structured manual process.

Other model dimension characteristics were controlled to the extent practicable. This was a between group, repeated measures design where each group performed two treatments, a less complex task, followed by a more complex task. Pilot testing demonstrated the importance of this treatment order and improved the experimental procedures. Every possible means of establishing parallel experiences for each type of group was employed. Printed instructions were maximally used and instructions for the two types of groups were identical. Both groups performed practice tasks prior to actual treatments to familiarize themselves with the task (and technology for CS groups) and to reduce learning effects. Special care in the experimental design was taken in two areas which Pinsonneault and Kraemer (1990) noted limited the validity of previous GDSS studies:

1. Several previous studies did not monitor the potential affects of a meeting facilitator (or did not provide enough information to determine if they did): In this study two facilitators were interchangeably used and read from scripts. Also, the effects of the facilitators on the various groups were statistically evaluated.

2. Previous findings were impressionistic in nature: In this study the use of real-world tasks with known outcomes by experts improved outcome quality metrics and dictated the overall length of the experiment of 2 and 1/2 hours.

6.1 Anonymity Controlled

To produce a parallel situation for computer-aided groups, participants were required to precede all comments and entries with their initials. Manually supported groups met in face-to-face meetings and anonymity was not possible. In any case, anonymity, an important characteristic of EMS, was not a factor in our research and was controlled for. In fact, by disallowing anonymity during EMS sessions, we are making a more conservative test for the effect of technology. Anonymity has been considered a major positive attribute in EMS sessions because it helps groups focus on the discussion and not the status of the discussants and some reluctant participants are more likely to contribute. In this case, those elements of group process complexity due to differences in status and reluctance to contribute are controlled for to a certain extent and any positive benefits normally attributed to anonymity in EMS should not occur in this experimental design.

6.2 Tasks

Ill-structured tasks are an especially appropriate class of problems to test the efficacy of group support technology (Easton 1988; Mason and Mitroff 1981; Tyran et al. 1990). Stakeholder identification and assumption surfacing are the crucial initial steps in ill-structured problem solving (Easton 1988; Mason and Mitroff 1981; Nunamaker et al. 1990).

The tasks used are non-routine, ill-structured ones adapted from two field case studies reported by Mason and Mitroff. The less complex task is based on a Pharmaceutical company pricing problem primarily entailing stakeholder identification and assumption surfacing, and also rating of stakeholders and assumptions in terms of importance, and likelihood or certainty of occurrence. The more complex task is based on the U.S. Bureau of Census case and involves determination of the basis and characteristics of a policy for adjustment of the census count. The Census case contains many more issues and viewpoints and is thus more complex. The cases supply data for evaluation of complexity as well as expert results which can be used as a benchmark for measurement of outcome quality, a major limitation in previous research studies (McGrath and Hollingshead 1993; Pinsonneault and Kraemer 1990).

	Less Complex Case	More Complex Case
Stakeholders	13	57
Critical Issues	2	7

6.3 Subjects

The experimental groups required participants with sufficient domain knowledge to handle the cases. Pilot testing demonstrated that the caliber of student subjects would have sufficient expertise to perform the exercise and, in fact, they outperformed a sample of faculty subjects in certain tasks. A subject pool of upper level business school students were selected (68.9% of the subjects were graduate students, 31.1% were undergraduate). The average age of the participants was 27.5, with an age range of 19 to 63. Participants were 43.2% female, 56.8% male.

6.4 Group Composition

Sixteen groups participated in the experiments with a total of 132 subjects; eight of the groups were computer supported (63 subjects, 65.1% MBA, 48% female) and eight were manually supported (69 subjects, 72.5% MBA, 39% female). In seven classes, participants were randomly assigned for equivalency, half to manual support and half to computer support; the eighth pair of groups was acquired as a matter of convenience. The makeup of the groups were remarkably similar, with the manually supported groups having slightly more subjects and a greater percentage of graduate students. Both CS and MS groups had the same means and standard deviations on a self-reported survey of the following characteristics:

1. Work experience as indicated by previous experience in making actual business decisions was relatively high (3.0 on 5 point scale, with 1 being very low and 5 being very high and SD of 1).

2. Participants' previous experience working in groups was very high (4.0 on 5 point scale, with 1 being very low and 5 being very high and SD of 1).

3. Perception of "how successful group solving is" was average (3.0 on 5 point scale, with 1 being not successful to 5 being very successful).

4. The mean number of people in their test group with whom they previously worked was 2 with a SD of 2.

6.5 Group Size

Group sizes ranged from seven to ten, with the CS and MS groups having a roughly equivalent number in each pair of groups; that is, groups were not skewed.

6.6 Process Support (Technology)

Groups were either supported by computer-aided technology or manually supported in a closely parallel manner. Computer-aided groups used one of the sophisticated EMS currently available which handles both convergent and divergent cycles (VisionQuest by Collaborative Technologies Corporation, Austin, Texas).

6.7 Outcome Variables

Outcome variables measured correspond to the hypotheses. Task Outcome Quality was measured by counting critical stakeholders established by real-world experts when they completed the actual task. Participation Equality was obtained by counting the number of comments by each participant for each task. The absolute value of the deviation from an ideal participation norm was then used as a measure of individual participation. Ideation was measured by counting the number of unique alternatives, i.e., the number of stakeholders and stakeholder assumptions identified by the group. Task Completion Time, which included the time to rank assumptions and stakeholders, was the time required for the group to complete the tasks. User satisfaction was evaluated in two ways: in terms of Satisfaction with the Outcome of the group's effort, and in terms of Satisfaction with the problem solving or group work Process.

7. RESULTS

Analysis of variance in this 2 x 2 design was accomplished with ANOVA (using SPSS Manova) with repeated measures at a significance level of .05. Statistical tests for facilitator bias were negative. Two graders were used and Cronbach alphas for inter-rater reliability were high (>.97). Table 1 shows mean and standard deviation results for the dependent variables.

Table 2 provides results from analysis of variance. In general, the experimental results confirm that with sufficient task and process complexity the value of technology is observable. There was a significant difference between support types for all variables except satisfaction.

7.1 Task Outcome Quality

For both tasks, the CS groups identified more of the valid stakeholders than the MS groups ($F_{1,14} = 20.46$, $p < .001$). As predicted, there was no significant difference between MS and CS groups for the less complex task ($F_{1,14} = 2.91$, $p > .1$), but there was a significant difference between MS and CS groups for the more complex task ($F_{1,14} = 22.91$, $p < .001$). That is, the incremental change in Task Outcome Quality for computer supported groups was greater as complexity increased. For the simpler task, technology supported groups found 13.8% more stakeholders than manually supported groups, but for the complex task, technology supported groups found 89.3% more stakeholders.

7.2 Participation Equality

There was a significant difference between CS groups and MS groups in terms of Participation Equality ($F_{1,14} = 5.88$,

Table 1. Means and Standard Deviations

Dependent Variables	Manual Support Less Complex Mean (SD)	Manual Support More Complex Mean (SD)	Computer Support Less Complex Mean (SD)	Computer Support More Complex Mean (SD)
Outcome Quality	8.125 (1.356)	7.000 (1.773)	9.250 (1.282)	13.250 (3.240)
Ideation	40.875 (9.775)	33.875 (16.848)	50.625 (11.070)	52.750 (15.295)
Participation Equality	7.255 (1.143)	8.930 (1.415)	6.003 (2.470)	5.486 (2.740)
Time	44.750 (9.099)	38.125 (9.613)	36.125 (5.139)	35.000 (8.468)
Satisfaction:				
Outcome	3.159 (.678)	3.149 (.942)	3.232 (.843)	3.134 (.998)
Process	3.826 (.907)	3.821 (1.058)	3.812 (1.033)	3.791 (1.095)

Table 2. ANOVA Results (F-values)

Dependent Variables	Support	Task Complexity	Support X Task Complexity	Task L.C.	Task M.C.
Outcome Quality	20.46*	5.09*	16.19*	2.91	22.91*
Ideation	6.02*	.50	1.74		
Participation Equality	5.88*	2.82	10.07*	1.69	9.98*
Time	5.09*	.247	.73		
Satisfaction:					
Outcome	.48	.03	.03		
Process	.13	.02	.06		

*Significant at alpha < .06

$p < .03$). As predicted, there was no significant difference between MS and CS groups for the less complex task ($F_{1,14} = 1.69$, $p > .20$), but there was a significant difference between MS and CS groups for the more complex task ($F_{1,14} = 9.98$, $p < .01$). In other words, Participation Equality means were better (lower) for technology treatments for both tasks, but there was not a significant difference at the .05 level for the less complex task. Like Task Outcome Quality, the incremental change in Participation Equality for computer supported groups, was better (deviation from the ideal norm was lower) as complexity increased. Thus, for both task outcome quality and participation equality, structured support and technology are differentiated, i.e., as group process complexity increased by completing the more complex task, the use of the technology positively affected outcome quality and participation equality at a statistically significant level.

7.3 Ideation

There was a significant difference between CS and MS groups ($F_{1,14} = 6.02$, $p < .03$), but no significant interaction ($F_{1,14} = 1.74$, $p > .20$) and no main effect for task types. These results indicate that the slope of the MS and CS outcomes by task type are similar, but the CS results are better for both tasks. In other words, the incremental change in Ideation was similar for both types of support as complexity increased. For the simpler task, CS groups listed 23.8% more than MS groups, and for the more complex task, CS groups listed 55.7% more than MS groups.

7.4 Task Completion Time

There was a significant difference between CS and MS groups ($F_{1,14} = 5.09$, $p < .05$), but no significant interaction ($F_{1,14} = .73$, $p > .40$). These results indicate that the slope of the MS and CS outcomes by task type are similar and CS results are better for both tasks. Therefore, the effects of the technology for Task Completion Time and Ideation are similar, i.e., as group process complexity increased by completing the more complex task, the use of the technology had a statistically significant positive affect on Ideation and Task Completion Time at an equivalent level for both the less complex and more complex task. Mean Task Completion Time for the more complex task was somewhat less than the less complex task, possibly as a result of learning gained with the less complex task.

7.5 User Satisfaction

This was determined from responses of individual participants, averaged for each satisfaction measure: outcome and process. There was no significant difference between MS and CS groups for either satisfaction variable.

8. DISCUSSION OF RESULTS

The goal of this research was to discover if EMS/GDSS affected task outcomes beyond the mere structure of the process inherent in EMS/GDSS. Overall results indicate that technology does impart benefits beyond the embedded structure. Figure 3 will be used to attempt clarification of overall results.

This general discussion model is used only for a point of reference and should not be thought of as some composite based on actual results. For this discussion, these lines represent the outcome values for different levels of support (computer support, manual support). Previous laboratory research can be considered to be in Region A; computer supported and structured manual treatments were not differentiated. Small groups (three to four) and difficulty in defining task complexity may explain this.

Previous research indicated that there may be some threshold level of group size, regardless of task complexity, which may be necessary to overcome the impedance of the support technology. Although this threshold is not defined, based on the literature, seven was used as the level which by consensus would no longer be considered a small group.

The lines in Figure 3 may be different for each outcome variable for the same level of group process complexity. For example, Outcome Quality and Participation Equality were in Region B, i.e., for the less complex task, these outcomes were not statistically different for CS and MS groups. As complexity increased, the computer support added increasing benefits, beyond just structure.

Ideation and Task Completion Time results were in Region C, i.e., CS groups outperformed MS groups in the less complex task and, as complexity increased, the relative benefits of the technology remained similar. It is possible that for these outcome variables, the threshold level of group process complexity where technology would demonstrate benefits over structure was passed earlier (Region B) with the increased group size, and that for the range of complexity in this experiment, a plateau has been reached. While Task Completion Time was better for CS groups for both tasks, the completion time declined for the second more complex task for both CS and MS groups. The most likely reason for this is that the subjects learned how to perform the policy task with the first treatment and were able to perform the second task more quickly.

Satisfaction results remained in Region A. The evidence and expectations for User Satisfaction are not at all clear cut. Among the possible explanations for these results is motivation (including perceived rewards). Motivation has not been objectively assessed in this study or in known prior studies. In field studies, for example, it is assumed that participants are motivated by an on-going task which is important to them and allows them to take part in the reward systems of their organization. Participants in laboratory studies are affected by a quite different set of stimuli. Satisfaction continues to provide ambiguous results in laboratory studies and deserves more research attention in the future.

Region D in Figure 3 is unknown but, for a given outcome, these lines may behave differently. For example, as process complexity increases with more entangled tasks and more numerous inputs, computer support may provide dramatic benefits. At the same time, at these higher complexities, manual support may become profoundly inadequate. These lines may even vary based on the nature of the increased process complexity, for example, increasing group size versus increasing task complexity.

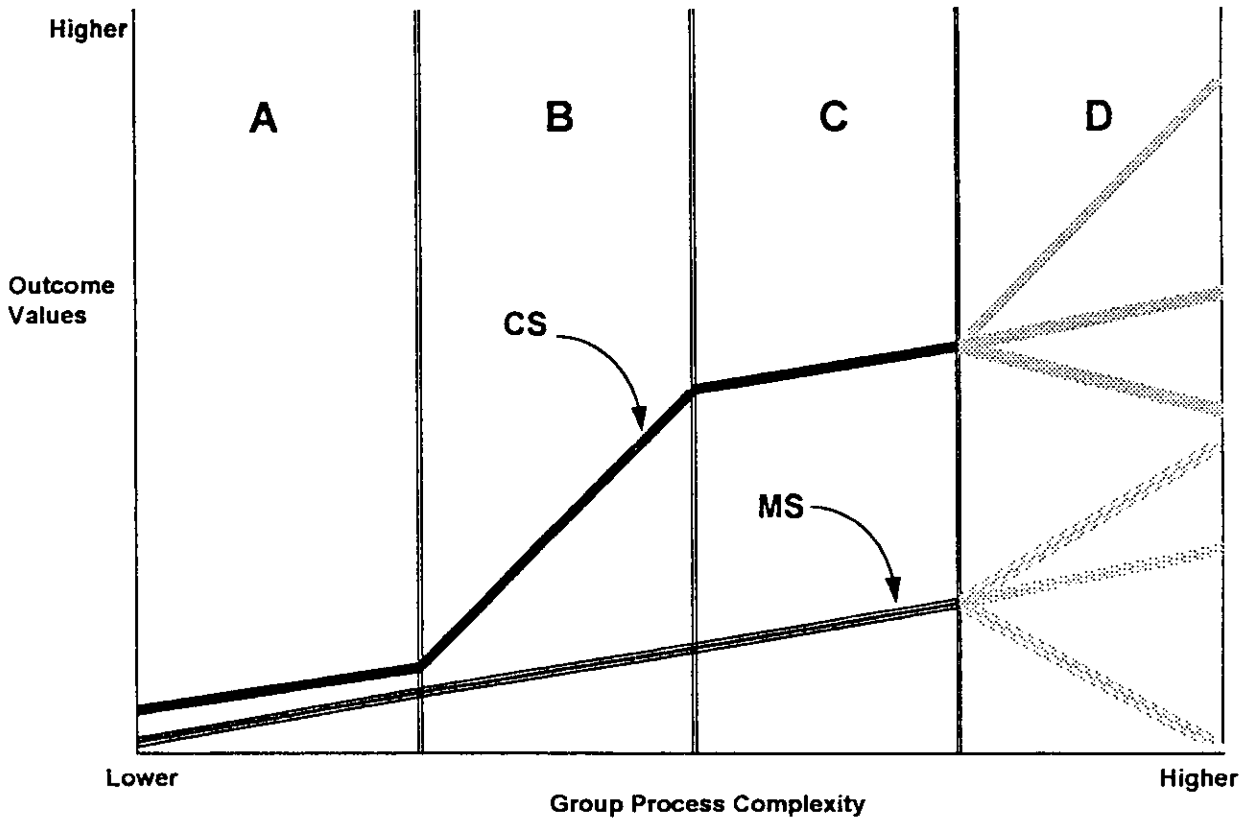


Figure 3. General Discussion Model

9. DISCUSSION OF LIMITATIONS

As a between group experiment with repeated measures, task complexity treatments were not reversed, i.e., all groups received the less complex task followed by the more complex task. However, order effects do not appear in the results. For Ideation and Task Completion Time, the CS groups outperformed the MS groups for both the less complex and more complex task and at a roughly equivalent rate. This has several implications. First, subject unfamiliarity with the technology did not interfere with performance This reinforces the finding that increased group process complexity, and not increased skill with the technology, was the explanatory factor for the statistically significant differences in Outcome Quality and Participation Equality for the more complex task. Second, the equivalent differences for Ideation and Task Completion Time for both the less complex and more complex task indicates that learning how to perform the policy task was at an equivalent rate for both groups.

Student subjects: Based on the demographics and pilot tests, they possessed the prerequisite skills and experience to perform the tasks.

Motivation: A problem in all controlled experiments. Controlled for here, nice if it can be measured in the future.

Small sample size: Miller (1986) emphasizes that a small sample with alpha = .05 may be "far more striking" than a result with the same or lower alpha value for a larger sample size.

10. CONCLUSIONS AND IMPLICATIONS

Previous literature indicates that small groups may not reach the minimum level of process complexity no matter what the level of task complexity. This work demonstrated that, when there is sufficient process complexity, the impact of technology is observed in key outcome variables and that process complexity is a probable explanatory factor for many of the conflicting results found in previous research. In addition to showing that computer supported groups outperform manual structured groups in four key variables, the manipulation of task complexity demonstrated that, for quality and participation, the benefits of the technology increased with increasing complexity. That is, although this study did not identify the minimum level of process complexity where technology's benefits balance its impedance for all outcome variables, the investigation does show that technology improves performance beyond providing structure.

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12. REFERENCES

Applegate, L. M. *Idea Management in Organization Planning*. Unpublished Ph.D. Dissertation, University of Arizona, 1986.

Applegate, L. M. "Technology Support for Cooperative Work: A Framework for Studying Introduction and Assimilation in Organizations." *Journal of Organizational Computing*, Volume 1, 1991, pp. 11-39.

Beauclair, R. "An Experimental Study of the Effects of Specific GDSS Applications on Small Group Decision Making." Working Paper, University of Louisville, 1987.

Campbell, D. J. "Task Complexity: A Review and Analysis." *Academy of Management Review*, Volume 13, Number 1, 1988.

Dennis, A. R.; George, J.F.; Jessup, L.M.; Nunamaker, J. F., Jr.; and Vogel, D. R. "Information Technology to Support Electronic Meetings." *MIS Quarterly*, December 1988, pp. 591-619.

Easton, A. *An Experimental Investigation of Automated versus Manual Support for Stakeholder Identification and Assumption Surfacing in Small Groups*. Unpublished Ph.D. Dissertation, University of Arizona, 1988.

Gallupe, R. B. *The Impact of Task Difficulty on the Use of a Decision Support System*. Unpublished Ph.D. Dissertation, University of Minnesota, 1985.

Gallupe, R. B.; DeSanctis, G.; and Dickson, G. W. "Computer-Based Support for Group Problem-Finding: An Experimental Investigation." *MIS Quarterly*, June 1988, pp. 277-296.

George, J. F.; Easton, G. K.; Nunamaker, J. F., Jr.; and Northcraft, G. B. "A Study of Collaborative Group Work With and Without Computer-Based Support." *Information Systems Research*, Volume 1, Number 4, December 1990, pp. 394-415.

Hackman, J. R. "Effects of Task Characteristics on Group Products." *Journal of Experimental Social Psychology*, Volume 4, 1968, pp. 162-187.

Kiesler, S. *Interpersonal Processes in Groups and Organizations*. Arlington Heights, Illinois: Harlan Davidson, 1978.

Lewis L. F. *Facilitator: A Microcomputer Decision Support System for Small Groups*. Unpublished Ph.D. Dissertation, University of Louisville, 1982.

Mason, R. O., and Mitroff, I. I. *Challenging Strategic Assumptions*. New York: John Wiley, 1981.

McGrath, J. E. *Groups: Interaction and Performance*. Englewood Cliffs, New Jersey: Prentice-Hall, 1984.

McGrath, J. E., and Hollingshead, A. B. "Putting the 'Group' Back in Group Support Systems: Some Theoretical Issues About Dynamic Processes in Groups with Technological Enhancements." In L. M. Jessup and J. S. Valacich (Editors), *Group Support Systems: New Perspectives*. New York: Macmillan, 1993.

Miller, R. G. *Beyond Anova, Basics of Applied Statistics*. New York: John Wiley & Sons, 1986.

Newell, A., and Simon, H. A. *Human Problem Solving*. Englewood Cliffs, New Jersey, Prentice-Hall, 1972.

Nunamaker, J. F., Jr.; Dennis, A. R.; Valacich, J. S.; Vogel, D. R.; and George, J. F. "Electronic Meeting Systems to Support Group Work: Theory and Practice at Arizona." Working Paper CMI-WPS-90-03, College of Business and Public Administration, University of Arizona, 1990.

Payne, J. W. "Task Complexity and Contingent Processing in Decision Making: An Information Search and Protocol Analysis." *Organizational Behavior and Human Performance*, Volume 16, 1976, pp. 366-387.

Pinsonneault, A., and Kraemer, K. L. "The Effects of Electronic Meetings on Group Processes and Outcomes: An Assessment of the Empirical Research." *European Journal of Operational Research*, Volume 46, 1990, pp. 143-161

Rao, V. S., and Jarvenpaa, S. L. "Computer Support of Groups: Theory-Based Models for GDSS Research."

Management Science, Volume 37, Number 10, October 1991, pp. 1347-1362.

Ruble, M. R. *An Empirical Test of a Decision Support System in a Group Decision-Making Environment.* Unpublished Ph.D. Dissertation, Arizona State University, 1984.

Shaw, M. E. "A Comparison of Individuals and Small Groups in the Rational Solution of Complex Problems." *American Journal of Psychology*, Volume 44, 1932, pp. 491-504.

Shaw, M. E. "Communication Networks." In Berkowitz (Editor), *Advances in Experimental Social Psychology*, Volume 1, 1964, pp. 111-149.

Shaw, M. E. *Group Dynamics: The Psychology of Small Group Behavior.* New York: McGraw-Hill, 1981.

Shaw, M. E. "Scaling Groups: A Method for Dimensional Analysis." *JSAS Catalog of Selected Documents in Psychology*, Volume 3, Number 8, MS # 294, 1973.

Steeb, R., and Johnston, S. C. "A Computer-Based Interactive System for Group Decision making." *IEEE Transactions on Systems, Man, and Cybernetics*, Volume 11, Number 8, August 1981, pp. 544-552.

Turoff, M., and Hiltz, S. R. "Computer Support for Group Versus Individual Decisions." *IEEE Transactions on Communications*, Volume 30, Number 1, January 1982, pp. 82-90.

Tushman, M. "Technical Communication in R & D Laboratories: The Impact of Project Work Characteristics." *Academy of Management Journal*, Volume 21, Number 4, 1978, pp. 624-645.

Tushman, M. "Work Characteristics and Subunit Communication Structure: A Contingency Analysis." *Administrative Science Quarterly*, Volume 24, 1979, pp. 82-98.

Tyran, C. K.; Dennis, A. R.; Vogel, D. R.; and Nunamaker, J. F., Jr. "The Design of Electronic Meeting Technology to Support Strategic Management." Working Paper CMI-WPS-90-06, College of Business and Public Administration, University of Arizona, 1990.

Van de Ven, A. H.; Delbecq, A. L.; and Koenig, R., Jr. "Determinants of Coordination Modes Within Organizations." *American Sociological Review*, Volume 41, April 1976, pp. 322-338.

Watson, R. T. *A Study of Group Decision Support System Use in Three and Four-person Groups for a Preference Allocation Decision.* Unpublished Ph.D., Dissertation, University of Minnesota, 1987.

Watson, R. T.; DeSanctis, G.; and Poole, M. S. "Using a GDSS to Facilitate Group Consensus: Some Intended and Unintended Consequences." *MIS Quarterly*, September 1988, pp. 463-477.

Valacich, J. S.; Dennis, A. R.; and Connolly, T. "Idea Generation in Computer-Based Groups: A New Ending to an Old Story." *Organizational Behavior and Human Decision Processes*, 1992.

Wood, R. E. "Task Complexity: Definition of the Construct." *Organizational Behavior and Human Decision Processes*, Volume 37, 1986, pp. 60-82.

Wood, R.E.; Mento, A.J.; and Locke, E.A. "Task Complexity as a Moderator of Goal Effects: A Meta-Analysis." *Journal of Applied Psychology*, Volume 72, Number 3, 1987, pp. 416-425.

Zigurs, I. *The Effect of Computer-Based Support on Influence Attempts and Patterns in Small Group Decision-Making.* Unpublished Doctoral Dissertation, University of Minnesota, 1987.