The Effects of Group, Task,Context, and Technology Variables on the Usefulness of Group Support Systems: A Meta-Analysis of Experimental Studies

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Using meta-analytic procedures, this article quantitatively integrated the results of 31 experimental studies on the effects of Group Support System (GSS) use. A total of eight dependent variables representing performance, satisfaction, consensus, and equality of participation were investigated. The use of GSSs was found to have positive main effects on decision quality, number of alternatives generated, and equality of participation, but negative main effects in terms of time to reach decision, consensus, and satisfaction. Further analysis showed the effects to be moderated by task, group, context, and technology variables. For example, larger groups achieved better performance and greater satisfaction from the use of GSS than smaller groups. Groups with a formal hierarchy using GSS did worse in terms of both performance and satisfaction compared to groups without formal hierarchy. Also, the level of GSS support emerged as influential on almost all dependent variables. Findings are discussed in terms of their implications for organizational use of GSS, design issues of GSS, and future research directions.

THE EFFECTS OF GROUP, TASK, CONTEXT, AND TECHNOLOGY VARIABLES ON THE USEFULNESS OF GROUP SUPPORT SYSTEMS
A Meta-Analysis of Experimental Studies

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INTRODUCTION

Group support systems (GSSs) combine communication, computer, and decision technologies to support problem formulation and solution in group meetings (DeSanctis & Gallupe, 1987). Various researchers have expressed concerns about the apparent inconsistencies in GSS research findings to date (e.g., Benbasat, DeSanctis, & Nault, 1993; Bui & Sivasankaran, 1990; Dennis &

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Gallupe, 1993; Jessup, Connolly, & Galegher, 1990; Nunamaker et al., 1989). It is clear that the conditions under which the use of GSSs is appropriate and beneficial are not well understood, nor is it clearly shown that the outcomes of GSS use are uniformly positive.

Qualitative reviews of the empirical work have attempted to integrate the seemingly conflicting results by attributing differences to one or more dimensions along which the studies differed, such as the type of support provided by the GSS (Pinsonneault & Kraemer, 1990); research setting (Dennis, Nunamaker, & Vogel, 1991); decision-aiding techniques (Benbasat, DeSanctis, & Nault, 1993); and the time when the studies were conducted (Dennis & Gallupe, 1993). Nevertheless, a systematic and quantitative analysis is still lacking (a notable exception is McLeod [1992], which includes only 12 studies compared to the 31 examined in this article). In this article, we report on a cumulative set of GSS findings using meta-analytic methods (Glass, McGraw, & Smith, 1981; Hunter & Schmidt, 1990).

Meta-analysis is rooted in the fundamental values of the scientific enterprise: replicability, quantification, causal and correlational analysis (Bangert-Drowns, 1986). By using this method, we were able to (a) estimate the overall magnitudes of GSS's effects on the various dependent variables, (b) examine whether these effects are consistent across studies, and (c) account for variations in magnitudes and directions of GSS's effects across studies.

The timing of the current exercise is also supported by Nunamaker, Dennis, Valacich, Vogel, and George (1991b), who indicated that we are at the conclusion of the initial phase of GSS research, a phase that mainly focused on experimental work comparing GSS to no-GSS groups. They further pointed out that the next phase of GSS research ought to isolate and explain why certain GSS features are of value to certain groups, tasks, and contexts. Consequently, this is a suitable point in time to sum up the findings obtained in the first phase of GSS research, and to do so in a quantitative manner so as

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to complement and strengthen the qualitative reviews that already exist.

This article is organized as follows. The next section presents the conceptual framework for organizing the variables, drawing upon small groups and GSS literatures for deriving our propositions. The Method section describes the method used in this research. The Results section presents the results of the analysis, based on continuous and categorical statistical models. The final section discusses these results and their implications for organizations and GSS design.

RESEARCH FRAMEWORK AND PROPOSITIONS

BACKGROUND

McGrath's (1984) framework has been proposed and used as a theoretical basis for studying the impacts of GSS use (DeSanctis & Gallupe, 1987). According to this framework, there are four major classes of inputs to the group process: (a) the standing group structure, (b) the environment in which the group operates, (c) the characteristics of the group task, and (d) the individual properties of group members. These four sets of properties, individually and jointly, shape the group interaction process.

Using McGrath's framework as a basis, several GSS frameworks have been developed (Mennecke, Hoffer, & Wynne, 1992; Nunamaker et al., 1991b; Pinsonneault & Kraemer, 1990). In general, there is a high degree of agreement among GSS researchers as to what groups of factors have the potential to moderate the effects of GSS use on meeting processes and outcomes. The commonalities found in these frameworks consist of (a) task characteristics, (b) group characteristics, (c) contextual or situational factors, and (d) technological factors. Although each set potentially comprises many variables, for this article, the framework used (see Figure 1) contains only those variables that have been included in most or all of the individual GSS studies that make up the sample for our meta-analysis.

DEPENDENT VARIABLES

We have not included all the dependent variables addressed in GSS research, but only those examined by a sufficient number of studies. The least-investigated dependent variable in our analysis, *satisfaction with outcome*, was investigated in seven reports.

Although various schemes exist for classifying dependent variables in GSS research (Mennecke et al., 1992; Pinsonneault & Kraemer, 1990; Zigurs & Dickson, 1990), a high degree of agreement can be found among them. In particular, two consensual categories that have surfaced, performance and satisfaction, as well as a third—termed "structural products" (Zigurs & Dickson, 1990)—have been included in our framework. The latter category includes *consensus* and *equality of influence* (also called *equality of participation*).

In our sample of GSS studies, we found three performance-related dependent variables that were commonly studied: (a) *decision quality*, (b) *number of alternatives generated*, and (c) *time to reach decision*. The three satisfaction-based dependent variables investigated in most GSS studies were: (a) *satisfaction with outcome*, (b) *satisfaction with process*, and (c) *confidence with outcome*. In addition to the above, consensus and equality of influence have also been studied in the majority of the studies.

PROPOSITIONS

Research in GSS has progressed beyond the early thinking that GSS has unequivocal effects, regardless of other moderating variables. Instead, what is considered more important and of greater interest is the issue of how GSS affects group outcomes under what conditions. Therefore, rather than proposing main effects of GSS use, we will focus on interaction effects. However, we only present propositions for which theoretical support exists, and thus these propositions do not cover all possible combinations of the input and output variables shown in Figure 1. Most propositions to be presented are directional in that we are predicting the additional value of having a GSS (over not having one) to be higher in one situation than in the other.

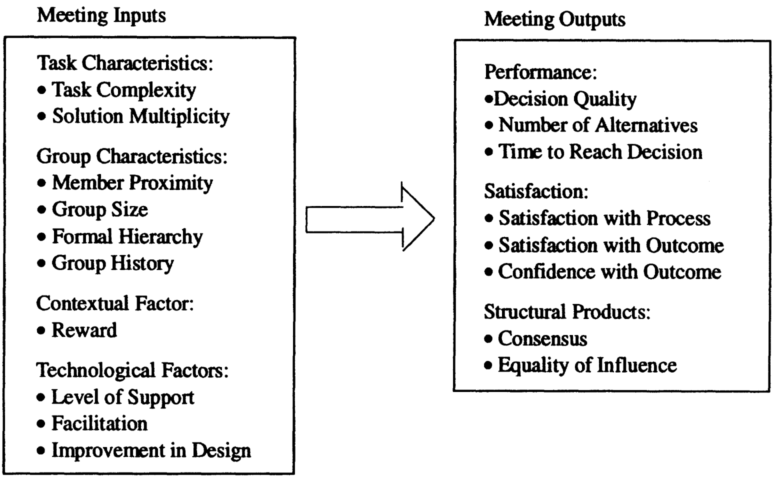

Figure 1: Variables Included in Meta-Analysis

TASK CHARACTERISTICS

Out of the several dimensions associated with task, *task complexity* and *solution multiplicity* have been empirically demonstrated to be the strongest and most stable dimensions, and they offer the greatest promise for understanding group processes (Morris, 1966).

Task complexity: Task complexity refers to the amount of effort required to complete the task (Morris, 1966). Alternatively, it has been defined as the degree of cognitive load required to solve a problem (Payne, 1976). For our meta-analysis, we have operationalized this dimension as the number of generic task components a group task comprises. These components are classified according to McGrath's (1984) group task circumplex: (a) generating, (b) choosing, (c) negotiating, and (d) executing. The last category, which basically includes psychomotor tasks, is not of major interest to GSS work. Also, because negotiation tasks are handled by Negotiation Support Systems (e.g., see Lim & Benbasat, 1993), we will not cover them in this article. Indeed, most GSS studies have dealt with generic tasks that consist of either generating or choosing or both. Following Gray, Vogel, and Beauclair's (1990) definition of complexity of response, we shall define task complexity according to the number of such components contained within a group task. Therefore, low complexity corresponds to either a generating or a choosing task, whereas high complexity corresponds to a generating-and-choosing task. Although we agree that a more intuitive approach to identifying complex tasks may be to search for evidence of nonroutine information processing, uncertainty reduction, or decision making (e.g., see Wagner & Gooding, 1987), we did not deem this type of information adequately available from our sample.

Problems with high complexity lend themselves well to the use of decision aids; the various tools available can assist by providing memory aids, structure, and sensitivity analysis (Bui & Sivasankaran, 1990).

Proposition 1: The effect size[1] of GSSs on performance (in terms of decision quality and time to reach decision) will be larger for tasks of greater complexity than for tasks of lesser complexity.

Number of alternatives cannot be compared in this regard, as it is only meaningful for generate tasks and the first phase of generate and choose tasks, and it is thus not expected to be affected by the number of task components.

Solution multiplicity: Solution multiplicity is defined as the degree to which there is more than one correct solution (Morris, 1966). Consequently, we will differentiate between group tasks that have only one correct solution and those that have more than one such solution. In terms of the task circumplex proposed by McGrath (1984), tasks that primarily involve generating ideas (by definition) yield multiple solutions, whereas those that involve making choices either have no correct answer (and thus have multiple solutions) or have one.

To adequately support intellective tasks (which have a correct answer), the GSS needs to provide aids for finding the correct answer (e.g., forecasting models) and deal with providing a rationale for choices (DeSanctis & Gallupe, 1987). Given that most GSS studies in our sample have not provided this kind of support (or at least many of them still lack an explanation facility), we propose:

Proposition 2: The effect size of GSSs on performance will be larger for tasks with multiple solutions than for tasks with a single solution.

GROUP STRUCTURE

Member proximity: Computer mediation in a dispersed setting might reduce communication efficiency, as typing and reading is probably more difficult than speaking and listening (Siegel, Dubrovsky, Kiesler, & McGuire, 1986). Moreover, the absence of verbal and visual communication greatly discourages, if not inhibits, the flow of social feedback, feelings, and social meanings, therefore decreasing the efficiency of interpersonal communication.

Proposition 3a: The effect size of GSSs on performance (in terms of time to reach decision) will be larger in face-to-face than in dispersed settings.

More communication richness is associated with a face-to-face setting, which permits mutual understanding and agreement between group members (Smith & Vanecek, 1989). Conversely, a dispersed setting, which forbids verbal communication and withholds visual information about meeting participants, lacks important social context cues necessary for higher levels of social demands (Dubrovsky, Kiesler, & Sethna, 1991) and results in depersonalization of the situation and behavior (Siegel et al., 1986). Consequently, members' social needs may be better met in a face-to-face setting than in a dispersed setting.

Proposition 3b: The effect size of GSSs on satisfaction will be larger in face-to-face than in dispersed settings.

Group size: In social psychology literature, it is generally agreed that performance improves as group size increases, until some optimum size is reached (Hare, 1981). Once group size is increased beyond the optimum, group members become less sensitive in their exploration of different points of view, tend to adopt more mechanistic methods of introducing information, and appear to rush to reach solutions. These observations are closely related to process losses (Nunamaker, Dennis, Valacich, & Vogel, 1991a); for example, production blocking, which becomes more severe as group size increases.

It is unclear as to what the optimum size may be in the case of GSS environment. Watson, DeSanctis, and Poole (1988) and Zigurs, Poole, and DeSanctis (1988) found no differences (in terms of most of the dependent variables we have included) between three- and four-person groups, indicating that optimal group size may be larger. In fact, because of the process support provided by GSSs, which reduces process losses and increases process gains (Nunamaker et al., 1991b), many of the problems previously associated with large groups (such as air-time fragmentation, production blocking, and so on) can now be alleviated. It is thus conceivable that the optimum group size will be larger in a GSS context than in a no-GSS context.

Proposition 4a: The effect size of GSSs on performance will become larger with increasing group size.

Larger unsupported groups, as compared to smaller ones, are more likely to have problems associated with reduced air time, unequal participation, and other process losses (Hare, 1981). Because GSSs are designed to address these shortcomings, it is expected that the use of GSSs will bring about a greater degree of improvement in members' satisfaction in larger groups than in smaller ones.

Proposition 4b: The effect size of GSSs on satisfaction will become larger with increasing group size.

Without GSSs, as group membership increases, the number of potential information exchanges rises geometrically, and the frequency, duration, and intimacy of information exchange all decline; as a result, consensus becomes harder to achieve (DeSanctis &

Gallupe, 1987). Envisioning a similar outcome, Hare (1981) argues that as group size rises beyond an optimal level, the range of ideas available increases, but only at the expense of reaching consensus in the absence of any clear-cut criteria for judgment.

GSS tools, especially those of the higher-level systems, possess the potential to assist in consensus formation. Because of group members' consideration as a group of ideas and options, greater shared understanding is expected. Because larger unsupported groups are more likely to experience lower consensus than smaller unsupported groups:

Proposition 4c: The effect size of GSSs on consensus formation will increase with increasing group size.

Formal hierarchy: There is some evidence to suggest that a leader, through the exercise of appropriate influence behavior, can improve group performance (Greene & Schriesheim, 1977; Schriesheim, Mowday, & Stogdill, 1979) and that the lack of leadership could also affect satisfaction and performance (O'Reilly & Roberts, 1978). Given that this is the case, we may initially expect the best achievable scenario (in terms of performance and satisfaction) to involve both GSSs and leadership.

However, it should be pointed out that the potential effect of formal hierarchy will only be present if and when the variable is salient in a particular group interaction. In a truly anonymous meeting, where there is no way whatsoever to identify who the leader or higher-status member is, it is difficult to imagine that leadership would affect meeting process and outcomes.

Proposition 5a: The effect size of GSSs on performance will be larger with the existence of a formal hierarchy within the group than without a formal hierarchy.

Proposition 5b: The effect size of GSSs on satisfaction will be larger with the existence of a formal hierarchy within the group than without a formal hierarchy.

Lim, Raman, and Wei (1990) found that whereas GSS use induces a more even distribution of influence when no formal leadership is present in the group, such effect is counterbalanced by elected leadership.

Proposition 5c: The effect size of GSSs on equality of influence will be smaller with the existence of a formal hierarchy within the group than without a formal hierarchy.

Group history: Hall and Williams's (1966) study on the difference between established and ad hoc groups (in a no-GSS context) found that established groups produce higher decision quality. Level of conflict acts as an intervening variable; specifically, conflict reduces decision quality in ad hoc groups but improves it in established groups. The level of conflict in GSS-aided situations can be expected to be high, as the GSS supports a greater exploration of ideas. Because conflict works for established groups but against ad hoc groups, we propose:

Proposition 6a: The effect size of GSSs on performance (in terms of decision quality) will be larger for established groups than for ad hoc groups.

Even with the aid of a GSS and its anonymous inputting procedures, the degree of anonymity is lower in an established than an ad hoc group, because in an established group, it is probably easier to identify proponents of ideas based on the style of writing and communications, or even based on the attitudes portrayed by those ideas. Because lower anonymity helps less in equalizing participation and influence, the social order that has been previously established may be preserved to some extent.

Proposition 6b: The effect size of GSSs on equality of influence will be smaller for established groups than for ad hoc groups.

CONTEXTUAL FACTORS

Relevant characteristics in this category include organizational culture, time pressure, rewards, and so on. However, the only one on which information is available in our sample of GSS studies is *rewards*.

Depending on what it is contingent upon (i.e., performance or task), reward has been found to influence performance to various degrees in no-GSS contexts (e.g., Tripathi, 1991). In all these cases, motivation has been found to be an important mediating variable (Tripathi, 1991). Nonetheless, motivation has not been a primary construct investigated in GSS research, and it is unclear how GSSs might affect group members' motivation levels. Because no evidence exists that leads us to expect an interaction effect between GSSs and rewards, we propose:

Proposition 7: The effect size of GSSs on performance will be similar whether reward is available or not.

INFORMATION TECHNOLOGY (GSS) FACTORS

Level of support: DeSanctis and Gallupe (1987) introduced the concept of level of support, differentiating among three levels of the GSS. The higher the level of the GSS, the more sophisticated the technology and the more significant the intervention into the group's natural (unsupported) decision process.

Sambamurthy and DeSanctis (1990) note that because a Level 2 GSS provides structure for groups to manage both their communication and consensus activities, groups using this system may perceive themselves as having considered all ideas, and having constructively dealt with the differences among their members. In contrast, Level 1 GSS users who are provided with communication but not consensus support might feel that their ideas were neglected in developing the final group recommendations. Consequently, they might be less satisfied.

Proposition 8a: The effect size of GSSs on performance will be larger with a Level 2 GSS than with a Level 1 GSS.
Proposition 8b: The effect size of GSSs on satisfaction will be larger with a Level 2 GSS than with a Level 1 GSS.
Proposition 8c: The effect size of GSSs on consensus formation will be larger with a Level 2 GSS than with a Level 1 GSS.

Facilitation: Dickson, Lee, Robinson, and Heath (1989) studied the differences between three types of interaction modes: chauffeured, facilitated, and user-driven.[2] Lack of facilitation led to the lowest degree of consensus. Based on the limited evidence available, we propose:

> *Proposition 9*: The effect size of GSSs on consensus will be larger with the availability of facilitation than without facilitation.

Improvement in design: It is reasonable to expect that computer systems today are generally better, both in functionality and usability, than they were a decade ago. Likewise, it is reasonable to believe that GSSs of today have better designs and support features than earlier generations.

We expect that better meeting outcomes will be associated with GSS studies that were conducted more recently. Although the year of publication (which is readily obtainable) has been used for this purpose, we acknowledge that the actual year the study was conducted would be a better surrogate.

> *Proposition 10a*: The effect size of GSSs on performance will increase with the year of publication.
> *Proposition 10b*: The effect size of GSSs on satisfaction will increase with the year of publication.

METHOD

SAMPLE OF STUDIES

In our meta-analysis, we have focused on experimental studies dealing with the comparison between GSS and no-GSS conditions, because to date this is the most commonly studied independent variable (Nunamaker et al., 1991b) and thus yields the largest sample possible.

Our sample consists mainly of studies published between 1970 and 1992, with 90% appearing after 1986, plus recent working papers. In order to generate the set of studies to be included in our meta-analysis, we started with the sample of studies we already had in hand and identified new ones by examining the bibliographies of these papers. We also searched the list of journals and conference proceedings where articles about GSS research were most likely to be published. We contacted more than a dozen active researchers in the GSS area to solicit their support in acquiring the working papers they had recently written, the ongoing and recently completed doctoral student and dissertation research projects in their schools, and any other empirical papers which they were familiar with in the GSS area. In addition, we searched the dissertation abstracts for any doctoral thesis research that was not identified through our other efforts. The sample (preceded with an * in the References) which was generated should thus reflect published and ongoing work, including doctoral dissertation research.

VARIABLES CODED FROM EACH STUDY

Year of publication (or reporting year) was readily available from each article or paper. In addition, the following variables were coded from the information provided: (a) task complexity, (b) solution multiplicity, (c) member proximity, (d) group size, (e) formal hierarchy, (f) group history, (g) rewards, (h) level of support, and (i) facilitation. One of the authors coded all 31 articles. However, to assess the reliability of the coding of the study characteristics, a doctoral student in information systems was trained and asked to code 26 of the articles. The rate of agreement between the two coders was 95%. Disagreements were resolved by discussion.

CODING AND ANALYSIS OF EFFECT SIZE

For each of the comparisons, a standardized estimate of effect size was computed according to the formula developed by Cohen (1988). When information about means and standard deviations was not provided, the effect size was estimated through a variety of techniques (see, e.g., Glass et al., 1981, chap. 5). Whenever tests of statistical significance were performed but the actual statistics were not reported, a probability value of .05 was assumed if the results were reported as significant; when the group difference was reported as nonsignificant, the effect size was conservatively estimated as zero (Glass et al., 1981).

A positive effect size indicates that GSS use led to a better outcome (e.g., higher decision quality) than no-GSS, and a negative number means the reverse. The only exception was with time to reach decision, for which a positive effect size indicates that GSS use required a longer meeting time than no-GSS use. Where appropriate, the effect sizes were corrected for attenuation due to measurement unreliability (Hunter & Schmidt, 1990). All effect sizes were subsequently corrected for the bias from the overestimate of the population effect size, especially for small samples (Hedges, 1981).

After all the effect sizes had been coded, the study outcomes were combined for each dependent variable by averaging the effect sizes, each weighted by the inverse of its variance. To determine whether the studies shared a common effect size, the homogeneity of each set of effect sizes was examined (Hedges & Becker, 1986). For each set of heterogeneous effect sizes, a regression model was used to test the effect of the moderating variables on the corresponding dependent variable (Hedges & Olkin, 1985). In those situations where the sample size was too small (relative to the number of predictors) for attempting regression analysis, categorical models (analogous to the idea of analysis of variance) were tested for the effect of each moderating variable on the corresponding dependent variable (Hedges & Olkin, 1985). It should be noted that there exist alternative approaches to performing meta-analysis (e.g., Hunter & Schmidt, 1990; Glass et al., 1981). Our choice of Hedges's approach necessarily subjected our analysis to the limitations and biases pertaining to this procedure (e.g., see Orwin, 1983).[3]

RESULTS

HOMOGENEITY OF EFFECT SIZES

Table 1 summarizes the main effects of GSS use. A mean effect size that differs significantly from zero suggests an overall effect.

TABLE 1: Summary of Statistics for GSS versus No-GSS Differences

Dependent Variable	*Mean (weighted) Effect Size (d.)*	*Sampling Variance (v.)*	$Z(=d./\sqrt{v.})$	*Homogeneity Statistic,* H_T
Decision quality	.29	.01	3.53**	40.14*
Number of alternatives	1.03	.01	9.12**	51.36**
Time to reach decision	.94	.03	5.12**	19.55**
Satisfaction with process	.05	.00	.83	162.06**
Satisfaction with outcome	–.43	.01	–4.65**	96.92**
Confidence with outcome	.06	.01	.61	10.67
Consensus	–.53	.02	–3.54**	35.24**
Equality of participation/influence	.46	.01	4.28**	36.56**

$*p < .05$; $**p < .01$.

For most of the dependent variables, a significant Z statistic was reported, thus rejecting the hypothesis that the population effect size equals zero in each case. A homogeneity statistic, H_T, was also calculated (Hedges & Olkin, 1985). Since the effect sizes were heterogeneous for all dependent variables except confidence with outcome, moderating variables were used to account for variability in the GSS versus no-GSS differences.

MULTIPLE REGRESSION ANALYSIS

Multivariate tests of continuous models for the GSS versus no-GSS differences were conducted (Hedges & Olkin, 1985). These models are least squares regressions, calculated by weighting each effect size by the reciprocal of its variance. These models yield a test of the significance of each predictor as well as a test of model specification, which evaluates the degree to which systematic variation remains unexplained in the regression model. The error sum of squares statistic, H_E, provides this test of model specification (Hedges & Olkin, 1985).

TABLE 2: Multiple Regression Analysis for GSS versus No-GSS Effect Sizes

Dependent Variable	*Moderating Variable*	*Standardized Regression Coefficient*	*Multiple R^2*	N	H_E	X^2	*Proposition Confirmed?*
Decision quality			.75	22	6.44	32.67	
	Task complexity[a]	−1.04**					No
	Solution multiplicity[b]	.71					No
	Group size	.75*					Yes
	Formal hierarchy[c]	.09					No
	Group history[d]	.17					No
	Reward[e]	.02					No
	Level of support[f]	.57*					Yes
	Recency in design	−.42					No
Number of alternatives			.96	14	5.51	22.36	
	Solution multiplicity	−.38					No
	Group size	.66					No
	Formal hierarchy	−.22*					No
	Reward	.34**					No
	Level of support	−.70**					No
	Recency in design	−15.07**					No

continued

TABLE 2: continued

Dependent Variable	*Moderating Variable*	*Standardized Regression Coefficient*	*Multiple* R^2	N	H_E	X^2	*Proposition Confirmed?*
Satisfaction with process			.92	16	11.10	25.00	
	Member proximity[g]	.71**					Yes
	Group size	2.88**					Yes
	Formal hierarchy	–.37**					No
	Level of support	.69**					Yes
	Recency in design	10.42					No
Consensus			.57	8	20.40**	14.07	
	Group size	–1.31					No
	Level of support	.43*					Yes
	Facilitation[h]	–.26					No
Equality of participation/influence			.47	13	18.74	21.03	
	Formal hierarchy	–.15					No
	Group history	–.57*					Yes

NOTE: Models are weighted least squares regressions calculated with weights equal to the reciprocal of the variance for each effect size. Effect sizes are positive for differences in the GSS direction and negative for differences in the no-GSS direction.
a. 0 = low complexity, 1 = high complexity.
b. 0 = single solution, 1 = multiple solutions.
c. 0 = no formal hierarchy, 1 = formal hierarchy.
d. 0 = ad hoc, 1 = established.
e. 0 = no reward, 1 = reward.
f. 0 = Level 1, 1 = Level 2.
g. 0 = dispersed, 1 = face-to-face.
h. 0 = absent, 1 = present.
*$p < .05$; **$p < .01$.

For purposes of the regression analysis, the categorical variables (i.e., all except group size and year of study) were coded as dummy variables. Each model in Table 2 contained only those predictors that have been hypothesized to be influential in the section on research framework and propositions. Three dependent variables were absent from Table 2. Confidence with outcome was not further analyzed because its homogeneity assumption was not rejected (see Table 1); time to reach decision and satisfaction with outcome could not be analyzed using regression models because in each case, the sample size was too small relative to the number of predictors hypothesized. The last two dependent variables were dealt with using alternative statistical models to be described below. The reason multiple regression models were attempted first is that both continuous variables (e.g., group size and year of study) and categorical variables can be accommodated by these models.

For each of the five models shown in Table 2, there was at least one significant moderating variable. As reflected in the values of the multiple R^2s, the models were either moderately or quite successful in accounting for variability in the magnitude of the effect sizes. This is supported by the tests of model specification, which, in all cases but one, reported nonsignificant values of H_E, thus not rejecting the model specifications. Regression model for consensus cannot be regarded as correctly specified since $H_E = 20.40$ is significant at $p < .01$. Alternative models which include additional interaction terms were not added to this model because of the small number of observations and the multicollinearity that resulted.

TESTS OF CATEGORICAL MODELS

As pointed out earlier, time to reach decision and satisfaction with outcome could not be tested using regression analysis due to their small sample sizes. Subsequently, categorical models were used to test these two sets of effect sizes (Hedges & Olkin, 1985). The results are shown in Table 3. Although group size and year were predicted in the section on research framework and propositions for their effects on satisfaction, they were excluded from the categorical models because they are continuous variables.

TABLE 3: Tests of Categorical Models for Technology Effect Sizes

Dependent Variable	*Moderating Variable and Class*	*Between-Class Effect (H_B)*	*n*	*Weighted Effect Size (d_j)*	*Homogeneity Within Each Class (H_{wj})*	*Proposition Confirmed? (see Table 1)*	*Fail-Safe* N (N_{fs})
Time to reach decision	Task complexity	5.82*				Yes	
	High		3	.44	2.20		10
	Low		5	1.33	11.53*		62
	Solution multiplicity	2.51				No	
	Multiple		4	1.16	14.60**		42
	Single		4	.55	2.43		18
	Member proximity	11.26**				Yes	
	Face-to-face		5	.47	2.27		19
	Dispersed		3	1.75	6.02*		50
	Formal hierarchy	9.78**				No	
	Present		2	1.81	5.87*		34
	Absent		6	.56	3.90		28

continued

TABLE 3: continued

Dependent Variable	*Moderating Variable and Class*	*Between-Class Effect (H_B)*	*n*	*Weighted Effect Size (d_j)*	*Homogeneity Within Each Class (H_{wj})*	*Proposition Confirmed? (see Table 1)*	*Fail-Safe N (N_{fs})*
	Reward	.65				Yes	
	Present		1	.56	0		5
	Absent		7	1.00	18.90**		63
	Level of support	5.82*				Yes	
	Level 1		5	1.33	11.53*		62
	Level 2		3	.44	2.20		10
Satisfaction with outcome	Member proximity	19.58**				Yes	
	Face-to-face		5	–.12	76.62**		1
	Dispersed		2	–.97	.72		17
	Level of support	21.34**				Yes	
	Level 1		4	–.58	65.86**		19
	Level 2		3	.72	9.72**		19

NOTE: Effect sizes are positive for differences in the GSS direction and negative for differences in the no-GSS direction.
$*p < .05$; $**p < .01$.

Table 3 shows several significant between-class effects (analogous to main effects in an analysis of variance) for GSS versus no-GSS differences. In addition to providing a test of the significance of between-class effects, this approach provides a test of the homogeneity of the effect sizes within each class. The between-class effect is estimated by H_B, and the homogeneity of the effect sizes within each class is estimated by H_w (Hedges & Olkin, 1985). Although several significant between-class effects were found, none of these categorical models can be regarded as having a good fit of the effect sizes; for each model, the hypothesis of homogeneity of the effect sizes was rejected within at least one class.

The mean effect size for each class was calculated by weighting each effect size by the reciprocal of its variance. Also reported in Table 3 is the fail-safe *N* statistic, N_{fs}, for each moderating effect examined (Orwin, 1983). In general, the N_{fs} values here indicate that the so-called file drawer problem poses no significant threat to the current analysis, despite the small numbers of studies involved. Among the more robust results are, for example, the effect of GSS technology on time to reach decision with a Level 1 GSS, which requires about 12 times (62) as many studies with a zero effect size as the sample size used (5) to lower the observed effect size to a value of .1.

DISCUSSION AND CONCLUSIONS

This section discusses the implications of findings of our meta-analysis. Whenever appropriate, the implications of the findings are described in terms of their organizational impact, GSS design recommendations, and future research issues.

MODERATING EFFECT OF TASK VARIABLES

Task complexity significantly moderates the relationship between GSS use and decision quality. Contrary to our expectations, groups working on lower-complexity tasks benefited more by the use of GSSs than those working on higher-complexity tasks. Based on the operationalization of complexity used in this article, this finding indicates that GSS use in single-component tasks (i.e., generating or choosing tasks) led to more effective performance than dual-component tasks (i.e., generate-and-choose tasks). We think that this result is due to the less-than-adequate support provided by current GSSs in consolidating and organizing multiple ideas generated (see Bostrom, Anson, & Clawson, 1993, for a discussion of the sequencing of meeting activities). In other words, although idea generation and ranking/rating tools have been successful in supporting the individual phases of generating ideas or choosing a solution, better designs are required to improve the management of both. An alternate interpretation of this observation, of course, is that GSSs as used in laboratory experiments have been designed only to meet the requirements of the studies and thus have not been intended as perfect systems.

MODERATING EFFECT OF GROUP VARIABLES

Member proximity was found to significantly moderate the relationship between GSS use and time to reach decision as well as that between GSS use and satisfaction with process. As predicted, the undesirable effect of GSS use to prolong a meeting was worse in a dispersed than face-to-face setting. This has basically to do with the different communication modes available in each setting; typing to transmit information generally takes longer than speaking (McGrath & Hollingshead, 1993). Moreover, systems used in face-to-face settings permit both electronic and verbal communications, whereas systems used in dispersed settings are restricted only to electronic communication. The detected difference need not exist if the media richness (Daft & Lengel, 1986) of both types of setting can somehow be made comparable through the use of multimedia techniques to provide verbal communication and perhaps even video-image transmission to group members in dispersed locations (Olson & Atkins, 1990).

The effect of GSS use on group members' satisfaction with the meeting process was stronger in face-to-face meetings than in dispersed meetings. This again may be due to the absence of visual access in the latter setting. It is generally agreed that visual cues provide nonverbal communication (McGrath & Hollingshead, 1993). Whereas verbal and electronic communications may transmit both task- and social-oriented messages, nonverbal communication carries mainly social-oriented messages, which aim at fulfilling social and emotional needs. Satisfaction, an inherently emotion-related measure, has apparently had its relationship with GSS use mediated by the amount of social-oriented messages available in the meeting. In other words, member proximity has moderated the effect of GSS use on satisfaction through affecting the degree of social-oriented communication allowable in a meeting.

Group size has been found to significantly moderate the relationship between GSS use and decision quality as well as that between GSS use and satisfaction with process. Because of the greater potential for incurring process losses in large, unsupported meetings, the increase in performance due to GSS use was more evident in larger groups than in smaller groups. This finding, which is consistent with field study results (Dennis, Valacich, & Nunamaker, 1990), has positive organizational implications because three forces act to increase the size of group meetings, as pointed out by Dennis, George, Jessup, Nunamaker, and Vogel (1988). First, one may presume that the issue to be addressed by the group is one that could benefit from the increased domain knowledge and skills provided by the members in the group. Huber (1984) points out that as business environments become more complex, the need for specialized domain knowledge and skills, and consequently the desired size of the group, increases.

Second, Ackoff (1981) argues that it is important for those charged with executing a plan or implementing a decision to understand why the plan or decision was made. The best way to do this is to include as many of these people as possible in the group, again increasing the desired group size. Third, there are political reasons for increasing the size of the group. By including additional participants in the decision-making group and allowing them to represent their constituencies, their support is more likely to be gained for implementing the decision, or at least spreading the risks.

Formal hierarchy has been found to be a significant moderating variable on the relationships between GSS use and three dependent variables, namely, number of alternatives generated, time to reach decision, and satisfaction with process. Contrary to our expectation, in groups with formal hierarchy the extent to which GSS use increased the number of alternatives generated was smaller than in groups without formal hierarchy; the extent to which GSS use increased time to reach decision was greater; and the extent to which GSS use affects satisfaction with process was smaller. Therefore, the underlying theme appears to be that formal hierarchy reduced the benefits of GSS use. This is likely due to the fact that the spirit of GSSs (DeSanctis & Poole, in press), arguably, is to promote democratic meetings and thus its use is not in line with the concept of hierarchy.

This finding suggests a tradeoff that an organization or business unit intending to use the technology has to make. On the one hand, there are several advantages in bringing together all hierarchical levels involved in the decision in one meeting; these advantages range from getting faster organizational approval for decisions to improving organizational communication (Huber, 1988). On the other hand, our findings show that the presence of hierarchies in the meeting prolonged the meeting, prevented members from exploring more, and perhaps unorthodox, alternative solutions, and reduced members' satisfaction with the decision-making process. Despite these differences, however, it is interesting to note that the relationship between GSS use and a key indicator of performance, decision quality, has not been moderated by formal hierarchy.

As predicted, group history has been found to significantly moderate the relationship between GSS use and equality of participation; in established groups, there was a smaller effect of GSS use on equality of participation. As explained in the section on research framework and propositions, this outcome has basically to do with the established social order and the lower degree of anonymity implementable in an established group. This finding has important organizational implications, because most organizational groups are, to varying degrees, established. Correspondingly, the use groups are, to varying degrees, established. Correspondingly, the use of GSSs cannot be expected to equalize members' participation in these groups to the same extent it did for ad hoc groups. Thus, although to a lesser extent with the use of GSSs, participants still defer to group members of higher status. To some degree, because established groups essentially preserve the established hierarchy, this finding is related to the previous one regarding formal hierarchy, which was found to diminish the benefits of GSS use in affecting group outcomes. This is not necessarily undesirable, especially in an organizational context, because it is correct to expect a more useful and more extensive contribution from the more senior members, who are generally more experienced, qualified, and resourceful.

MODERATING EFFECT OF CONTEXT VARIABLES

The presence of rewards was associated with a larger increase in the number of alternatives generated due to GSS use. Apparently, rewards and incentives (contingent on performance) induce motivation and thus complement the positive effect of GSS use on group performance. However, the fact that rewards did not influence decision quality runs counter to this finding, especially if generating more alternatives is not an end in itself. The concern here is with an issue of methodology, namely, experimental artifacts. When subjects are rewarded for generating more alternatives, they will find a tool in GSSs which helps them achieve that goal. On the other hand, if the additional alternatives are not creative enough to improve decision quality or if the GSS is not helpful in organizing the ideas generated to effect a better outcome, then rewards would not lead to an increase in quality. We therefore recommend that researchers investigate the role rewards and motivation have in the causal chain from the generation of more alternatives to the achievement of better outcomes (Rao & Jarvenpaa, 1991).

MODERATING EFFECT OF TECHNOLOGY VARIABLES

Level of GSS support has been found to be a significant moderating variable on the relationships between GSS use and decision quality, number of alternatives generated, time to reach decision, satisfaction with process, satisfaction with outcome, and consensus. The only exceptions were confidence with outcome, whose relationship with GSS use was not found to be heterogeneous, and equality of participation, which was not hypothesized to be affected by the level of support.

As predicted, the effect of level of support was positive on all but one of the dependent variables. Level 2 GSSs generally caused greater improvement in performance, satisfaction, and consensus than Level 1 GSSs. These results thus highlight the importance of the modeling and structuring capabilities of GSSs. Although fundamental communication support increases meeting effectiveness, it lowers the satisfaction of group members. Putting together communication aid and modeling support not only leads to greater member satisfaction, but further increases group performance.

It is also interesting to note that higher-level GSSs caused the generation of fewer alternatives but higher decision quality, as compared to lower-level GSSs. The relationship between the exploration of more ideas and a better final choice was thus moderated by the level of GSS support, with the modeling and structuring tools of Level 2 GSSs being primarily responsible for this moderation.

Contrary to our prediction, studies conducted earlier reported greater impact of GSS use on the number of alternatives generated than those conducted later. It is interesting to note the similarity of this finding with that of the level of support. A correlation of .64 between the two moderating variables indicates the likelihood that the two findings are related. It appears that the GSSs used in the later studies were less focused on generating alternatives as compared to the earlier ones, thus having a smaller impact on number of alternatives generated.

LIMITATIONS OF STUDY

This study has several limitations. First, because most studies included in this analysis are laboratory experiments, our findings are subjected to the same limitations faced by such studies. Second, related to the above, most studies contained in our sample investigated single meetings. In natural settings, organizational groups may take several meetings to complete a task. Furthermore, the pre- and postmeeting activities that are influential on the success of the meeting and in the implementation of the decisions taken in the meeting were not examined in the sample studies. Third, our study, being a meta-analysis, inherits all limitations of the technique and is subject to the same criticisms. For example, meta-analysis has been criticized for attempting to "add apples to oranges." Nonetheless, advocates of the technique have also pointed out its merits, such as allowing a quantitative and objective integration of results. We believe that meta-analyses and narrative integrative reviews each plays a distinct role and that together they complement each other. Particularly, in a field that has progressed beyond its infant stage such as GSS, both techniques are desired. Finally, considering the fact that the current analysis has tested regression models, which require a large number of observations in comparison to the number of predictors, the relatively small number of observations in most models here poses a limitation.

SUGGESTIONS FOR RESEARCHERS

Interestingly, the moderating variable which was found to be most influential (i.e., it had an impact on almost all dependent variables) was level of GSS support, a technology variable. Although most GSS researchers discuss the potential influence of variables such as task characteristics, decision context, group characteristics, and so on, our meta-analysis indicates that the support features provided by the GSSs were of major importance. There are two research implications that follow from this. First, the technology variable, or GSS, should not be treated as a black box. Research in the future, in addition to investigating features external to GSSs (e.g., facilitation) (Anson, Bostrom, & Wynne, in press), should also examine the individual and joint effects of the specific features provided by the GSS (e.g., decision aids, data input features, and so on). Second, it is important to look at how these features influence the process of group decision making and how the specific components of the technology are appropriated by the group (DeSanctis & Poole, in press).

Although GSSs have been found to improve the overall decision quality, number of alternatives generated, and equality of participation, the reduction in consensus is problematic. Lack of consensus could be due to several reasons. We know from our findings that GSSs lead to the generation of more alternatives. This is due to features supported by GSSs, such as anonymity in input and secondary channels of communication, which increase inputs from those who hold minority opinions and those who are reticent. Rao and Jarvenpaa (1991) note that an increased number of alternatives leads to divergence and conflict, which when resolved through the application of greater cognitive resources results in better outcomes and consensus. However, if the tools provided by the GSS used in the sample studies were inadequate to support these processes, then there would not be a resolution of conflict. Alternatively, it is possible that the experimental conditions, such as the type of facilitation available or the lack of adequate time provided to the subjects to reach a state of consensus, were not amenable to the resolution of conflict. Clearly, because an improvement in decision quality without a concomitant improvement in consensus is not a desired state of affairs, the lack of consensus is an issue that researchers should more fully investigate in the future. Greater exploration of these issues should further advance our understanding of GSS use, thus enhancing the potential of GSSs as productive tools in organizations.

NOTES

1. The effect size of GSSs refers to the GSS versus no-GSS difference; thus, Proposition 1 may be represented as: [GSS(High complexity) – No-GSS(High complexity)] > [GSS(Low complexity) – No-GSS(Low complexity)].

2. Although process facilitation is an interesting topic and has recently begun to receive some attention in the laboratory (e.g., Anson et al., in press), most studies conducted to date have either provided passive, technical facilitation or none (Dennis et al., 1991). Correspondingly, the current proposition focuses on technical rather than process facilitation.

3. A copy of the detailed effect sizes is available from the first author.

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