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## **ABSTRACT**

### **VOTING IN GROUP SUPPORT SYSTEMS: THEORY, IMPLEMENTATION, AND RESULTS FROM AN EXPLORATORY STUDY**

by  
**Kung-E Cheng**

Group decision making is essential in organizations. Group Support Systems (GSS) can aide groups in making decisions by providing tools and process support. GSS is especially useful for geographically or temporally distributed groups. Researchers of GSS have pointed out that convergence processes are hard to accomplish in GSS. Voting tools in GSS can be a valuable asset in alleviating the difficulty of convergence processes because voting is a concise communication of individual preferences with a well defined procedure that is accepted by group members. In addition, voting results can serve as a group memory of the convergence processes. Field observations by researchers have shown that using voting in GSS can lead to many positive outcomes. Researchers also suggest that rather than using voting blindly, voting should be used properly in GSS to achieve desired results. However, there is an insufficiency of theory and experiments in research of voting in GSS. Voting with the computation power and communication capability in GSS can have a pronounced effect on decision processes and outcomes. In order to gain better understanding of voting in GSS, a framework was developed by expanding existing frameworks of GSS with factors related to voting. These factors were scrutinized for their potential effects on processes and outcomes. Several ways of classifying voting methods were also discussed. The framework can be used as a guiding basis for future research and usage of voting in GSS.

Functionalities of sophisticated voting tools to support group decision making were explored based on the proposed GSS voting framework, related theories and studies, and review of existing GSS voting tools and practices. Approaches for integration of sophisticated voting tools with existing GSS were also discussed.

Data were collected from an exploratory experiment to examine the effects of bandwidth of voting methods. While there is no significant difference in levels of consensus between the two voting method bandwidth conditions, groups with a high bandwidth voting method use less rounds of voting and posted fewer messages during discussion than groups with low voting bandwidth methods do. Subjective measures such as information use, group cohesiveness, decision confidence, and satisfaction although not significant in statistical tests, did show a trend in the direction as the framework predicted. Factors for effectively utilizing voting tools in group decision processes were also discussed by comparing the interactions of groups reaching a high level or low level of consensus.

Using voting for group decisions is a complex issue. Organizations and groups can benefit by using voting for reaching decisions more effectively and efficiently with better understanding of voting in group decision making. Several lines of future researches on voting and GSS were proposed. Possible topics include theory building/validation, tools implementation/application, and organizational impact. The framework presented in this research is only the beginning for better understanding of voting and group decision making.

**VOTING IN GROUP SUPPORT SYSTEMS:  
THEORY, IMPLEMENTATION, AND RESULTS  
FROM AN EXPLORATORY STUDY**

**by  
Kung-E Cheng**

**A Dissertation  
Submitted to the Faculty of  
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Doctor of Philosophy in Information Systems**

**Department of Information Systems**

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**APPROVAL PAGE**

**VOTING IN GROUP SUPPORT SYSTEMS:  
THEORY, IMPLEMENTATION, AND RESULTS  
FROM AN EXPLORATORY STUDY**

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*We shall not cease from exploration  
And the end of all our exploring  
Will be to arrive where we started  
And know the place for the first time. -- T. S. Eliot*

**Dedicated to all explorers of knowledge**

**and**

**to all who have supported my exploration, especially my parents.**

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## TABLE OF CONTENTS

Chapter	Page
1 INTRODUCTION.....	1
2 DECISION MAKING PROCESSES.....	4
2.1 Decision as Rational Choice .....	4
2.2 “Limited” or “Bounded” Rationality .....	6
2.3 Factors for Limited Rational in Decision Making .....	8
2.3.1 Incomplete Information .....	8
2.3.2 Limited Search for Solution.....	8
2.3.3 Problem Complexity .....	9
2.4 Groups and Decision Making.....	9
2.4.1 Definition of Group .....	10
2.4.2 Advantages of Groups in Decision Making.....	11
2.4.3 Disadvantages of Groups in Decision Making .....	12
2.5 Outcomes of Group Decision Making .....	15
2.5.1 Production Function Outcomes .....	15
2.5.2 Group Well-being Function Outcomes.....	16
2.5.3 Member-Support Function Outcomes .....	16
2.6 Technology to Support Group Decision Making.....	17
3 THEORIES OF GROUP SUPPORT SYSTEMS .....	18
3.1 The Need for GSS .....	19
3.2 Classifications of GSS.....	21

**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
3.2.1 Time and Space.....	21
3.2.2 Levels of Group Decision Support Systems (GDSS) .....	22
3.2.3 GCSS and GDSS.....	23
3.2.4 Synchronous GSS and Asynchronous GSS .....	23
3.3 Theoretical Frameworks for GSS.....	24
3.3.1 Taxonomy of GSS.....	24
3.3.2 EMS Research Model by Dennis et al. ....	25
3.3.3 GDSS and GCSS framework by Pinsonneault and Kraemer.....	26
3.3.4 GSS Framework by Hollingshead & McGrath.....	27
3.3.5 GSS Framework by Fjermestad & Hiltz.....	28
3.4 GSS Effects .....	30
4 FACTORS AND THEIR EFFECTS IN GSS .....	31
4.1 Individual Level Factors .....	31
4.2 Group Level Factors.....	32
4.2.1 Group Size .....	32
4.2.2 Stage of Group Development.....	33
4.2.3 Group Composition.....	34
4.3 Leadership .....	35
4.4 Reward Structure.....	35
4.5 Task.....	37

**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
4.5.1 Task Type.....	37
4.5.2 Task Complexity.....	39
4.6 Technology Support.....	40
4.6.1 Parallel Input.....	40
4.6.2 Anonymity .....	40
4.6.3 Communication Media.....	42
4.6.4 Tools Supported.....	44
4.7 Formal Procedures .....	45
4.8 Process Factors: Group Process Gains and Losses .....	46
4.9 Outcome Factors .....	49
4.10 Opportunity in GSS Research .....	52
5 VOTING IN GSS.....	53
5.1 Lessons and research findings about Voting in GSS .....	53
5.2 A Framework to Study Voting in GSS .....	56
5.3 Effectiveness of GSS Voting .....	57
5.4 Two Aspects of Voting .....	59
5.4.1 Aggregation Aspect of Voting.....	60
5.4.2 Communication Aspect of Voting .....	62
5.5 Input Factors and GSS Voting .....	64
5.5.1 Task Support.....	65

**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
5.5.2 Task Characteristics .....	67
5.5.3 Group Characteristics.....	68
5.5.4 Process Structure.....	68
5.5.5 Voting Procedures.....	69
5.5.6 Voting Methods .....	69
5.5.7 Access to Voting Results .....	74
5.5.8 Frequency of Voting .....	75
5.5.9 Dynamic Listing of Alternatives.....	76
5.5.10 Representation of Voting Result.....	77
5.6 Process Factors in Voting in GSS .....	80
5.7 Output Factors in Voting in GSS .....	80
5.7.1 Task-related Outcomes .....	80
5.7.2 Group-related Outcomes.....	81
5.8 The Need for Research on GSS Voting .....	81
<b>6 DESIGNING VOTING TOOLS IN GSS .....</b>	<b>82</b>
6.1 Possible Benefits of Voting Tools in GSS .....	82
6.2 Implications of Social Choice Theory in GSS Voting.....	83
6.3 Implications of Media Synchronicity Theory in GSS Voting.....	84
6.4 Voting Tools and Group Process Gains/Losses.....	86
6.4.1 Synergy .....	86

**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
6.4.2 Failure to Remember.....	87
6.4.3 Conformance Pressure .....	87
6.4.4 Free Riding.....	88
6.4.5 Domination .....	88
6.4.6 Information Overload.....	88
6.5 Integration with other GSS Tools .....	89
6.5.1 Integration with Idea Generation Tools .....	89
6.5.2 Integration with Discussion Tools .....	90
6.6 Survey of GSS Voting Tools .....	90
6.6.1 Delegation of Vote.....	92
6.7 Building GSS Voting Tools .....	93
6.7.1 Security .....	93
6.7.2 Implementation Approaches .....	93
7 GSS VOTING TOOL PROTOTYPE .....	95
7.1 Features Implemented in the Prototype.....	95
7.2 Integration with Host Program.....	96
7.3 Control Flow in the Prototype.....	97
7.4 Templates for Voting Methods .....	98
7.5 Extending the Voting Tool Prototype .....	100



**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
8 EXPERIMENT DESIGN AND REVISIONS .....	101
8.1 Original Experiment Design .....	101
8.1.1 Selection of Task.....	102
8.1.2 System.....	103
8.1.3 Subjects .....	104
8.1.4 Procedure .....	104
8.2 First Revision of Experiment Design.....	105
8.2.1 Subjects and Incentive .....	105
8.2.2 Task.....	106
8.2.3 Procedure .....	107
8.3 Second Revision of Experiment Design .....	108
8.4 Hypotheses to Be Tested in the Experiment .....	112
8.4.1 Hypotheses for Objective Measures .....	112
8.4.2 Hypotheses for Subjective Measures.....	113
8.4.3 Summary of Hypotheses.....	116
9 RESULTS AND DISCUSSION .....	117
9.1 Background Information of Subjects .....	117
9.2 Objective Measures.....	120
9.2.1 Level of Consensus .....	122
9.2.2 Rounds of Voting.....	123

**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
9.2.3 Number of Messages Posted.....	123
9.2.4 Summary of Findings from Objective Measures.....	124
9.3 Subjective Measures.....	125
9.3.1 Perceived Process Gains/Losses .....	128
9.3.2 Information Use .....	128
9.3.3 Perceived Usefulness of Voting Tool .....	129
9.3.4 Perceived Decision Process Quality .....	130
9.3.5 Perceived Decision Quality.....	131
9.3.6 Group Cohesiveness.....	132
9.3.7 Decision Confidence.....	133
9.3.8 General Satisfaction.....	133
9.3.9 Summary of Findings from Subjective Measures.....	134
9.4 Group Interactions.....	135
9.4.1 Early Participation by Members .....	136
9.4.2 Leadership.....	136
9.4.3 Well Defined and Announced Procedure for Voting.....	137
9.4.4 Using Voting Tool to Identify Agreements .....	137
9.5 Limitations .....	138
9.5.1 Recruitment of Subjects.....	138
9.5.2 Artificial Task .....	139
9.5.3 Unfamiliarity with Asynchronous Discussion and Voting Tools.....	140

**TABLE OF CONTENTS**  
**(Continued)**

<b>Chapter</b>	<b>Page</b>
10 SUMMARY AND CONCLUSION.....	141
10.1 Summary of Study .....	141
10.2 Contributions.....	142
10.2.1 Contributions to Theory.....	142
10.2.2 Contributions to Practices.....	142
10.3 Directions for Future Studies .....	143
10.3.1 Expanding and Validating the Framework .....	143
10.3.2 Designing of Sophisticated GSS Voting Tools.....	144
10.3.3 Matching GSS Voting to Specific Situations .....	144
10.3.4 Examining Organizational Issues in GSS Voting.....	144
10.4 Conclusion .....	145
APPENDIX A THE SOCIAL CHOICE THEORY.....	146
APPENDIX B THE LAW OF COMPARATIVE JUDGMENT.....	162
APPENDIX C INSTITUTIONAL REVIEW BOARD APPROVAL.....	177
APPENDIX D STUDY CONSENT FORM.....	181
APPENDIX E INSTRUCTIONS TO SUBJECTS.....	185
APPENDIX F PRE-DISCUSSION QUESTIONNAIRE.....	198
APPENDIX G EXPERIMENTAL TASK.....	201
APPENDIX H POST-DISCUSSION QUESTIONNAIRE.....	207
APPENDIX I AFTER EXPERIMENT DEBRIEFING.....	212
REFERENCES .....	215

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
3.1	Example of Group Support Systems in Time and Space Domain .....	21
4.1	Summary of the Rewarding Methods .....	36
4.2	Dimensions in Media Synchronicity Theory .....	43
4.3	Common Group Process Gains .....	47
4.4	Common Group Process Losses .....	48
5.1	Lessons of Using Voting in GSS .....	55
5.2	Findings of Studies on Voting in GSS .....	56
5.3	Commonly Used Voting Methods .....	60
5.4	Example of Condorcet Paradox .....	61
5.5	Media Characteristics of Voting as Communication .....	63
5.6	Ballot Complexity .....	71
5.7	Channel Capacity of Voting Methods.....	73
6.1	Table Features of GSS Voting Tools Based on Earlier Discussion.....	91
6.2	GSS Voting Tools Surveyed.....	92
7.1	Decision Table for Voting Tool System Actions.....	99
8.1	Experiment Design.....	102
8.2	Summary of Hypotheses .....	116
9.1	Ages and Working Experience of Subjects .....	118
9.2	Gender and Education Level of Subjects.....	118
9.3	Experience in Using Web-based Discussion Program.....	119
9.4	Self-reported Time Spend on Task by Subjects.....	119

**LIST OF TABLES**  
**(Continued)**

<b>Table</b>	<b>Page</b>
9.5 Objective Data from Experiment Groups .....	121
9.6 Summary of Findings of Objective Measures .....	125
9.7 Subjective Measures, Aggregated at Group Level .....	127
9.8 Instrument for Perceived Process Gains/Losses	128
9.9 Result of Perceived Process Gains/Losses.....	128
9.10 Instrument for Information Use .....	129
9.11 Result of Information Use.....	129
9.12 Instrument for Perceived Usefulness of Voting Tool .....	130
9.13 Result of Perceived Usefulness of Voting Tool.....	130
9.14 Instrument for Perceived Decision Process Quality .....	131
9.15 Result of Perceived Decision Process Quality .....	131
9.16 Instrument for Perceived Decision Quality.....	131
9.17 Result of Perceived Decision Quality .....	132
9.18 Instrument for Group Cohesiveness.....	132
9.19 Result of Group Cohesiveness .....	132
9.20 Instrument for Decision Confidence.....	133
9.21 Result of Decision Confidence .....	133
9.22 Instrument for General Satisfaction .....	134
9.23 Result of General Satisfaction .....	134
9.24 Summary of Findings of Subjective Measures .....	135

**LIST OF TABLES**  
**(Continued)**

<b>Table</b>	<b>Page</b>
A.1 Example of Condorcet Voting Paradox .....	150
A.2 Example of Borda Count .....	155
A.3 Example of Approval Voting.....	156
A.4 Voting Methods and Desired Properties.....	157
A.5 Information Required for Successful Manipulation .....	159
B.1 Torgerson's Classification of The Law of Comparative Judgment.....	168
B.2 Proportion of One Offence Was Judged as More Serious Than Others .....	170
B.3 Scale Value of Seriousness of Offenses.....	171

## LIST OF FIGURES

<b>Figure</b>		<b>Page</b>
2.1	Decision as a three-phase process.....	5
2.2	Model for decision/behavior process.....	7
3.1	Taxonomy of GSS.....	24
3.2	EMS research model by Dennis et al. ....	25
3.3	GDSS and GCSS framework by Pinsonneault and Kraemer.....	26
3.4	GSS framework by Hollingshead & McGrath.....	27
3.5	GSS framework by Fjermestad & Hiltz.....	28
3.6	Factors in the GSS framework by Fjermestad & Hiltz.....	29
4.1	Task circumplex.....	38
4.2	Desired media characteristics .....	44
4.3	Potential effects of GSS features on process gains and losses.....	49
5.1	Research framework for studying voting in GSS .....	57
5.2	Desired media characteristics for group processes .....	64
7.1	Control flow of the voting tool prototype .....	97
8.1	Timeline of events in the experiment.....	111
B.1	Mapping between discriminial processes and stimuli.....	163
B.2	Psychological scale and distribution of discriminial processes .....	164

## CHAPTER 1

### INTRODUCTION

Organizations usually depend on groups to accomplish vital tasks. Groups are used for several reasons: the task is too complex for an individual to handle, diversified expertise is required for the task, or there is a need to reflect the viewpoints or interests of stakeholders. Group Support Systems (GSS), which consist of hardware, software, and process components (Nunamaker, 1997), can aid groups in performing various tasks such as idea generation, problem solving, consensus building, negotiation, and execution, especially when members are geographically or temporally distributed (Briggs, Nunamaker, & Sprague, 1998; Dennis & Gallupe, 1993; DeSanctis & Gallupe, 1987; Fjermestad & Hiltz, 1999; Hollingshead & McGrath, 1995).

George and Jessup (1997, p. 505) criticize that GSS research usually take a simplistic view of group decision making by mapping the linear path of intelligence-design-choice in Simon's rational decision making model to brainstorming-idea analysis-voting activities. Nevertheless, even with this unsophisticated view of group decision making processes, GSS research has not focused on voting. For instance, Barkhi (2000) suggests that research on group collaboration typically concentrates on idea generation tasks. In a comprehensive review of GSS studies (Fjermestad & Hiltz, 1999), thirty-five of the 184 studies reviewed have reported their systems incorporate voting tools. However, only two studies have incorporated voting conditions into the experiment treatment and there is only one published study that reports group behavior on voting.



Although voting has not been studied extensively in GSS research, it is by no means a trivial activity for decision making. Collaboration Engineering, which is about design and deployment of collaboration processes for practitioners for recurring high value tasks, identified six general patterns in group collaboration: Generate, Reduce, Clarify, Organize, Evaluate, and Build consensus (Briggs, Kolfschoten, De Vreede, & Dean, 2006). In these collaboration patterns, building consensus is regarded as the most demanding function followed by the pattern of evaluation by facilitators in a recent survey (den Hengst & Adkins, 2007). Researchers of GSS have also found that converging to the final decision is considered more difficult to achieve in geographically or temporal distributed groups (Briggs et al., 1998). Voting can be a valuable mechanism to aid groups during evaluation and consensus building. Assessment of the field uses of GSS indicate that voting tools can be and should be used differently from the traditional paper-based voting because voting tools in GSS can take advantage of the enhancement in communication capability and computational capacity provided by computers. Voting in GSS should not be used to signify the end of the decision process as in traditional meetings. It can be used to discover areas where there is a lack of consensus among the group and enable the group to explore the issue at a deeper level (Kraemer & King, 1988; Nunamaker, 1997; Nunamaker, Briggs, & Mittleman, 1994). There are many factors that can affect the use of voting in GSS and this topic has not been systematically studied by researchers. In order to use voting to support group collaboration effectively, further research in voting with GSS is needed.

The primary goal of this research is to build a framework for exploring voting in GSS. An exploratory study was also conducted to observe the effects of GSS voting tools.

Chapter 2 will give an overview of the decision making process and the need for groups in decision making. The requirements to support groups in decision making will lead to the next two chapters on GSS. Chapter 3 reviews a variety of theories and classifications of GSS. GSS factors and research findings will be discussed in chapter 4. Chapter 5 reviews theories and practices of voting in GSS, then develops a framework for studying voting in GSS. Chapter 6 describes functional requirements for sophisticated voting tools in GSS. Chapter 7 depicts the design and implement of a prototype GSS voting tool which supports some of the advanced features described in chapter 6. The original design and revisions of an experiment to investigate effects of voting in GSS is documented in chapter 8. Chapter 9 will present findings from the experiment. The last chapter will emphasize contributions of this research and offers plans for future research.

---

## **CHAPTER 2**

### **DECISION MAKING PROCESSES**

A central theme of human activities is decision making. It is extremely commonplace. Decisions are made all the time and everywhere. However, the essence of decision making remains elusive. Researchers still debate about many aspects of decision making. This chapter reviews several schools of thought on the decision making.

#### **2.1 Decision as Rational Choice**

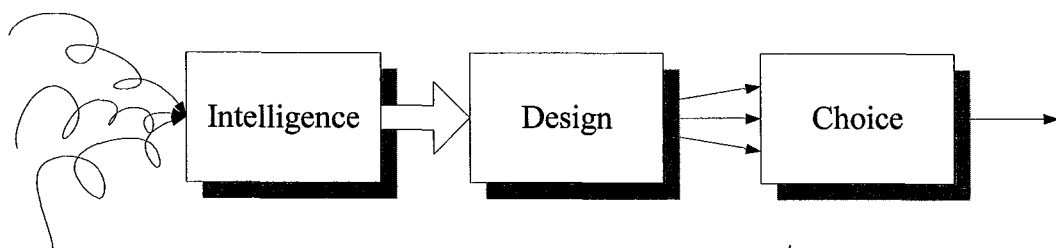
The most common view about decision making is that it is an action of rational choice (March, 1994). Before further discussion on decision making as rational choice, one should examine the term “rational” first. In the Concise Oxford Dictionary, “rational” is defined as:

1. of or based on reasoning or reason;
2. sensible, sane, moderate; not foolish or absurd or extreme;
3. endowed with reason, reasoning;
4. rejecting what is unreasonable or cannot be tested by reason in religion or custom.

From the definition, we can see that “rational” is linked to reason. However, the dictionary definition does not clarify what is being reasoned, the process or the outcome. This ambiguity is not accidental because people use “rational” to validate either process or outcome depending on context. People can justify their decision as rational if they made the decision by following certain guidelines or if the outcome of the decision is as they desired. As researchers in decision making, there is no such kind of luxury to

intermix process rationality and outcome rationality. Because the desirability of the outcome can change depending on people's perception, there is no objective standard in measuring the rationality based on the decision outcome. The process rationality view is adopted in this paper, i.e., a decision is rational if it is made by meeting certain guiding principles.

There are many models of rational decision making processes. Simon (1960) suggests that decision making is a cognitive process and can be decomposed into stages. He proposes that decision is a three-stage process of intelligence, design, and choice. In the intelligent phase, a decision maker senses the need to make a decision and collect information for the decision. The Decision maker formulates alternatives of actions and their possible consequences in the design phase. Finally, in the choice phase, the decision maker chooses an alternative or a mix of alternatives in order to achieve a preferred outcome (Figure 2.1). Under this model, a decision maker is rational if he/she collects all the available information pertaining to the decision, evaluates the consequences of all alternatives, and then chooses an action to optimize the possibility of desired outcome.



**Figure 2.1** Decision as a three-phase process.  
(adapted from Langley, Mintzberg, Pitcher, Posada, & Saintmacary, 1995)

Researchers have elaborated on Simon's model into more detailed steps. For example, Mintzberg and his colleagues (1976) have extend the decision making process

into a seven-routine model. Nutt (1984) offers a model of five stages, each with three components. No matter how many stages are in a model, a central theme of all these models is that making decision is to achieve an optimized outcome by evaluating alternatives with available information.

One major critic of Simon's model is that the decision making process is sequential with discrete steps. March (1994) suggests that decision making is organized anarchy because of complex interactions among decision makers, solutions, problems and choice opportunities. The Garbage Can Model of decision making process proposed by Cohen, March, and Olsen (1972) advocates that decision makers link events by their temporal order. A decision is made only during a choice opportunity when one or more decision makers, with the ability and enough energy to solve a problem, can apply solution(s) to the problem. This model signifies how the decision making process becomes organized anarchy under uncertain goals, preferences, and actions; however, it does not reject the notion that decision makers are rational about their choices. The decision maker still needs to collect information, design alternatives, and make a choice to reach a decision.

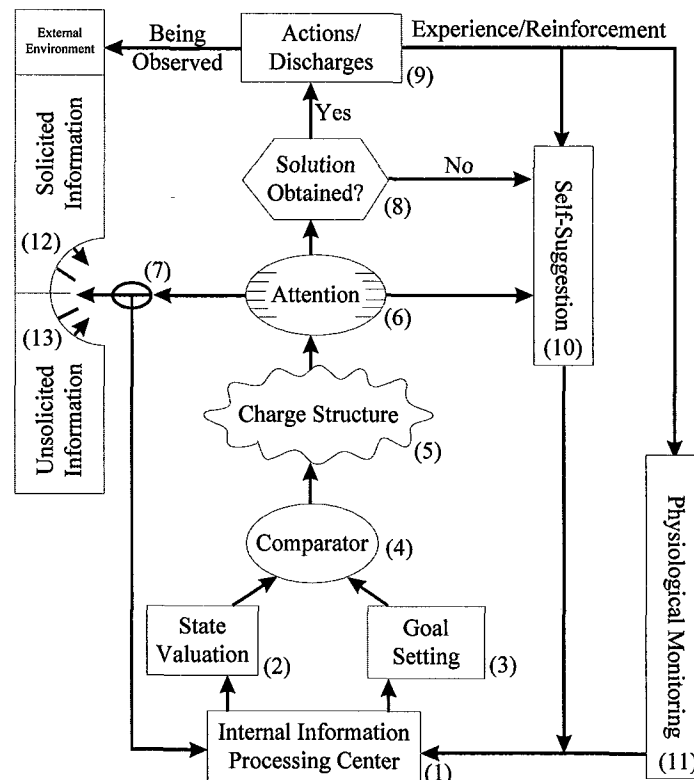
## **2.2 “Limited” or “Bounded” Rationality**

Even if decision makers are rational, they still face many factors that limit them in making a perfect decision. One problem is uncertainty between alternatives and possible outcomes as there are things not under control by decision makers. The other problem is “limited” or “bounded” rationality as the decision maker only has limited capability to be

rational. Yu (1984) has suggested a model for the decision/behavior process (Figure 2.2).

The following are the main ideas of the model:

1. Each individual has internal information-processing and problem-solving capacity. These capacities can vary with time.
2. Attention (Box 6) is a human's conscious time allocation of his/her internal information processing and problem-solving capacity over various activities and events.
3. There are a number of state variables that describe human physiological conditions, social situations, and self-suggested goals.
4. Each state variable is constantly monitored and interpreted. When a variable's current value diverges significantly from its goal value (ideal state), a charge (tension) will be produced.
5. The charges produced by the assorted states form a hierarchical system depending on the relative importance of the states and on how significant the deviations of the perceived values from the ideal values are.



**Figure 2.2** Model for decision/behavior process.

(Adapted from Yu, 1984, p. 37)

6. Attention is directed to release the charges in the most efficient way. These ways involve (a) actions and discharges when solutions are obtained (Boxes 8 and 9); (b) acquiring external information (Boxes 7, 12, and 13); or (c) self-suggestion for internal thinking, justification, and rationalization (Box 10). All of these functions feed back to the internal information processing center.

### **2.3 Factors for Limited Rational in Decision Making**

Some factors limiting the decision maker from making rational decisions are discussed based on Yu's decision/behavior process model.

#### **2.3.1 Incomplete Information**

Not all information is used in the decision making process. A decision maker has limited capability in collecting and processing information. These activities of collecting or processing information have mental and/or physical costs to the decision maker. The decision maker may give up a piece of information due to the high cost of collecting or processing this piece of information. On the other hand, attention is a scarce resource. Many mental activities are competing for it. When the decision maker fails to pay attention to certain pieces of information, that information is usually ignored in the decision making process. Decision makers are also biased to search for and to accept information that confirms their belief and supports their initial decision, rather than evaluating all information with equal consideration.

#### **2.3.2 Limited Search for Solution**

It takes mental effort and time to generate alternatives for the decision and to do a complete search for the optimal solution among all the generated alternatives. The decision maker may overlook alternatives because those alternatives have not been

considered as the solution to the problem. The decision maker usually does a “satisficing” search for solutions instead of a “maximizing” search, evaluates alternatives and stops the search when he/she finds one alternative that satisfies his/her requirements (Simon, 1956). This strategy of searching for solutions may not lead to the optimal solution because it depends on the path of the search. One example is anchoring in decision making (Kahneman, 1992; Tversky & Kahneman, 1974). The decision makers may come up with different solutions if they are given different pieces of information as starting points.

### **2.3.3 Problem Complexity**

Even if the decision maker is willing to collect all information, construct all possible alternatives, and evaluate all the alternatives, the decision maker still faces an obstacle in decision making, that is, problem complexity. The nature of the problem may be too complex for the decision maker to comprehend. The decision maker might lack the necessary knowledge or skill to process the information, form alternatives, or evaluate all the alternatives.

## **2.4 Groups and Decision Making**

There are several ways to overcome some of the problems faced by a single decision maker. For example, information systems can help decision makers in retrieving and organizing information. Mathematic models or other decision aids can be provided to decision makers to augment their capacity in processing information.

Another way to overcome the limitation of a single decision maker is to have several people working together as a group on the same decision. Groups, or teams, can



also be formed to make decisions due to the need to reflect diverse viewpoints or interests of stakeholders. Groups have advantages in making decisions compared to individuals. However, groups also face many problems that do not arise on the individual level in decision making. The diversity in group composition might lead to misunderstanding and conflict during decision making. The advantages and disadvantages of group decision making will be discussed later in this section.

### **2.4.1 Definition of Group**

McGrath (1991) suggests that groups are complex, intact social systems consisting of several members. Groups are embedded in, or loosely coupled to, surrounding systems, such as organizations or societies. Groups perform multiple purposeful functions that make contributions to the surrounding systems, to the groups themselves, and to the members of the groups. McGrath labels these functions as production function, group well-being function, and member-support function. The outcomes of these functions are related to group effectiveness. The outcomes of group functions will be discussed in a later section.

Decision making activities in groups include detecting problems, elaborating on problems, generating possible solutions, evaluating solutions, and planning how to implement solutions (DeSanctis and Gallupe, 1987). This definition resembles Simon's rational decision model. Group activities are not limited to decision making only, however, those activities are outside of the scope of this research.

## **2.4.2 Advantages of Groups in Decision Making**

Groups are comprised of more than one individual. Thus, groups have more resources than a single individual may possess. This gives groups some advantages in decision making.

**2.4.2.1 More Information.** Individuals have different backgrounds. They view the same problem from different perspectives and observe different pieces of information for the problem. The information advantage was referred to as the “N-heads rule” by Norman Dalkey (1969). The rule states:

*“The basis for the N-heads rule is not difficult to find. It is a tautology that, on any given question, there is at least as much relevant information in N heads as there is in any one of them. On the other hand, it is equally a tautology that there is at least as much misinformation in N heads as there is in one.”*

A group can pool all the information from all the members to make decisions. A group also has more mental capacity to recall and process information than a single individual has. A piece of information can enter into consideration if any one of the members can recall it. However, as was pointed out by Dalkey, there is also more misinformation in a group. It is important to help a group identify and focus on the relevant information and remove misinformation in the decision process.

**2.4.2.2 More Potential Solutions.** Simply by having more heads, a group should be able to come up with more alternatives than an individual could. Moreover, members of the group can also learn from each other, emulate a capable member’s action, or be inspired by alternatives proposed by others to formulate more potential solutions.

**2.4.2.3 Combined Ability.** Members of a group bring their expertise to bear in problem solving. Members can solve different parts of a problem based on their proficiency and later combine their solutions together to form the group solution. Even if

some members are expert in the same area, they can still help each other by mutually checking other's solutions to improve the quality of a decision.

### **2.4.3 Disadvantages of Groups in Decision Making**

Group decision making is not without its problems. Some of the problems are discussed in the following sections.

**2.4.3.1 Coordination.** When more than one person tries to achieve the same goal together, the goal-seekers must perform activities to organize themselves while a single person doesn't have to do these activities to achieve the same goal. These extra activities are coordination (Malone, 1988). Members of a group need to establish goals, procedures, allocate shared resources, and schedules to make decisions. If a problem is complex, the group may also be required to divide the problem into sub-problems among its members. Then there is the problem of how to divide the problem and how to combine members' solutions of the sub-problems into the final group solution. If the sub-problems are interrelated, when one member makes changes in his/her solution, it may cause a cascade of changes in other members' solutions. These coordination overheads require extra work and effort in groups.

**2.4.3.2 Communication.** Members in a group have to exchange information. The information can be related to the decision or coordination. Communication of information takes effort and time. Communication among members can also be misunderstood because of ambiguity in language or different backgrounds of members. This creates confusion within the group.

**2.4.3.3 Conflicts.** Most studies in group decision making have assumed that members in a group are cooperative in solving problems, since members are working

toward the same goal. Yet individual members of a group may be in fact competing to show that they are the most capable member and their solutions are the best solutions; or to place their personal goals over others members' goals (Tjosvold, 1995). Even if the members are cooperative, they may have different interpretations of the same problem, different goals, different priorities among problems, and different preferences among alternatives. The group has to resolve these conflicts, thus reducing its effectiveness in decision making.

**2.4.3.4 Group Pressure.** The minority in a group may succumb to the pressure of the majority and abandon their position without expressing their opinions. Asch's classical "line judgment" experiment (Asch, 1951) has shown that the power of a unanimous majority can force the minority to adopt an obviously incorrect answer. In some cases, the pressure to maintain harmony in the group becomes so strong that it leads to dysfunction in the decision making processes. Groups in this situation generate few alternatives, do limited or selective search for information, and have bias in evaluating alternatives. Janis (1972) coined the term "groupthink" to describe this kind of breakdown in group decision making.

**2.4.3.5 Radical Decisions.** Groups sometimes make more radical decisions than individuals do (Stoner, 1968). This phenomenon in group decision was first known as "risky-shift" because it was observed that groups made riskier choices than individual members did. Groups might also shift to more cautious decisions, the terms "choice shift" or "group polarization" are now commonly used to refer to this phenomenon. There are several proposed explanations for this behavior. Two leading theories for the choice shift are social comparison theory of normative processes and persuasive augment

theory of information processes. The social comparison theory posits that extreme positions are often socially desirable as the person who proposed them will be considered as having more positive traits such as higher ability or creativity. In the beginning of discussion, a member will be less likely to express extreme ideas fearing he or she will be labeled as an extremist. However, the group member may find some other members expressing opinions that are slightly more extreme than his or her current position during group discussion, thus encouraging the member to express more extreme opinions. The group will move toward a more radical decision after discussion (Sanders & Baron, 1977). The persuasive augment theory holds that individual choices are determined by individuals weighing remembered pro and con arguments. These arguments are then applied to possible choices and the most positive alternative is selected. Members usually utter the pro arguments in favor of the group tendency and con arguments against the group tendency during the discussion. The group moves to a more radical position after discussion because as each member exposes arguments, the number of pro arguments for the radical alternative, and the number of con arguments for opposite alternatives will increase (Burnstein & Vinokur, 1977). Either theory cannot fully explain choice shift. It seems both social comparison and persuasive augment are causing choice shift in parallel as shown in a meta-analysis by Isenberg (1986).

In addition to these two theories, the diffusion of responsibility is also a possible cause for groups making more radical decisions than individuals. An individual in a group will feel less responsible for the decision if the outcome is a failure. The individual also has less fear about punishment or retaliation for the decision because his

or her individual action is not the central focus of the decision. Anonymity in discussion may decrease the fear of punishment even further. (Dion, Baron, & Miller, 1978)

## **2.5 Outcomes of Group Decision Making**

Groups carry out multiple functions at the same time. These functions have outcomes that affect the surrounding social units, the groups themselves, and their members. Although these functions can be separated conceptually, they are intertwined due to the complexity of group processes. They also affect further group activities because the experience of the past and the expectation of the future will affect the group's current performance (McGrath, 1984). It is important to look at the outcomes of these group functions.

### **2.5.1 Production Function Outcomes**

The production function contributes to the surrounding social units of the group. For decision making groups, production function outcomes can be measured by effectiveness and efficiency. Decision quality is the central theme of group decision making. A good decision by the group is a great contribution to the surrounding social units. It can also justify the continuing existence of the group and make the members feel accomplished. On the other hand, a bad decision can harm the surrounding social units, threaten the very existence of the group, and depress its members.

The resources and time spent by groups to make decisions are measures of efficiency of the production function. Groups using less resources and time to reach decisions have an advantage over groups that use more resources or time to reach the same decision because they have a higher return on resources or better turnaround time.

### **2.5.2 Group Well-being Function Outcomes**

Groups need to maintain themselves as sustainable social units. They have to justify their existence and make members willing to stay. One outcome of the group well-being function is group cohesiveness, that is, how members feel they belong to the group and whether they are willing to work together again. A group with high cohesiveness is more motivated to perform tasks and has less conflict among members, leading to better production function outcomes. However, non-task related communication is needed to create and maintain group cohesiveness, which might reduce the production function efficiency.

### **2.5.3 Member-Support Function Outcomes**

Members need rewards for their participation in group activities. The rewards could be tangible or intangible. Position or role in the group, recognition of an individual's ability, and friendship with other members are examples of intangible rewards for the group member. The distribution of rewards among members is also important. Members' willingness to work in the group decrease if they do not feel they have received reasonable rewards for their contributions to the group. The group will be hard to motivate members working toward the group's goal and ultimately suffers poor production function outcomes.

## **2.6 Technology to Support Group Decision Making**

Groups have advantages and disadvantages in making decisions. Technology can offer some assistance in enhancing the benefits of pooled information and combined ability while reducing the problems of coordination and communication. Group Support

Systems (GSS) or Group Decision Support Systems (GDSS) are information systems with technology and process components to support group in making decisions. The next chapter will review theories about GSS.



## CHAPTER 3

### THEORIES OF GROUP SUPPORT SYSTEMS

Group Support Systems (GSS), which have hardware, software, and process components, intend to support groups engaged in a wide range of tasks (Nunamaker, 1997). Examples of common group tasks include idea generation, problem solving, consensus building, negotiation, and execution (Briggs, Nunamaker, & Sprague, 1998; Dennis & Gallupe, 1993; DeSanctis & Gallupe, 1987; Fjermestad & Hiltz, 1999; Hollingshead & McGrath, 1995). A group of people has more knowledge, information, and brainpower than a single individual does. Thus, a better solution of a given problem can be found by a group of people because of synergy, mutual stimulation, learning, and piggybacking of ideas. However, working in a group setting also gives rise to additional problems. GSS are designed to help groups by streamlining the process, achieving better outcomes, and/or reducing the cost for members to participate in group activities. Most research on group support systems deals with names and acronyms like “Group Decision Support System” (GDSS), “Electronic Meeting System” (EMS), “Computer Mediated Communication” (CMC), or “Computer Supported Cooperative Work” (CSCW) (Dennis, George, Jessup, Nunamaker, & Vogel, 1988; Gallupe, DeSanctis, & Dickson, 1988; Grudin, 1994; Hollingshead & McGrath, 1995; Nunamaker, Dennis, Valacich, Vogel, & George, 1991; Turoff, 1991). The term “Groupware” is sometimes also associated with group support systems (Johansen, 1988).

### 3.1 The Need for GSS

Distance is a constraint for groups. Globalization has caused many international companies to have staff members working in diverse geographic locations. Even domestic companies now set up remote branches to take advantages of operating in different locations. For example, an R&D center and a manufacturing factory can be set up at different places to attract high quality engineers while lowering manufacturing costs. Yet, these people at diverse locations still have to work as a group to solve problems such as how to transfer a new manufacturing process from the R&D center to the factory.

Time is another constraint for group activities. Sometimes it takes more effort to arrange a group meeting than to hold the meeting itself, since incompatible schedules have made it difficult to have all the key individuals present. Moreover, branches of an organization can be located in different time zones, and thus it may be difficult to have all members of a group attending the same meeting during normal working hours, even with telecommunication support.

There is another kind of time constraint for participation in group activities. Imagine that there are ten people in a group. If each of the participants takes a turn and talks for only three minutes, half an hour will pass away. However, group discussion usually does not proceed like this. Many threads are introduced, and it generally takes hours for the discussion to reach a fruitful result, if any. Usually with more people in a discussion, the more diverse viewpoints there are, and therefore the more potential conflict in the discussion. Small groups may be able to control discussion time length better than large ones do, but most situations will not allow limited numbers of

participants in a discussion, especially those involved with topics that have crucial outcomes or for which the problems are too complicated to be solved by a small group.

Sometimes members of a group come from diverse levels of the organization. If someone speaks out and the majority of the group supports what he or she is saying because of his or her status, others may well agree with the speaker even if they do not believe the expressed opinions are right. In most cases, people simply want to secure their jobs, avoid conflicts, and therefore are not willing to object to the speaker, who could be likely a supervisor or manager in the organization. Sometimes a well-presented speech paired with personal charisma could mask the poor content of a proposal which may actually need further discussion and modification by the group.

Some individuals might be reluctant to speak up in a group discussion because they have extreme ideas, which they think may either offend others or cause conflict. People who have lower positions in an organization often withhold their options because they believe nobody will listen to their ideas. Or people are afraid that their ideas are immature and they will be ridiculed. Some individuals may not contribute their ideas because they do not want to prolong the meeting. On the other hand, there are people who might simply not get the opportunity to speak out in a group discussion, due to time constraints.

There are merely the most common problems with group discussion. The positive and negative effects of working in a group (process gains and losses) will be discussed in a latter section. GSS provides groups with technology and process supports, thus enhancing the benefits of working in a group while decreasing the problems associated with group activities.

## 3.2 Classifications of GSS

### 3.2.1 Time and Space

A popular taxonomy of GSS has been suggested by researchers (Dennis et al., 1988; Ellis, Gibbs, & L., 1991; Johansen et al., 1991). As shown in Table 3.1, a 2 by 2 matrix is formed with time and space as axis. Each cell has its unique characteristics and requires different technology support. Examples of group tasks in these cells are discussed below.

**Table 3.1 Example of Group Support Systems in Time and Space Domain**

		Time	
		Same Time	Different Time
Space	Same Place	Meeting room	Work shift
	Different Place	Distributed group meeting	Computer conference

**3.2.1.1 Same Place, Same Time.** These GSS are for face-to-face meetings of a group. On the low end of technology, there are tools such as computer projection screens which project computer images onto a public screen. On the high end, there are meeting rooms with networked computers equipped with appropriate software for group process support.

**3.2.1.2 Different Time, Same Place.** This cell is best described by workers working in shifts at places like hospitals, factories, and military installations. Members of a group need to pass updates and status reports regarding their activities to their colleagues to ensure continuous operation. Group memory is very important in this setting so that there is a quick and smooth transition from one work shift to the next.

**3.2.1.3 Same Time, Different Place.** Teleconferencing of geographic dispersed groups is one example of this domain. Video/audio and computer-assisted teleconferences not only

allow participants to communicate with others at great distance, but also give the users the feeling of being in the same meeting room as other participants.

**3.2.1.4 Different Time, Different Place.** This is best explained with the example of a computer conference, a computer system that supports entering and retrieving of messages that are essential for the group discussion. Members of the group can work together regardless of the differences in both time and place. Decision aids and group process support can also be built into the system and facilitate the group performance.

### **3.2.2 Levels of Group Decision Support Systems (GDSS)**

The term GDSS was first proposed by Huber (1984). DeSanctis and Gallupe (1987) define GDSS as a combination of communication, computer, and decision technologies to support problem formulation and solution in a group meeting. They have suggested a three-level taxonomy for GDSS classification. Each level of GDSS intends to attack a particular group problem or to fulfill some group needs. In DeSanctis and Gallupe's classification, a higher level GDSS supports higher level of process. Moreover, their definition of GDSS includes systems that support decisions both directly and indirectly.

**3.2.2.1 Level 1 GDSS: Communication Only.** The goal of a level 1 GDSS is to remove communication barriers by providing information aids for individual members and enabling information exchange among members. Level 1 systems may provide features such as broadcast or point-to-point electronic messaging, common view screens or public screens on everybody's workstation, anonymous input and voting, as well as idea organizing.

**3.2.2.2 Level 2 GDSS: Decision Aids.** A level 2 GDSS provides decision models and decision techniques to help a group in making decisions. It can help reduce the

uncertainty and maintaining the proper procedure in the decision process. Common features in a level 2 GDSS are a variety of models for planning, risk assessment, as well as nominal group techniques.

**3.2.2.3 Level 3 GDSS: Machine-Induced Communication.** A level 3 GDSS can enforce formalized procedures and select appropriate rules for discussions by machine-induced group communication patterns. A level 3 GDSS is best described as an intelligent agent that can actively filter and structure information for the group.

### **3.2.3 GCSS and GDSS**

Pinsonneault and Kraemer (1990) reviewed 28 GSS studies based on a classification of GCSS and GDSS. GCSS stands for Group Communication Support System, which is a system that supports communication between group members. Its main purpose is to reduce the communication barriers within a group. For example, everybody can express ideas at the same time by typing simultaneously, rather than speaking one after another. GCSS is roughly equivalent to level 1 and level 3 GDSS in DeSanctis and Gallupe's GDSS classification. Pinsonneault and Kraemer's GDSS is a system that supports formal decision processes. Its main purpose is to reduce the noise in decision processes. It is roughly equal to DeSanctis and Gallupe's level 2 GDSS classification. These two systems are not mutually exclusive. A system can act as both GCSS and GDSS.

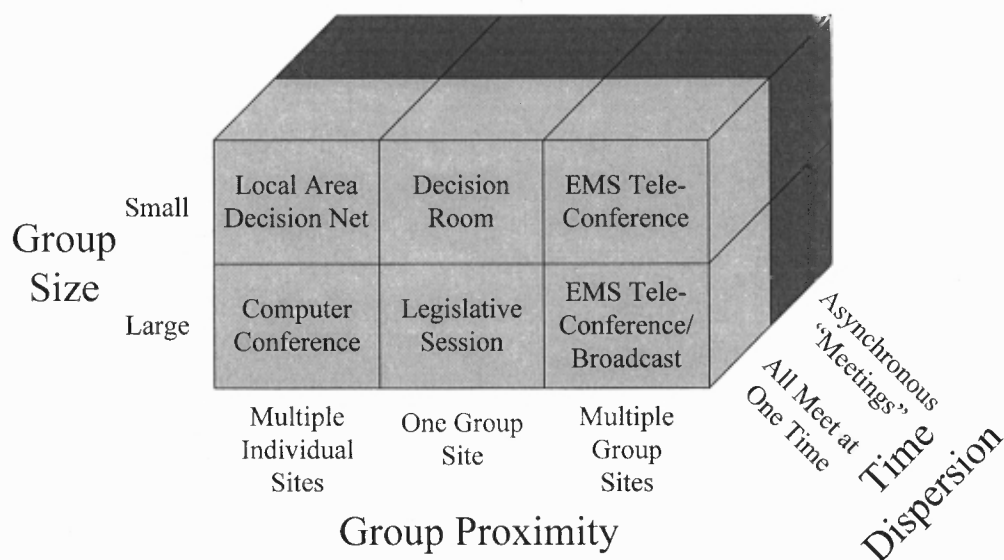
### **3.2.4 Synchronous GSS and Asynchronous GSS**

Most studies on GSS have been focused on groups using the system at the same time (synchronous GSS) (Turoff, Hiltz, Bahgat, & Rana, 1993). However, an asynchronous GSS has the advantage of allowing members to work on a problem independently at the

times they prefer. Nonetheless, coordinating the process of an asynchronous group is more difficult than coordinating the process of a synchronous group (Dufner, Hiltz, Johnson, & Czech, 1995; Kraemer & King, 1988). The asynchronous GSS will need to provide support to integrate members' efforts. However, due to the difficulty of coordinating all members to work together at the same time, asynchronous GSS has gained attention in GSS research.

### 3.3 Theoretical Frameworks for GSS

#### 3.3.1 Taxonomy of GSS

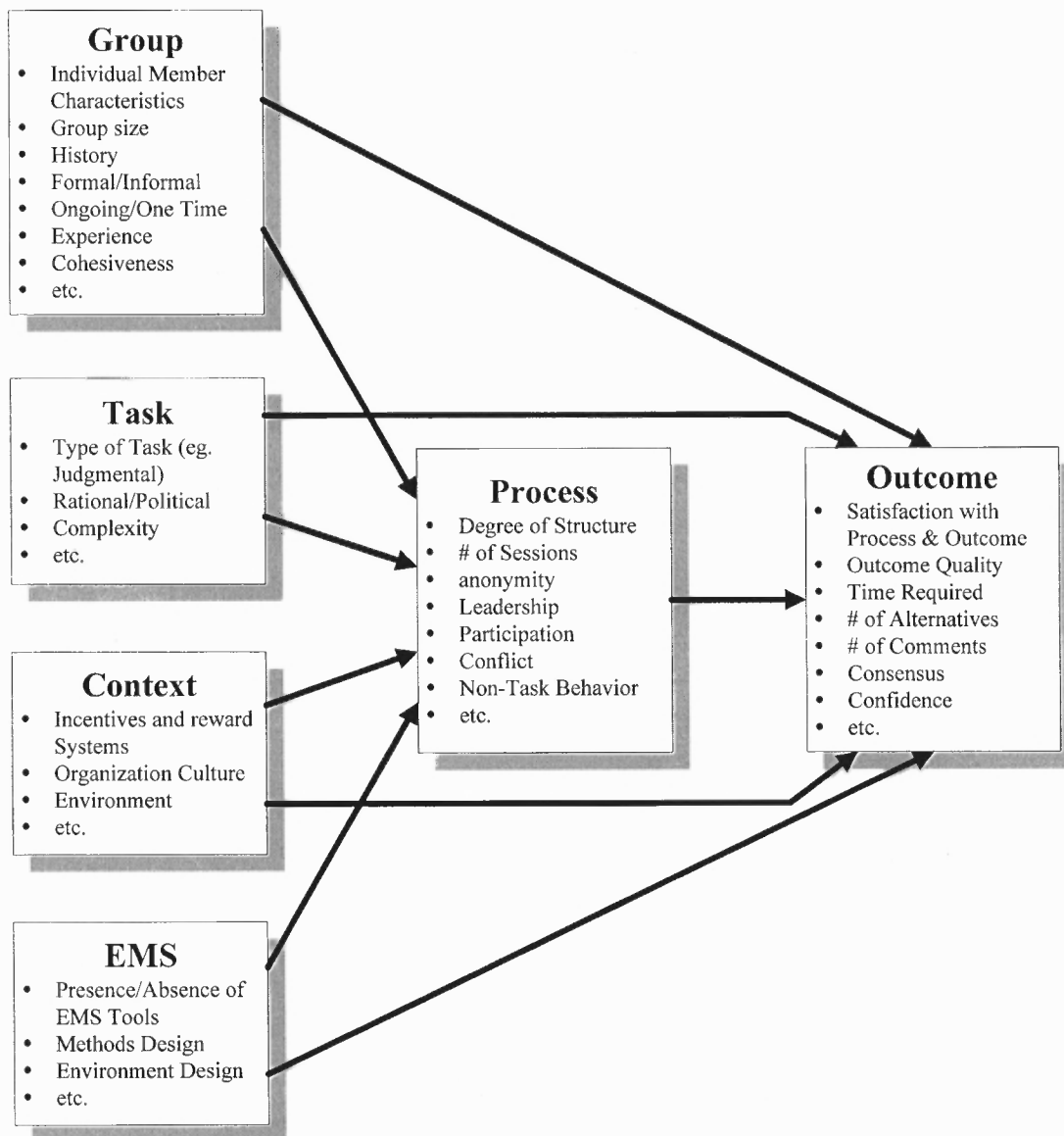


**Figure 3.1** Taxonomy of GSS.  
(Adapted from Dennis et al., 1988, p. 609)

DeSanctis & Gallupe (1987) suggest a framework of three dimensions, i.e., group size, task type, and member proximity, for studying GSS. They also propose that the effect of a GSS is contingent, as the support in a GSS needs to be appropriate for the group size, the task type, and communication mode, if it is to be beneficial. Johansen (1988) offers a taxonomy of GSS based on time and space. The model has been integrated into a three-

dimensional taxonomy of group size, group proximity, and time dispersion (Dennis et al., 1988) (Figure 3.1).

### 3.3.2 EMS Research Model by Dennis et al.



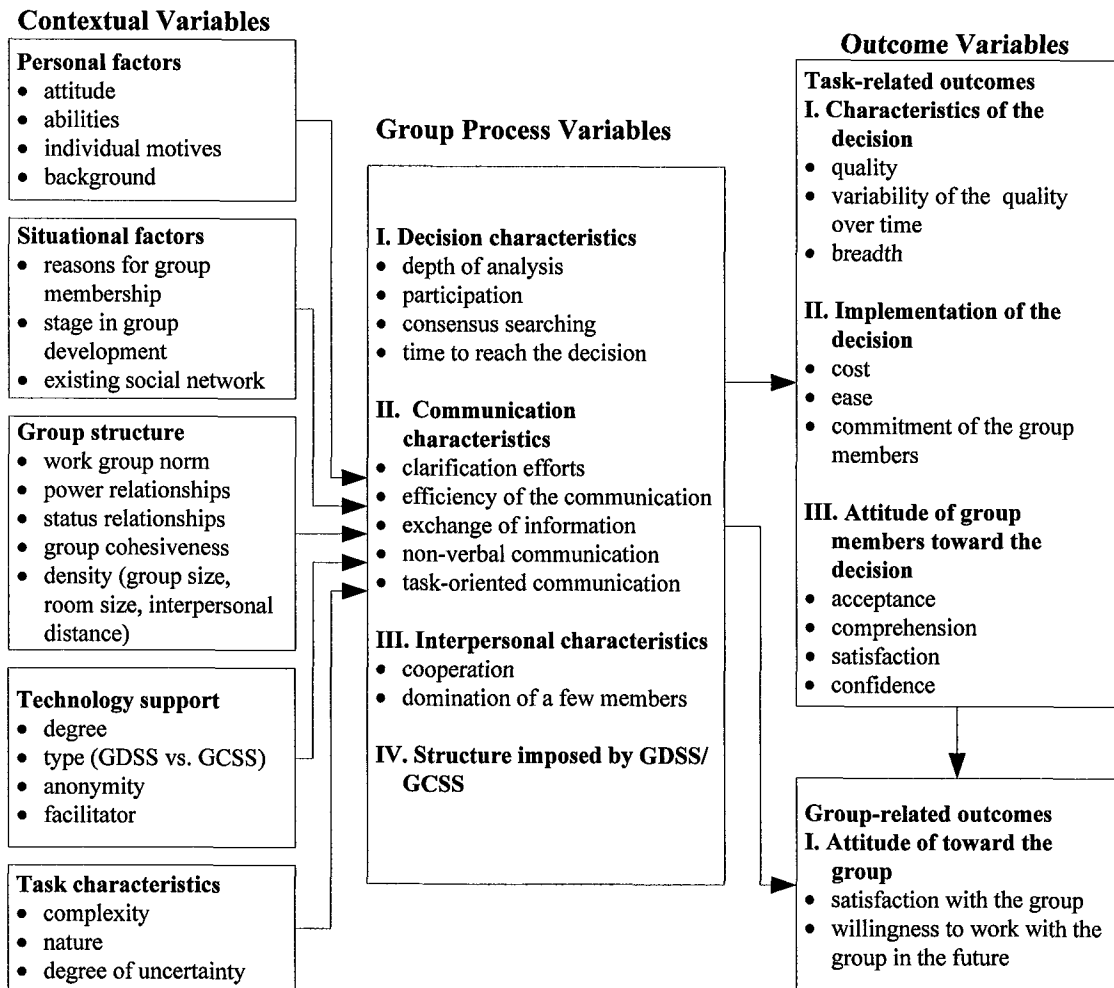
**Figure 3.2** EMS research model by Dennis et al.  
(Adapted from Dennis et al., 1988, p. 595)

Researchers in GSS usually take the system approach of input-process-output in studying GSS (Dennis et al., 1988; Fjermestad & Hiltz, 1999; Gray, Vogel, & Beauclair, 1990;



McGrath & Hollingshead, 1994; McLeod, 1992; Nunamaker et al., 1991; Zigurs & Buckland, 1998). Dennis et al. (1988) has proposed a research model to study the effect of EMS (Figure 3.2) by integrating many previous models (Gallupe et al., 1988; Watson, DeSanctis, & Poole, 1988). There are six sets of variables in this model: group, task, context, EMS, process, and outcome.

### 3.3.3 GDSS and GCSG framework by Pinsonneault and Kraemer

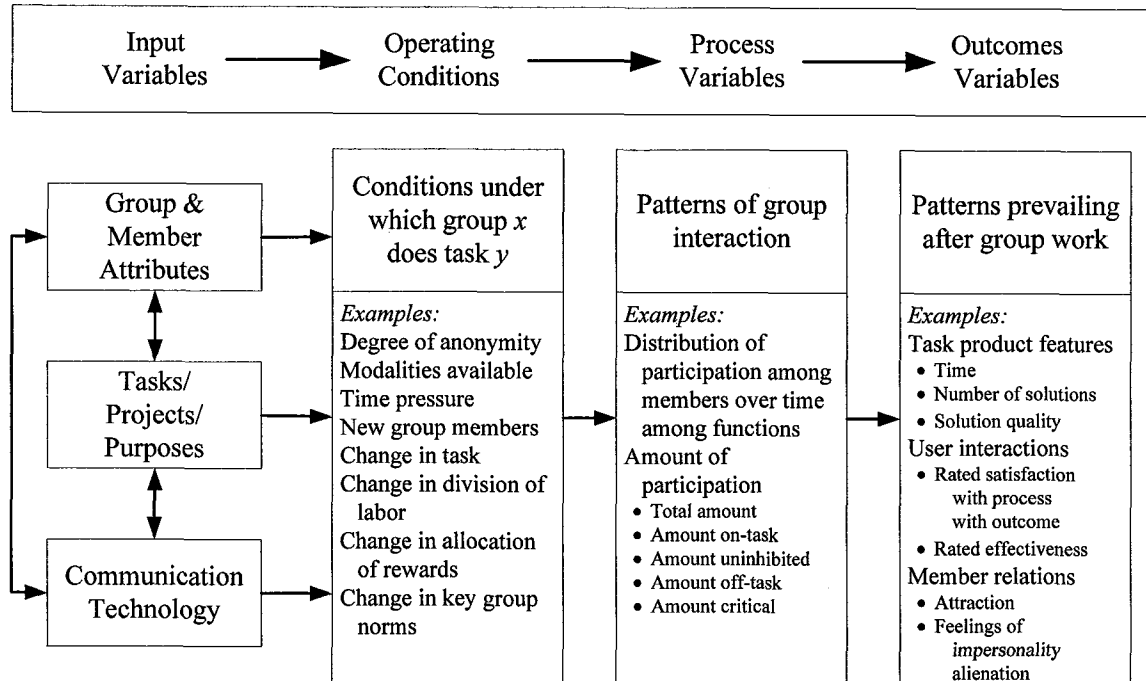


**Figure 3.3** GDSS and GCSG framework by Pinsonneault and Kraemer. (Adapted from Pinsonneault & Kraemer, 1990, p. 146)

Pinsonneault and Kraemer (1990) have proposed a framework of contextual variables, group process variables, and outcomes variables in their review of GDSS and GCSG

research (Figure 3.3). The contextual variables in their framework are further divided into personal factors, situational factors, group structure, technology support, and task characteristics. The outcomes variables are broken into task-related outcomes and group-related outcomes.

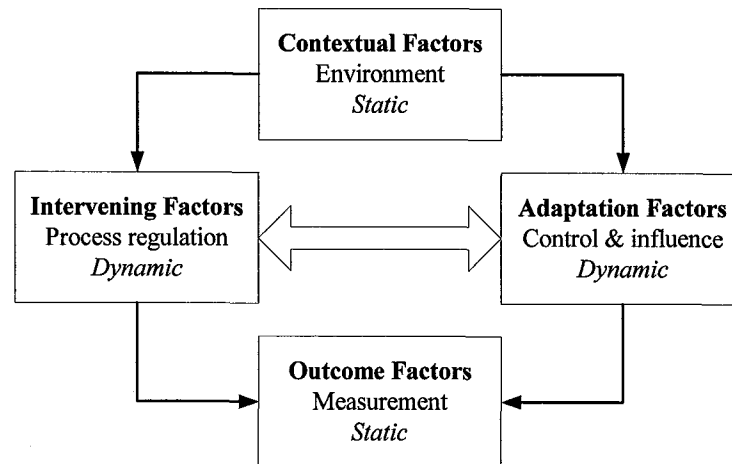
### 3.3.4 GSS Framework by Hollingshead & McGrath



**Figure 3.4** GSS framework by Hollingshead & McGrath.  
(Adapted from Hollingshead & McGrath, 1995, p. 56)

Hollingshead & McGrath (1995) have developed a four-stage model of input variables, operational conditions, process variables, and outcomes variables based on the Time, Interaction, and Performance (TIP) theory (McGrath, 1991) in their review of empirical research on computer-assisted groups (Figure 3.4). The input variables consist of three sub-groups: group & member attributes, tasks/projects/purposes, and communication technology.

### 3.3.5 GSS Framework by Fjermestad & Hiltz



**Figure 3.5** GSS framework by Fjermestad & Hiltz.

(Adapted from Fjermestad & Hiltz, 1997)

Fjermestad & Hiltz (1999) have conducted the most comprehensive review of GSS experiments to date. Their framework for analyzing GSS includes four major categories or factors: contexture factors, intervening factors, adaptation factors, and outcome factors (Figures 3.5 and 3.6) (Fjermestad & Hiltz, 1997). Contexture factors are independent variables in a GSS experiment. They comprise the environment or conditions of the group for the task. The contexture factors include technology (tool support, process support, communication mode, et al.), group (group size, composition, leadership, member ability, values, et al.), task (task type, structure, et al.), and context (environment, culture, et al.). Intervening factors are moderating or mediating variables. They represent the structure of the group interaction resulting from or adding to the circumstance created by contexture factors. Experiment methods (design, session length, et al.) and summary variables (communication bandwidth, performance strategies, change in task or rewards, et al.) are examples of intervening factors. Adaptation factors are control variables at either individual or group level that can be either input, intermediate

outcome, or outcome variables. Examples of adaptation factors are variables of group adaptation process (general spirit, level of effort, et al.), process gains/losses (synergy, information overload, et al.), and intermediate role outcomes (role assumption by technology, actual roles of participants, et al.). Outcome factors are the results of the interaction of three factors. They can be efficiency measures (time to decision, time to consensus, et al.), effectiveness measures (decision quality, decision confidence, depth of analysis, et al.), satisfaction measures (cohesiveness, decision satisfaction, process satisfaction, et al.), consensus, and usability measures (learning time, number of errors, et al.).

INPUT	PROCESS		OUTPUT
CONTEXTUAL FACTORS	INTERVENING FACTORS	ADAPTATION FACTORS	OUTCOME FACTORS
<p><b>1. TECHNOLOGY:</b></p> <ul style="list-style-type: none"> <li>• Task support (Tools): Agenda, electronic brain storming, voting, cognitive feedback, etc.</li> <li>• Process Structures: Anonymity, time, proximity, settings, procedures, control &amp; structure; e.g. sequential Vs parallel process; levels 1, 2, and or 3, structural features--restrictiveness, comprehensiveness, agenda setting NGT, DI, DA, facilitator, chauffeur, moderator.</li> <li>• Communications Mode: FIF. CMC. GSS. DSS, text, graphics, voice, image, sound, and video.</li> <li>• Design: Room configuration, interface, embeddability, extensibility, flexibility, functionality &amp; usability.</li> </ul> <p><b>2. GROUP:</b></p> <ul style="list-style-type: none"> <li>• Group characteristics: Size and salience, ad-hoc, established.</li> <li>• Composition: Heterogeneity, organizational &amp; job tenure, shared norms, member status, history &amp; experience, subject type (student, MBA, professional, etc.).</li> <li>• Leadership: Formal leadership, style, attitude, skills, power, and organizational position</li> <li>• Member characteristics: Attitudes, values, power, personal beliefs, age, sex, preferences, self confidence. Skills, demographics, personality traits, initial quality, &amp; experience (systems &amp; tasks).</li> <li>• Meeting structure: Clarity of objective, specific work norms.</li> <li>• Initial levels: Cohesiveness, task understanding, consensus, and agreement</li> <li>• Group Structures: Styles of interacting, knowledge &amp; experience with structures, perceptions of others knowledge.</li> </ul> <p><b>3. TASK:</b></p> <ul style="list-style-type: none"> <li>• Type: Generate, choose, negotiate, and execute; gain/ loss.</li> <li>• Characteristics: <ul style="list-style-type: none"> <li>• Structure: Structured to unstructured</li> <li>• Equivocality: High to low</li> <li>• Analyzability: High to low</li> <li>• Complexity: High to low</li> <li>• Importance: High to low</li> <li>• Enjoy ability: High to low</li> <li>• Predictability: High to low</li> </ul> </li> <li>• Source: Internal to external</li> <li>• Degree of task knowledge</li> <li>• Degree of agreement on values</li> </ul> <p><b>4. CONTEXT:</b></p> <ul style="list-style-type: none"> <li>• Environment: Competition, uncertainty, time pressure, evaluative tone.</li> <li>• Organizational: Information system, age, goals, reward structure, organizational size, etc.</li> <li>• Cultural: American, British, Chinese, Hawaiian, Singaporean, etc.</li> </ul>	<p><b>1. METHODS:</b></p> <ul style="list-style-type: none"> <li>• Experimental design</li> <li>• Task implementation</li> <li>• Session length</li> <li>• Number of sessions</li> <li>• Order (order of treatment or task)</li> <li>• Training: technology, group process and task</li> <li>• Rewards for participants</li> </ul> <p><b>2. SUMMARY VARIABLES RESULTANT COMMUNICATION DIMENSIONS:</b></p> <ul style="list-style-type: none"> <li>• Bandwidth</li> <li>• Media richness</li> <li>• Social presence</li> </ul> <p><b>GROUP MEMBER PERCEPTION &amp; PROBLEM SOLVING:</b></p> <ul style="list-style-type: none"> <li>• Nature and utilization of task performance strategies</li> <li>• Level and utilization of member knowledge &amp; skill</li> <li>• Level &amp; coordination of member effort</li> <li>• Task: importance, visibility, understanding, &amp; commitment</li> <li>• Individual: values, personal needs, level of interest, and degree of frustration</li> <li>• Psychological differences</li> <li>• Biases</li> </ul> <p><b>ORGANIZING CONCEPTS:</b></p> <ul style="list-style-type: none"> <li>• Information processing systems</li> <li>• Consensus generating systems</li> <li>• Behavior motivation &amp; regulation</li> </ul> <p><b>OPERATING CONDITIONS</b></p> <ul style="list-style-type: none"> <li>• Modalities available</li> <li>• Changes in task, rewards, norms &amp; division of labor</li> </ul>	<p><b>1. GROUP. ADAPTATION PROCESS:</b></p> <ul style="list-style-type: none"> <li>• Structuration</li> <li>• Social technology</li> <li>• Structural features</li> <li>• General spirit</li> <li>• Faithful/Ironic</li> <li>• Rules, resources- use, attitude, control, and consensus</li> <li>• Comfort, respect</li> </ul> <p>Process Variables</p> <ul style="list-style-type: none"> <li>• Participation</li> <li>• Consensus generating</li> <li>• Normative regulation</li> <li>• Effectiveness, Influence</li> <li>• Level of effort</li> </ul> <p>Process Issues</p> <ul style="list-style-type: none"> <li>• Diffusion of responsibility</li> <li>• Deindividuation</li> <li>• Pressure to consensus</li> <li>• Coordination</li> </ul> <p><b>2. PROCESS GAINS/LOSSES:</b></p> <p>Process Gains</p> <ul style="list-style-type: none"> <li>• Synergy, learning memory</li> <li>• Clarity, Choice shift</li> </ul> <p>Process Losses</p> <ul style="list-style-type: none"> <li>• Free riding</li> <li>• Evaluation apprehension</li> <li>• Attenuation blocking</li> <li>• Information overload</li> <li>• Flaming</li> <li>• Dominance</li> </ul> <p><b>3. INTERMEDIATE ROLE OUTCOMES</b></p> <ul style="list-style-type: none"> <li>• Role assumption by technology</li> <li>• Actual roles of participants</li> <li>• Task-related &amp; group-building: recorder, gatekeeper, follower, information/opinion seeker, information/opinion giver, proceduralist, motivator, explainer, evaluator</li> <li>• Values</li> </ul>	<p><b>1.EFFICIENCY MEASURES:</b></p> <ul style="list-style-type: none"> <li>• Decision time</li> <li>• Number of decision cycles</li> <li>• Time spent in activities</li> <li>• Time spent waiting for responses</li> <li>• Time to consensus</li> </ul> <p><b>2. EFFECTIVENESS MEASURES:</b></p> <ul style="list-style-type: none"> <li>• Communication</li> <li>• Number of comments</li> <li>• Idea Quality</li> <li>• Decision quality</li> <li>• Decision confidence</li> <li>• Process quality</li> <li>• Creativity/Innovation</li> <li>• Level of understanding</li> <li>• Task Focus</li> <li>• Depth of Evaluation</li> <li>• Commitment to results</li> </ul> <p><b>3. SATISFACTION MEASURES:</b></p> <ul style="list-style-type: none"> <li>• Cohesiveness</li> <li>• Conflict management</li> <li>• Influence</li> <li>• Confidence Attitude</li> <li>• General satisfaction</li> <li>• Decision Satisfaction</li> </ul> <p><b>4. CONSENSUS:</b></p> <ul style="list-style-type: none"> <li>• Decision agreement</li> <li>• Commitment</li> </ul> <p><b>5. USABILITY MEASURES:</b></p> <ul style="list-style-type: none"> <li>• Learning time</li> <li>• Willingness to work together again</li> <li>• System utilization</li> <li>• Number of errors</li> <li>• Design Preference</li> </ul>

**Figure 3.6** Factors in the GSS framework by Fjermestad & Hiltz. (Adapted from Fjermestad & Hiltz, 1997)

### 3.4 GSS Effects

Considerable GSS research has been conducted or reviewed based on these frameworks. Results of using GSS were mixed. The next chapter will discuss factors and their effects by looking into theories and experiment findings.

## **CHAPTER 4**

### **FACTORS AND THEIR EFFECTS IN GSS**

This chapter presents a brief discussion of factors considered in GSS research. Results from past research on GSS effects on a particular factor are usually mixed (Fjermestad & Hiltz, 1999; Hollingshead & McGrath, 1995; Kline & McGrath, 1999; Kraemer & Pinsonneault, 1990). Meta-analyses on GSS studies in the early 1990s have identified some moderators, such as group size, group history, and type of GSS (Benbasat & Lim, 1993; McLeod, 1992). However, there was no theory to explain the moderating effects. Two major schools of thought, the decision theorist school and the institutionalist school, have offered explanations of the mixed effects of GSS use (Dennis, Wixom, & Vangerberg, 2001). The decision theorist school holds a contingency view that GSS effectiveness is determined by fit among factors, for example, media characteristics and task fit (Daft & Lengel, 1984; Dennis & Valacich, 1999) and technology and task fit (Rana, Turoff, & Hiltz, 1997; Zigurs & Buckland, 1998). The institutionalist school argues that the group may or may not adapt the social structure prompted by the technology. This is illustrated as “faithful” or “unfaithful” appropriations in the adaptive structuration theory (DeSanctis & Poole, 1994). The group processes and outcomes will vary as determined by how the group adopted GSS.

#### **4.1 Individual Level Factors**

Factors related to individuals, such as ability, attitude, value, experience, cognitive style, and oral or written communication skill, may play an important role in the use of GSS

(Dennis, George, Jessup, Nunamaker, & Vogel, 1988). For example, in a study about the relative advantage of using GSS, researchers have found that about 40% of the variance can be explained by certain individual characteristics (Karahanna, Ahuja, Srite, & Galvin, 2002). However, there has been little research on the role of individual attributes. One reason could be that there are simply too many dimensions of individual attributes, so it is difficult to form enough groups into different combinations in a GSS experiment (Massey, Clapper, & Blue, 1997). This may also reflect the fact that a real operational organization will find it difficult to form groups with a particular combination of individual attributes.

Experience with the task and the GSS plays an important role in task performance. One major problem with GSS research is the use of undergraduate students as subjects. Remus (1989) has reported that undergraduate students make poorer decisions than part-time MBA students. Thus, the result of GSS studies with undergraduate students as subjects will have validity problems when the results are extrapolated to professionals. Unfortunately, many GSS studies use undergraduate students as subjects because they are readily available in academic settings.

## **4.2 Group Level Factors**

### **4.2.1 Group Size**

It is widely believed that a numerically larger group should be able to outperform a smaller group in idea generation because of the positive process gains such as synergy, mutual stimulation, and learning. However, empirical studies have challenged this belief by showing that groups using verbal communication become worse in idea generation when their size becomes larger (McGrath, 1984; Steiner, 1972).

Diehl and Stroebe (1987) suggest that production blocking is the reason why a group performs no better than pooling all the individuals in the group. Group members have to take turns in verbal communication and the process becomes more dysfunctional as the group size increases. These process losses are listed in Nunamaker and coworkers' framework as air time fragmentation, attenuation blocking, concentration blocking, and attention blocking (Nunamaker, Dennis, Valacich, Vogel, & George, 1991). GSS technology can be used to remove these blocking barriers, thus a computer-assisted group should be able to generate ideas as well or better than the same number of individuals. Dennis, Valacich, and Nunamaker (1990) compare small (size 3), medium (size 9), and large (size 18) groups using GSS for idea generation. The result shows that the larger the group is, the better the performance and satisfaction of the group with GSS support.

The majority of GSS studies use group size of 5 or less members and seldom goes above 10 (Fjermestad & Hiltz, 1999). This is small compared to the real-world environment, where a group is usually composed of more than a dozen members. This is a gap between lab experiments and real world applications that needs to be filled in GSS research.

#### **4.2.2 Stage of Group Development**

Pinsonneault and Kraemer (1990) suggest that the stage of group is a very important factor in GSS effectiveness. The stage of a group reflects the familiarity among group members. The members of an emerging group know little about each other, while people in a mature group know each other well. When a group becomes mature, norms and procedures are established for the group to carry out its functions. Coordination overhead and group process losses are smaller in a mature group. The benefits of a GSS might not



be so strong in mature groups, compared to an emerging group. On the other hand, a mature group may have learned and adopted the GSS into its norms and procedures, and thus can take full advantage of GSS and outperform an emerging group.

A study of audio conferencing of established groups by Harmon, Schneer, and Hoffman (1995) shows that there is little or no change in performance and group structure between audio conferencing and face-to-face meeting. They suggest that the structure of an established group is mostly unaffected by the demands of new situations. However, a GSS may provide more technology support than audio conferencing does, and more studies are needed to clarify the effect of the stage of group on GSS use. However, the stage of group has not been taken into account in most GSS studies, because most GSS studies use students as subjects and conduct experiments in a limited timeframe.

#### **4.2.3 Group Composition**

A group can be heterogeneous in many aspects: gender, member ability, member attitude, culture, or domain of knowledge. One study by Valacich and his colleagues compared groups on idea generation with members holding homogeneous knowledge to groups with members holding heterogeneous knowledge. The results suggested that greater performance gains were achieved by heterogeneous groups (Valacich, Mennecke, Wachter, & Wheeler, 1993). Since larger groups are inherently more heterogeneous, the authors hypothesize that larger groups will perform better than smaller groups on idea generation. A later study confirmed this hypothesis.

There are GSS studies on culturally heterogeneous and homogeneous groups (Anderson & Hiltz, 2001; Chidambaram & Judith, 1993; Daily, Whatley, Ash, & Steiner,

1996). Although there are some conflicting findings that may be due to the task types used in these experiments, it has been shown that culturally heterogeneous groups can use GSS at least as effectively as culturally homogeneous groups. This is important in today's environment as many organizations operate around the globe and have people from different cultures working as a group.

On the other hand, diversity in groups may also lead to process loss (Steiner, 1972). Members with diverse values will need more effort to establish common procedures and coordinate their activities. A GSS with formal processes and procedure might be able to reduce this kind of process loss (Nunamaker et al., 1991).

### **4.3 Leadership**

Leadership is crucial in group processes. Leaders can set goals, motivate members, and shape group processes. Fjermestad and Hiltz (1999) were surprised to see that 188 of the 200 (94%) studies they reviewed did not have leaders. They considered this finding shocking because most real working groups have leaders. The small number of GSS studies with leaders makes it difficult to make any significant conclusion about leadership in GSS.

### **4.4 Reward Structure**

Rewards can be given equally to the entire group (equality norm) or to individuals based on contributions (performance or equity norm) (Gavish, J. H. Gerdes, & Kalvenes, 2000). The performance norm rewards individuals based on the proportion of contributions to the result. It will motivate members to work harder because members cannot free ride on

others' efforts. But this approach increases intra-group competitions. By contrast, the equality norm rewards the whole group equally based on the overall outcome. This approach can improve group cohesiveness, but individuals might contribute less because there is less incentive for an individual to put in more effort. The two reward methods usually are mixed together in many organizations (Nelson, 1994). Table 4.1 is a summary of the features of reward methods by Gavish, Gerdes, and Kalvenes (2000).

**Table 4.1 Summary of the Rewarding Methods**

<b>Feature</b>	<b>Performance Norm</b>	<b>Equality Norm</b>
<b>Basis of Reward</b>	Individual performance	Group performance
<b>Individual Effort</b>	Increased relative to equality-based rewards	decreased relative to performance-based rewards
<b>Emphasize Individual Differences</b>	Yes (quality of contributions)	No (focus on final result)
<b>Consequences</b>	High individual efficiency and group competition	Intra-group harmony and group solidarity
<b>Common Applications</b>	Economic, scientific, and technical	Mutual support, close relationships

(Adapted from Gavish et al., 2000, p. 394.)

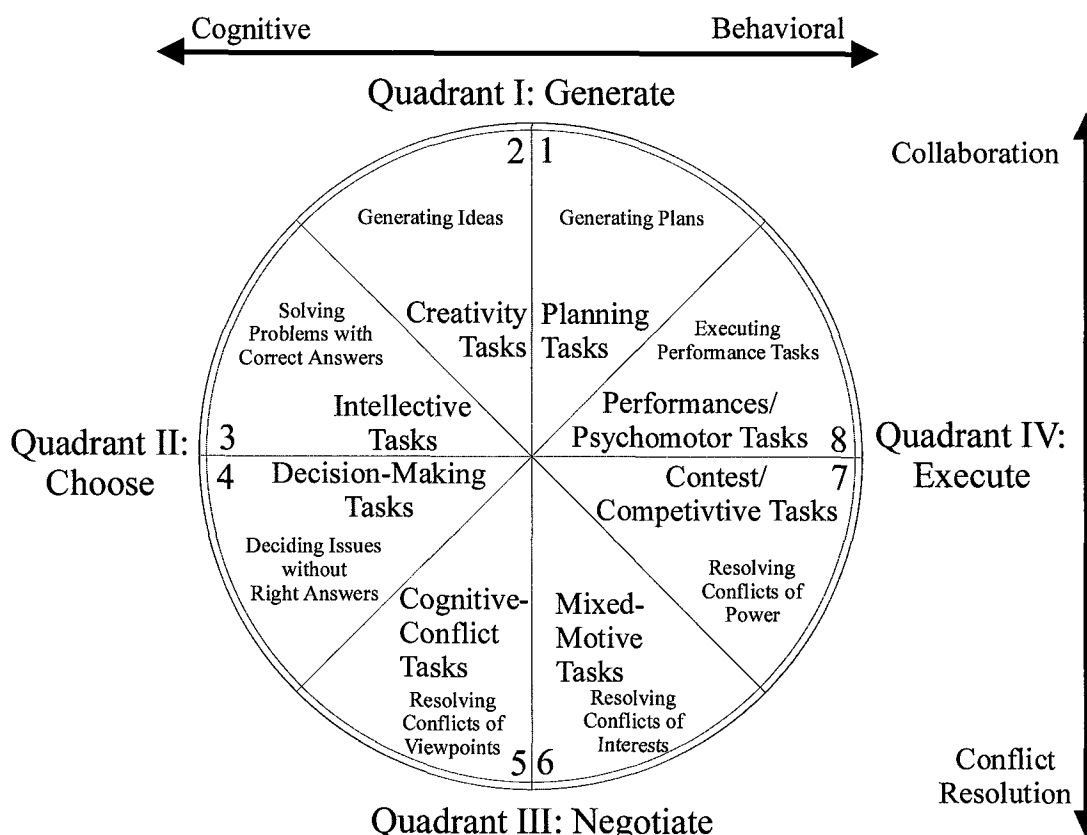
Reward structure has so far not received much emphasis in GSS research. Since reward structure is important in motivating group members toward quality of work and/or cooperation (Dennis, Nunamaker, & Vogel, 1990), this might be one source of the inconsistency in the GSS findings.

## 4.5 Task

### 4.5.1 Task Type

It is evident that different kinds of tasks should have different processes and technology support. For example, idea generation is a divergent process in which members are encouraged to go in different directions while selection is a convergent task in which members need to narrow down to few alternatives for agreement. Procedures and tools that are useful in divergent tasks are not suitable in convergent tasks.

Task classification is an important and fundamental step in GSS design. Task type alone might explain 50 percent of the variance in group performance (Poole, Seibold, & McPhee, 1985). Several task classification schemes have been proposed by researchers (Hackman, 1968; Hackman & Morris, 1978; Laughlin, 1980). Figure 4.1 shows the *task circumplex* of task classification developed by McGrath (1984). This task classification framework divides tasks by two axes, behavior/cognitive and collaboration/resolution, into eight subtypes. The framework has been partially validated by empirical experiments (Straus, 1999). According to Fjermestad and Hiltz (1999), 52% of GSS studies reviewed used type 4 tasks (preference or decision-making tasks). Type 2 tasks (idea generation or creativity tasks) accounted for 39.5% of the GSS studies, and type 3 tasks (intellective tasks) were used 31% of the time. There is very little GSS research with tasks in the execution quadrant.



**Figure 4.1 Task circumplex.**  
(Adapted from McGrath, 1984)

Several frameworks have been proposed to match task type with technology support (Goodhue & Thompson, 1995; Rana et al., 1997; Zigurs & Buckland, 1998). One theory is the Task-Technology Fit Theory (TTFT) (Zigurs & Buckland, 1998). It contends that information processing support features, such as voting and modeling, should match the task. For example, information processing support has little value for simple divergent tasks such as idea generation because the outputs from individuals are added to the group output, and members are supposed to diverge. On the other hand, it is important to have information processing support in the choice phase because members need to develop a shared understanding to reach a decision. However, task-technology fit alone may not be sufficient to improve GSS performance. In the Fit-Appropriation

Model (FAM) (Dennis et al., 2001), task-technology fit is moderated by appropriation, that is, how groups adopt a GSS affect performance. The fit between task and technology is a necessary but not sufficient condition for performance gains. FAM has been partially verified by meta-analysis.

Another way of classifying tasks in GSS experiments is whether the task is real or artificial. Briggs and his colleagues argue that outcome satisfaction is related to the degree of accommodation of individuals' vested interests (Briggs & de Vreede, 1997). In this regard, real tasks performed by real working groups may provide the most realistic results for GSS research. However, it is difficult to conduct controlled experiments in this manner. On the other hand, artificial tasks are easy to control in experimental settings. Reusing a task that has been studied before will also provide another advantage of being able to compare results among different experiments. Nevertheless, overuse of a task may limit the generalization of findings from experiments because of little variation in task implementation (Fjermestad & Hiltz, 1999).

#### **4.5.2 Task Complexity**

Studies investigating task complexity have found that as task complexity increases, the decision quality and depth of analysis also increases in groups using GSS (Gallupe, DeSanctis, & Dickson, 1988). This suggests that complex tasks and larger groups will benefit more from GSS. Yet the GSS experiments conducted to date have mostly used small groups with simple tasks due to the limited time allowed in GSS experiments (Fjermestad & Hiltz, 1999). Research is needed to clarify the magnitude of benefit of GSS for complex tasks.

## 4.6 Technology Support

### 4.6.1 Parallel Input

A major problem with face-to-face groups is that members have to take turns to express their thoughts. The need to wait to speak leads to production blocking and poor performance (Diehl & Stroebe, 1987). GSS can alleviate this problem by providing parallel inputs for members. Members can input information simultaneously. There is no need to wait for another member to finish before one can contribute (Nunamaker et al., 1991). But parallelism can also lead to information overload, that is, an individual is presented with information which exceeds his or her cognitive capacity (Dennis, 1996; Hiltz & Turoff, 1985). GSS with information processing support may be able to alleviate the overload (Grise & Gallupe, 2000; Losee, 1989).

### 4.6.2 Anonymity

Although not every GSS supports anonymity, it has become a very popular feature in GSS. Many GSS studies have focused on anonymity because it is a feature that can be easily implemented in GSS but it is hard to do in face-to-face situations. There can be different types of anonymity. The membership of the group can be known or unknown to members. Members can be in a GSS without any identity associated with them or can be identified with pen names or aliases (Valacich, Dennis, & Nunamaker, 1992). The last approach may enable group members to build their credentials based on their contributions while remaining unidentified. When ideas are submitted anonymously, individuals do not feel it is a personal attack if some one else criticizes their ideas. Anonymity enables people who fear to express their ideas to speak even if the idea is unpopular. People can also change their positions without the fear that they appear as

inconsistent or indecisive. Anonymity can lead to a more critical analysis of issues and a freer interchange of opinions (L. M. Jessup, Connolly, & Galegher, 1990; L.M. Jessup, Connolly, & Tansik, 1990; L. M. Jessup & Tansik, 1991; Nunamaker, 1997; Valacich et al., 1992). Since each comment would be regarded the same in a GSS with anonymity support, it is impossible to tell who submitted the comment. Powerful individuals can not dominate the discussion by showing their identities (Nunamaker, Briggs, & Mittleman, 1994). Thus, equal participation of members would be promoted in GSS settings with anonymity.

However, there are problems associated with anonymity. One problem is flaming, that is, uninhibited behaviors such as name calling, swearing, insults, impolite statements, threats and put-downs, crude flirtations of a demeaning or sexually explicit nature, and attacks on groups or individuals (Walther, Anderson, and Park, 1994). Although flaming can mean informality and humor as opposed to reduced sociability in a group (Weedman, 1991), it often creates a negative atmosphere and reduces task-related communications (Connolly, Jessup, & Valacich, 1990; Jessup & George, 1997). Flaming exists even when people post comments with their identities (Lea, O'Shea, Fung, & Spears, 1992; Sproull & Kiesler, 1986). The situation could become worse when people feel they can get away with what they have said because of anonymity (Jessup & George, 1997).

There is yet another problem: how to identify an individual who should be rewarded or punished in a group with anonymous GSS. Diffusion of responsibility will become more serious in anonymous groups because members will feel they are safe from punishment from their actions. Since it is hard to identify the individual who should be rewarded, the reward is generally given to the entire group (equality-based norm) rather



than based on an individual's contribution (performance-based norm). High-ability individuals might feel that they do not receive sufficient reward (financial gains and/or recognition) for their efforts and that others are free riding on their hard work. They might, therefore, reduce their efforts while using anonymous GSS ("sucker effect", as mentioned by Matsui, Kakuyama, & Onglatco (1987)). This is a major dilemma for anonymous GSS. Gavish and his colleagues (2000) have proposed a method of secretly rewarding individuals based on their performances in anonymous GSS. Their reward distribution method, based on public key encryption that even the rewarding agent cannot know the identity of the recipient, make it possible to distribute individualized reward to an anonymous member while guaranteeing that only the contributor can claim his or her reward and protect the identity of the anonymous contributor. Unfortunately, their method cannot be fully implemented in places where tax law requires disclosure of the recipient identity to a tax collecting agency.

#### **4.6.3 Communication Media**

There are theories, such as Media Richness Theory (Daft & Lengel, 1984) and Media Synchronicity Theory (Dennis & Valacich, 1999; Dennis, Valacich, Speier, & Morris, 1998), on matching the characteristics of the communication media and group tasks. Media Richness Theory argues that the richness of communication media should fit the characteristics of the task. Richer media enable group members to transmit information in various styles, to use multiple cues, to personalize messages, and to receive rapid feedback. The richer media, such as face-to-face meetings, are better for tasks that are equivocal, that is, for which there exist multiple interpretations of available information. On the other hand, leaner media, such as computer mediated communication, are suited

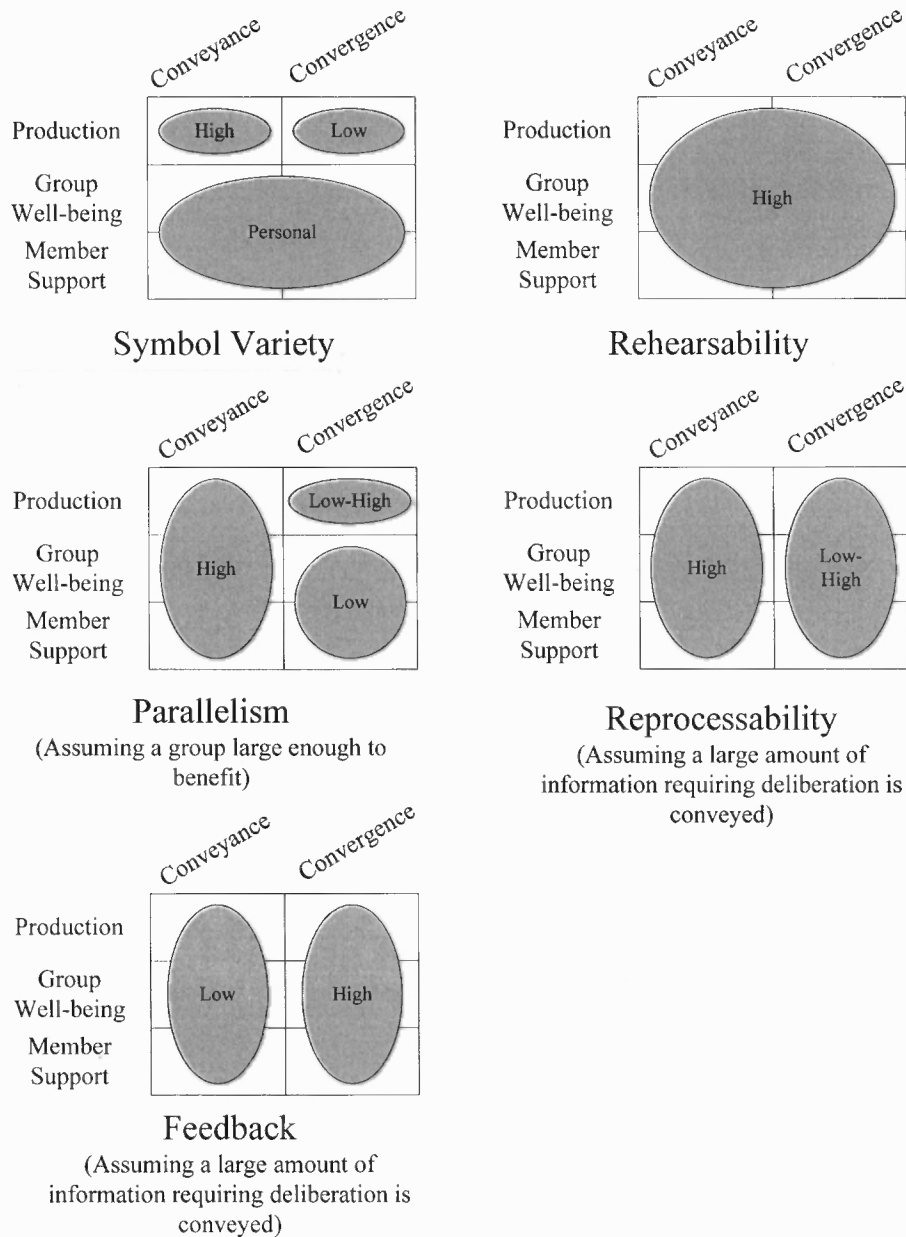
for tasks with uncertainty, that is, where there is a framework to interpret information but little information is available.

Dennis and Valacich (1999) pointed out that data from empirical studies does not fully support media richness theory. They proposed a Media Synchronicity Theory which classifies media in five dimensions: immediacy of feedback, symbol variety, parallelism, rehearsability, and reprocessability (Table 4.2). The capabilities of media should support the conveyance and convergence communication processes across the production, group well-being, and member support group functions. They also suggest desired media characteristics of the five capabilities for the communication processes (Figure 4.2).

**Table 4.2 Dimensions in Media Synchronicity Theory**

<b>Immediacy of feedback</b>	The extent to which a medium enables users to give rapid feedback on the communications they receive.
<b>Symbol variety</b>	The number of ways in which information can be communicated.
<b>Parallelism</b>	The number of simultaneous conversations that can exist effectively.
<b>Rehearsability</b>	The extent to which the media enables the sender to rehearse or fine tune the message before sending.
<b>Reprocessability</b>	The extent to which a message can be reexamined or processed again within the context of the communication event.

(Adapted from Dennis & Valacich, 1999)



**Figure 4.2 Desired media characteristics.**

(Adapted from Dennis & Valacich, 1999)

#### 4.6.4 Tools Supported

**4.6.4.1 Voting tools.** Although many researchers have suggested voting tools to be very important in GSS (Kraemer & King, 1988; Nunamaker et al., 1994), the use of voting tools has not been studied much in GSS research. The next chapter will be devoted to voting in GSS.

**4.6.4.2 Modeling tools.** Huber (1997) argues that information systems and decision aids should be designed as a cohesive whole because operations research methods can help make decisions more rational and effective. In the definition of GDSS by DeSanctis and Gallupe (1987), the Level 2 systems provide decision modeling techniques such as decision trees, risk analysis, and forecasting method to aid groups reduce the uncertainty in their decisions.

Modeling tools based on Multi-Criteria Decision Making (MCDM) and Game Theory are most often incorporated in GSS (Jarke, 1986). MCDM models would force members to consider criteria, and preferences more thoroughly, thus leading to better decision quality. However, there has been relatively little research about group problem modeling and group decision-aid (Choi, Suh, & Suh, 1994). Data from controlled experiments are scarce. For example, only 6 studies in the review by Fjermestad and Hiltz (1999) have used MCDM tools.

Most group problems are complex and unstructured. The Analytic Hierarchy Process (AHP) has been suggested as a group problem modeling tool (Choi et al., 1994). Nevertheless, AHP may require extra effort by group members and lead to lower outcome measurements if the group members are not familiar with this process. (Davey & Olson, 1998)

## **4.7 Formal Procedures**

Pinsonneault and Kraemer (1990) argued that formal decision procedures used in GDSS might be the most important factor for positive findings. This statement seems to be valid, since the some of the positive results are missing in those GCSG studies which do

not utilize formal decision procedures in their systems. But given the date of their review, the lack of positive results for GCSS might also be caused by limitations of computer and communication technology available at that time. Advances in technology that can enhance communications in GSS, such as multi-tasking operation environment, high speed network, and graphic user interface might help groups achieve positive results.

Formal procedures in GSS are an important factor because the interaction between formal procedures and technology support might enhance positive effects as GSS can provide better control and feedback. Dowling & St. Louis (2000) compare idea generation between a computer-assisted asynchronous Nominal Group Technique (NGT) setting and a non-computer-assisted synchronous nominal group technique setting. They found that the computer-assisted asynchronous NGT groups generated more and better ideas than non-computer-assisted synchronous NGT groups. They even made a bold suggestion that organizations waste resources by arranging face-to-face meetings when it is possible to conduct the same activities asynchronously in GSS with better outcomes.

#### **4.8 Process Factors: Group Process Gains and Losses**

Steiner (1972) suggests that group productivity is affected by process gains and process losses. Common process gains include more information, synergy, more objective evaluation, stimulation, and learning; process losses include time fragmentation, production blocking, conformance pressure, free riding, domination, socializing, and information overload (Diehl & Stroebe, 1987; Hiltz & Turoff, 1985; Nunamaker et al., 1991). Tables 4.3 and 4.4 list common process gains and losses and Figure 4.3 shows the

potential effects of GSS features on process gains and losses ((Nunamaker et al., 1991, p. 46 & p. 48).

**Table 4.3 Common Group Process Gains**

<b>Process Gains</b>	<b>More information</b>	A group has more information than any one individual member does.
	<b>Synergy</b>	A member can use information in a way that the original holder did not, because that member has different skills or information.
	<b>More Objective Evaluation</b>	Groups are better at catching errors than individuals.
	<b>Stimulation</b>	Working as a group may stimulate and encourage individuals to perform better.
	<b>Learning</b>	Members can learn from more capable members to improve their performance.

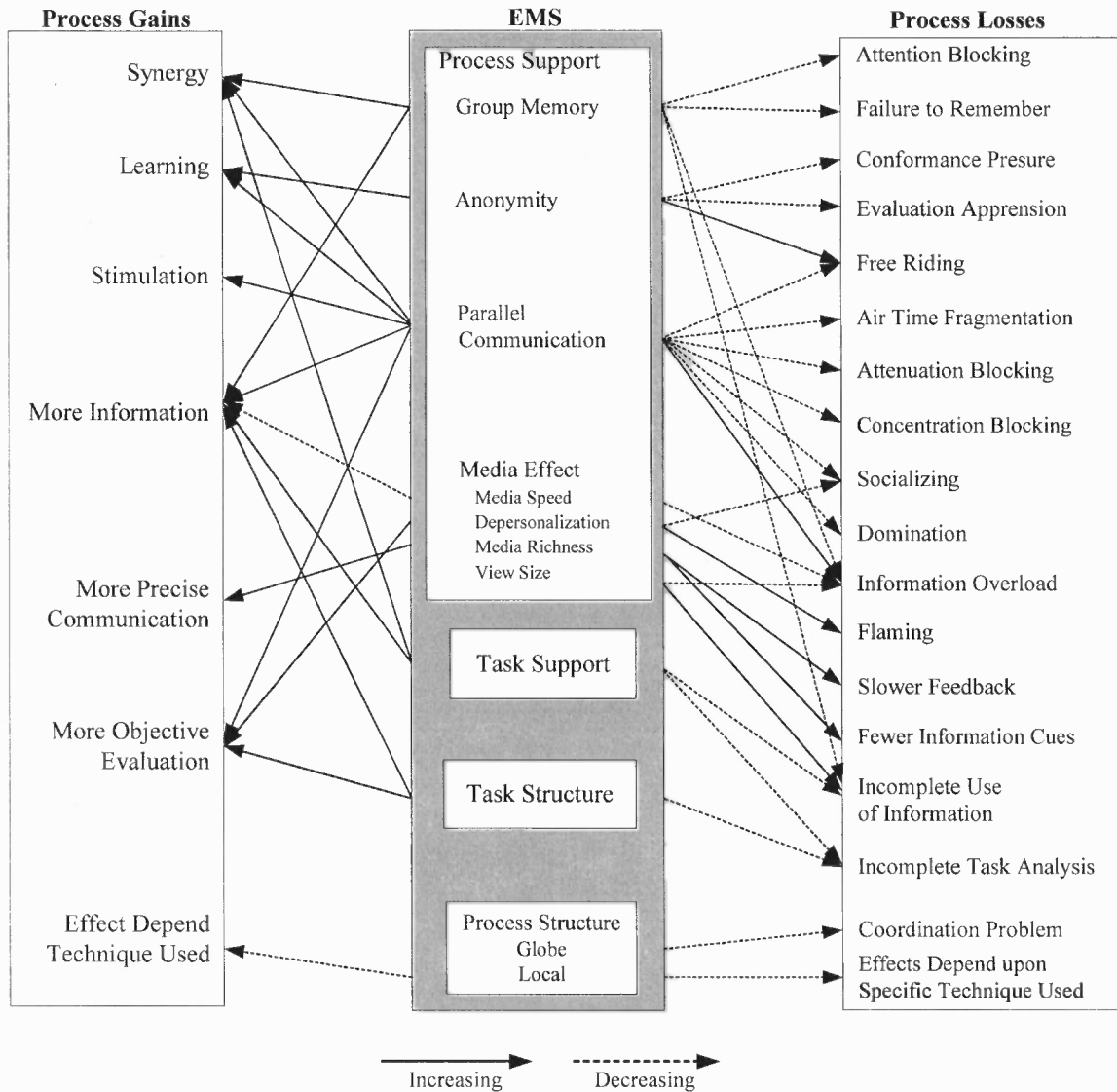
(Adapted from Nunamaker et al., 1991, p. 46)

Group process is more complicated than simply classifying as gains and losses. For example, socializing is listed as a process loss because a group might spend time on socializing rather than working on task, thus reducing group (task) productivity. Nevertheless, socializing is needed for group well-being function to maintain the group's cohesiveness; otherwise, the group cannot function effectively in the future. This tradeoff shows the delicacy of group dynamics and the difficulty in balancing the factors in GSS design and usage.

**Table 4.4 Common Group Process Losses**

<b>Process losses</b>	<b>Air Time Fragmentation</b>	A group must divide the available speaking time among members.
	<b>Attenuation Blocking</b>	A subset of production blocking. Members are prevented from contributing their ideas as they occur. Ideas are lost due to forgetting or suppressing.
	<b>Concentration Blocking</b>	Fewer comments are made because members concentrate on remembering comments rather than generating new ones.
	<b>Attention Blocking</b>	Newer comments cannot be generated because members are listening to others speak and can not pause to think.
	<b>Failure to Remember</b>	Members lose track of communication, missing or forgetting other's comment.
	<b>Conformance Pressure</b>	Members fail to criticize others' comment due to politeness or fear.
	<b>Evaluation Apprehension</b>	Members withhold ideas because of fear of negative evaluation.
	<b>Free Riding</b>	Members rely on others to complete tasks.
	<b>Cognitive Inertia</b>	A discussion moves along alone only one train of thought, because members refrain from contributing comments that do not relate to the current comment.
	<b>Socializing</b>	Members spend time on non-task related discussions.
	<b>Domination</b>	Some member(s) monopolize the group's time.
	<b>Information Overload</b>	Information flows in faster than it can be processed.
	<b>Coordination Problems</b>	Difficulty to integrating members' contributions because group does not have an appropriate strategy.
	<b>Incomplete Use of Information</b>	Incomplete access of necessary information.
<b>Incomplete Task Analysis</b>	Incomplete analysis and understanding of task.	

(Adapted from Nunamaker et al., 1991, p. 46)



**Figure 4.3 Potential effects of GSS features on process gains and losses.**  
 (Adapted from Nunamaker et al., 1991, p. 48)

#### 4.9 Outcome Factors

The outcomes of using GSS usually are divided into task related and group-related outcomes. The task-related outcomes are equivalent to production function outcomes and group-related outcomes can be mapped to group well-being function and member-support function outcomes in McGrath's group outcomes classification (McGrath, 1984).



GSS outcomes from past research are mixed. The results from empirical studies of GCSS and GDSS reviewed by Pinsonneault & Kraemer (1990) have shown that they do have very different outcomes. Both GDSS and GCSS improve the quality of decision and depth of analysis. However, GCSS has negative effects on time to reach decision and members' satisfaction. Although GDSS does produce more positive outcomes, they indicate that due to lack of control groups in those studies, it is not clear whether the positive results are from formal procedure or technology support. Selection effect might also contribute to the positive findings about electronic meeting studies, as most participants in those studies were interested in electronic meetings. They recommend that a more comprehensive theoretical framework is needed to examine the relationship among inputs, process, and outcomes.

Hollingshead and McGrath (1995) have reviewed over 250 experiments, case studies, and field studies on GSS. Their conclusion is that it is problematical to generalize the findings of these studies. They mention that difficulties arise from the confounding of communication system, task type, and research strategy. They also mention that most studies ignore group and member variables. Finally they point out that most studies are clustered with the same technology, the same research strategy, the same task type, and a particular set of dependent variables by research locale.

In their mega-review of about 200 controlled experiments of GSS, Fjermestad and Hiltz (1999) found that the majority of studies yield "no significant difference" between face-to-face mode and GSS mode. There were roughly the same number of positive results and negative results reported in GSS studies when using hypothesis as unit of analysis. They also observed that the following conditions were most likely to achieve

positive results: level 2 GSS with analysis tools, knowledgeable and motivated subjects, medium to large size groups, groups with a facilitator, and task type that matches to the communication medium.

Meta-analysis provides a better understanding of GSS effects by aggregating data from many studies. Results from two meta-analyses in the early 1990s by McLeod (1992) and Benbasat and Lim (1993) showed that GSS slightly improves decision quality and the number of ideas generated, increases time needed to complete the task, and reduces member satisfaction. However, they concluded that the effects were inconsistent and suggested that there might be many moderating factors.

A meta-analysis of decision room GSS focused on task types (Hwang, 1998) showed that GSS increased the amount of communications for generation tasks but not for choice tasks. User satisfaction is also related to task type; the negotiation task tends to yield the lowest user satisfaction. The use of GSS improves decision quality, regardless of task type.

In another meta-analysis, Dennis and his colleagues report that the inconsistency of GSS outcomes can be explained with Fit-Appropriation Model (FAM) (Dennis et al., 2001). When there is a fit between GSS structure and task type, along with appropriate support, the use of GSS increases the number of ideas generated, increases the satisfaction of members, and decreases time to reach decision. If groups did not receive appropriate support, GSS structure and task fit improves effectiveness (decision quality and number of ideas generated), but groups require more time to complete the task and feel less satisfied with the process. On the other hand, if there is no match between GSS

structure and task, appropriate support may increase member satisfaction but has no effect on effectiveness and efficiency.

#### **4.10 Opportunity in GSS Research**

As can be seen from the review, factors in GSS are complex and interrelated. Theory is necessary for better understanding various aspects of GSS. Voting is an important issue in GSS, but it has not received enough emphasis in research. There is a research opportunity in investigating voting and decision processes and outcomes under a GSS. A framework that identifies factors associated with voting and scrutinizes their effects is needed to address the shortcomings of current GSS research. This framework should integrate theories from current GSS research and other related studies. This framework can provide the theoretical background for studying voting in GSS. The next chapter will be devoted to this framework.

## **CHAPTER 5**

### **VOTING IN GSS**

Since decisions are largely made by groups, it is necessary to combine members' views. Voting is a formal way to combine individual preferences into a group choice. George & Jessup (1997, p. 505) comment that GSS research usually maps the linear path of intelligence-design-choice in Simon's rational decision making model to brainstorming-idea analysis-voting activities. Nevertheless, even with this simple view of decision making processes, voting has not been the focus of GSS research. While most GSS have incorporated voting tools, e.g., EIES 2 (Dufner, Hiltz, Johnson, & Czech, 1995), PLEXSYS (Dennis, George, Jessup, Nunamaker, & Vogel, 1988), GroupSystems (Nunamaker, Dennis, Valacich, Vogel, & George, 1991), SAMM (Watson, DeSanctis, & Poole, 1988), CM<sup>3</sup> (Gavish, Gerdes, & Sridhar, 1995) and TERMS (Turoff, Hiltz, Bahgat, & Rana, 1993), researchers seldom report how voting tools are used in their studies. In addition, published research rarely mentioned what kind of voting method or procedure was implemented in the systems. In this chapter, a framework of voting in GSS is proposed by integrating related theories and examining various GSS factors.

#### **5.1 Lessons and research findings about Voting in GSS**

Kraemer and King (1988, p. 131) suggest that voting systems have a pronounced effect on group decision making, that is, voting systems allow groups to identify variance in issues rapidly and anonymous voting can reduce bias of dominant individuals. They also

suggest voting tools should not be used to signify the end of the decision process but to discover the lack of consensus and enable the group to explore the issue at a deeper level.

Nunamaker and his colleagues (Nunamaker, 1997; Nunamaker, Briggs, & Mittleman, 1994) have reported lessons learned with the use of six generations of GSS built at the University of Arizona. Their conclusion on electronic voting is similar to the suggestions of Kraemer and King (1988). They point out that voting in GSS plays a different role than paper-based balloting, which usually happened at the end of discussion. In that regard, they suggest that “polling” might be a more appropriate term than “voting” in the GSS context.

Nunamaker and his colleagues suggest that electronic voting encourages members to “vote early, vote often,” because it is fast, can preserve anonymity, help achieve equality among members, and minimize irrelevant influences. They also conclude that the use of voting/polling tools can uncover patterns of consensus and encourage thinking. Anonymous voting can bring up issues that were buried during normal conversation. Electronic voting can also facilitate decisions that are too painful to make using traditional methods. They also warn that all criteria should be clearly established and defined before voting. But even if all the criteria and hidden assumptions have surfaced, electronic voting sessions may not be successful if there are fundamental and irreconcilable disagreements between parties. This may illustrate that there are deeper problems that need to be resolved. They observed that groups using structured voting to focus discussion have higher decision quality than groups using traditional voting methods. However, their report does not illustrate the relationship among voting tools,

voting procedures, and decision outcomes. A summary of their findings is listed in Table 5.1.

**Table 5.1 Lessons of Using Voting in GSS**

- |  |
|--|
| <ul style="list-style-type: none"> <li>• GSS polling can be used to clarify communication, focus discussion, reveal patterns of consensus, or stimulate thinking.</li> <li>• Anonymous polling can bring out issues that remain buried during direct conversation.</li> <li>• GSS polling can demonstrate areas of agreement, allowing groups to close off discussion in those areas and focus only on areas of disagreement.</li> <li>• GSS polling can be used to formally register dissenting opinions.</li> <li>• GSS polling can fuse the aggregate judgment or opinions of all group members into a true group position.</li> <li>• GSS polling can facilitate closure of issues that are too painful to face using traditional methods.</li> <li>• Care must be taken to ensure that polling criteria are clearly established and defined.</li> <li>• Polling methods in decision groups need not be democratic.</li> </ul> |
|--|

(Adapted from Nunamaker, 1997, p. 185)

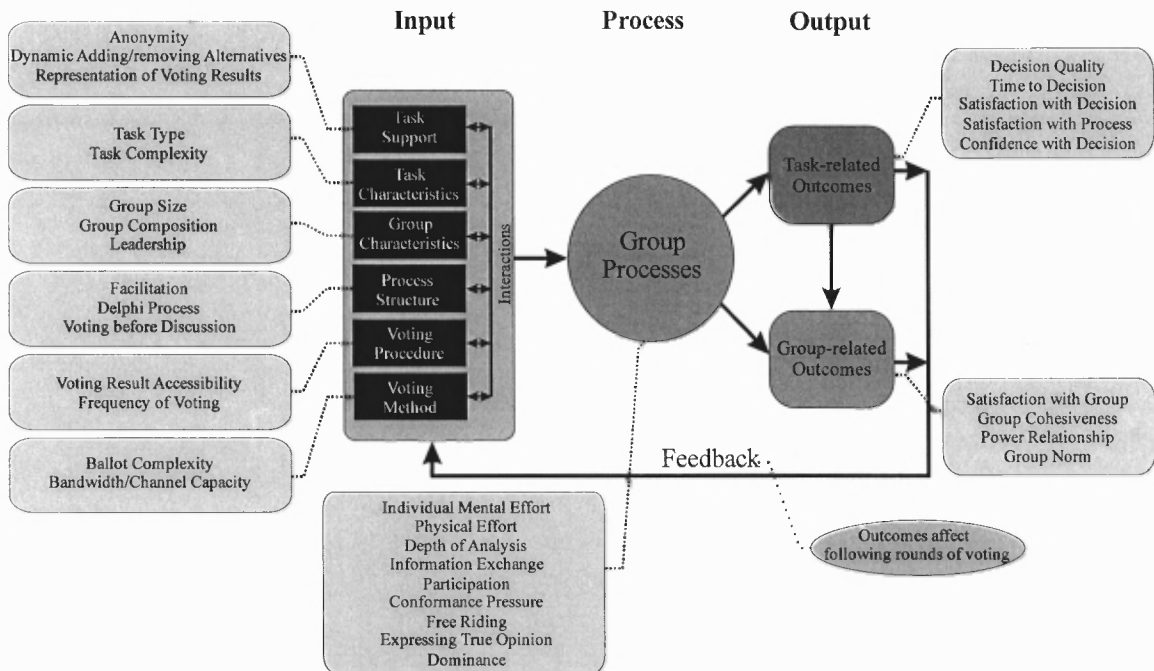
In a comprehensive review of GSS studies by Fjermestad & Hiltz (1999), thirty-five (35) of the 184 studies reviewed reported that their systems incorporate voting tools. However, only two studies have included voting conditions into the experimental treatment: One study (Beauclair, 1989) compares the participation, interaction, and satisfaction between Face-to-Face (FtF) voting and Computer-Mediated-Communication (CMC) voting; the other study (Dufner et al., 1995) compares discussion quality, perceived media richness, and satisfaction for groups with or without a voting tool. There is only one study (Winniford, 1991) that reports the group's voting behavior, i.e., number of votes needed to reach consensus in FtF or CMC conditions. A summary of findings related to voting from these studies are listed in Table 5.2.

**Table 5.2 Findings of Studies on Voting in GSS**

<b>Studies</b>	(Beauclair, 1989)	(Dufner et al., 1995)	(Winniford, 1991)
<b>Task</b>	Type 2; Idea Generation Task	Type 4; Decision Making Task	Type 4; Decision Making Task
<b>Independent Variables</b>	Brain Storming: FtF and GSS Voting: FtF and GSS	Task Support: Tools and No Tools Process Structure: Sequenced and Non-sequenced	Communication Mode: FtF and GSS Group Size: Large (10) and Small (5)
<b>Dependent Variables</b>	Participation Quality Interaction Satisfaction	Perceived Discussion Quality Perceived Media Richness Satisfaction	Decision Quality Number of Votes Decision Time Process Satisfaction
<b>Findings Related to Voting</b>	No significant differences between FtF voting and GSS voting for all three dependent variables.	Groups with tools had higher perceived discussion quality, perceived media richness, and satisfaction than groups without tools.	GSS groups needed more number of votes than FtF groups did. Large groups needed more number of votes than small groups did.

## 5.2 A Framework to Study Voting in GSS

It is clear that a framework is needed to study the effects of voting tools and voting procedures. The input-process-output system view similar to GSS models by Dennis et al. (1988), Pinsonneault and Kraemer (1990), Hollingshead & McGrath (1995), and Fjermestad & Hiltz (1999) was adapted (Figure 5.1). The following sections will present propositions of the framework.



**Figure 5.1** Research framework for studying voting in GSS.

### 5.3 Effectiveness of GSS Voting

Prior to discussing the components in the framework, one should scrutinize why voting can be effective in assisting decision-making processes by groups. Voting in GSS can be effective for the following reasons: it is a structured process, it is a condensed form of communication, it is implicitly accepted by group members, and the results of voting can serve as a record of the group's convergence process.

*Proposition 1: Voting is a structured process of combining members' preferences.*

The preferences of group members are combined into a group preference via a predefined, understandable procedure during voting. The inputs required for casting ones vote and the outputs of combined preferences are clear. There is very little ambiguity in the voting process.



*Proposition 2: Voting makes individual decision explicit.*

A member will make his or her personal preference on the task clear when casting his or her vote, no matter how the internal personal decision is reached by conscious or sub-conscious processes. Unlike expressing a choice via verbal or written communication, there is no uncertainty in interpreting the individual's expressed choice with voting.

*Proposition 3: Voting is an agreed and accepted procedure by members.*

When a group engages in voting, it entails that members agree with the voting procedure. The agreement may be either explicit or implicit. Because the process is accepted, members will be more willing to accept the outcome. Nevertheless, the voting procedure should be perceived as a fair process, otherwise members will lose trust in the outcomes of voting. Fair is a vague concept. It can have different meanings for different people under different contexts. For example, although people would consider a voting procedure to be fair if each member's views are incorporated into the final voting result, the weight of each member's opinion does not have to be equal because the weight of an individual vote can reflect one's expertise in the domain area or stakes on the issue (Nunamaker, Briggs, Mittleman, Vogel, & Balthazard, 1996-97).

*Proposition 4: Voting can serve as group memory of the decision making process.*

The result of voting is easy for the group to recall and reexamine. The valence model of group decision (Hoffman & Kleinman, 1994; Hoffman & Maier, 1964) suggests that during discussion, a group is attracted to or away from alternative solutions because of positive or negative comments expressed by members about each alternative. The valence for any particular solution is presumed to change as the result of the discussion. The valence for a solution is constructed by counting all the members' positive and

negative comments on the solution. Each positive comment will increase the valence index by one point. Conversely, a negative comment will decrease the valence index by one point. The group solution is the one that accumulated valence above the adoption threshold and with the highest valence points.

The difficulty of convergence process in GSS, especially for distributed groups, might be caused by members who might switch between tasks freely and lose track of the content of the discussion, thus the valences for solutions were not accumulated. A voting tool might serve as a group memory of the valences for solutions. The act of voting can be seen as contributing valences to alternatives and the result will reflect the valences accumulated by each solution at the time of voting.

#### **5.4 Two Aspects of Voting**

*Proposition 5: Voting is both aggregation and communication in group decision making.*

Traditionally, studies on voting focus on how preferences are combined into a final decision. In this regard, voting can be viewed as a way to aggregate members' opinions. This view of voting is especially true if voting is used only once at the end of the decision process. Theories and findings from Social Choice Theory (SCT)<sup>1</sup> (Arrow, 1997; Craven, 1992; McLean & Urken, 1995; Nurmi, 1987) can provide insight when the aggregation aspect is the main focus of studying voting in GSS. Alternatively, voting can be seen as a condensed form of human communication (Hiltz & Turoff, 1985). Members express their preference via a fixed format messages. This communication by voting in itself is not rich enough to articulate the reason behind the personal decision, but it will allow the easy discovery of agreement/disagreement among members. The

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<sup>1</sup> See Appendix A for a review of Social Choice Theory and group decision making.

communication effect of voting will be more apparent when a group uses multiple rounds of voting to reach a decision.

#### 5.4.1 Aggregation Aspect of Voting

There are many ways of combining members' preferences. In SCT terminology, the way of combining preference is called a choice rule, choice scheme or choice function. We will use the term "voting method" in the context of GSS voting. Table 5.3 is a list of commonly used voting methods and their descriptions.

**Table 5.3 Commonly Used Voting Methods**

Voting Methods	Description
Plurality Method	Also called Simple Majority Voting. Everybody has one vote. Each person endorses the most preferred alternative. The alternative that has the most votes wins.
Majority Rule	Similar to the plurality method except that the winning alternative must have more than a preset threshold, usually 50% of the total votes. If no alternative achieved the winning threshold, voters cast their votes again until one alternative wins.
Approval Voting	Every voter can cast one vote for any number of alternative(s) he/she approves. The alternative with the most votes is declared as the winner.
Multiple Vote	When electing $k$ winners, a member can cast up to $k$ votes. Each alternative can receive one vote for one member at most.
Borda Count	Each alternative is given a count based on its ranking on each individual's preference. For $n$ alternatives, the most frequently used method to assign a count to an alternative is $n-1$ points for each ballot that is ranked first, $n-2$ for second, etc., down to 1 point for second to last, and 0 for last place. The alternative with the highest total count wins.
Average Score Rating	Voter has a fixed amount of scores that can be assigned to alternatives. Each alternative is given a total score by adding the scores by all voters. The alternatives with the highest total score wins.

One critical topic in SCT is the question of what constitutes a good choice rule. Condorcet, one of the pioneers in SCT, argued that a good choice scheme should select the alternative that beats every other alternative in pairwise comparisons. This alternative, called the Condorcet winner, is superior to any other alternative in one to one competitions. However, there may be no Condorcet winner in some situations. This is

known as Condorcet Paradox. For example, with voters holding preferences as shown in Table 5.4, alternative  $a$  will beat alternative  $b$  in a pairwise comparison with a score of 70% to 30%. Alternative  $b$  will defeat alternative  $c$  because 70% of the voters prefer  $b$  to  $c$ . Yet alternative  $c$  will top alternative  $a$  because 60% of the voters prefer  $c$  to  $a$  while only 40% of the voters prefer  $a$  to  $c$ . There is no Condorcet winner in this case. The Condorcet winning criterion argues that a choice rule should pick the winner if there is one. Conversely, we can also build a Condorcet loser criterion, an alternative that loses to every other alternative in pairwise comparisons should never be chosen by a choice scheme.

**Table 5.4 Example of Condorcet Paradox**

Percentage of Voters	Preference	Result of Pairwise Comparison
40%	$a > b > c$	$a$ vs. $b$ 70%:30%
30%	$b > c > a$	$b$ vs. $c$ 70%:30%
30%	$c > a > b$	$c$ vs. $a$ 60%:40%

There are many other criteria proposed by SCT researchers as desirable properties of a good choice scheme. For example, the monotonicity criterion maintains that an alternative should not be harmed by having more support. If an alternative already won under a choice scheme, it should remain the winner if some people change their preferences in favor of this alternative and nothing else has changed.

An ideal choice scheme should be stable. Independence of Irrelevant Alternatives (IIA) states that out of a set of alternatives,  $a$  is preferred to  $b$  under a choice scheme, then if any other alternative  $c$  is added to or removed from the set,  $a$  should still be preferred to  $b$  because  $c$  is irrelevant to the pair  $a$  and  $b$ . With this stability, if the first choice becomes unavailable, the second choice will become the new winner without the

need for another round of voting because the order between the original second choice and all the other alternatives will not change in the absence of the original winner.

The Pareto condition deals with unanimity in individual preference. The weak form of the Pareto condition asserts that if every voter ranks alternative  $a$  above  $b$ ,  $b$  should never become the winner if  $a$  is available. The strong form of the Pareto condition argues that if everyone believes alternative  $a$  is at least as good as  $b$  and at least one member regards  $a$  as better than  $b$ , then  $b$  should not be chosen when  $a$  is available for choice.

For a fair choice scheme, no individual or a small group of individuals should be able to dictate the outcome of a social choice, regardless of the preferences of other people. A choice scheme is said to have a dictator if under that choice scheme, a certain individual prefers  $x$  to  $y$ , then the group prefers  $x$  to  $y$ , regardless of other individuals' preferences. In other words, the choice is based on the preference of one person. There could be a hierarchy of dictators in the choice system. When the upper dictators are indifferent about alternatives, then the next dictator's preference would decide the system's choice.

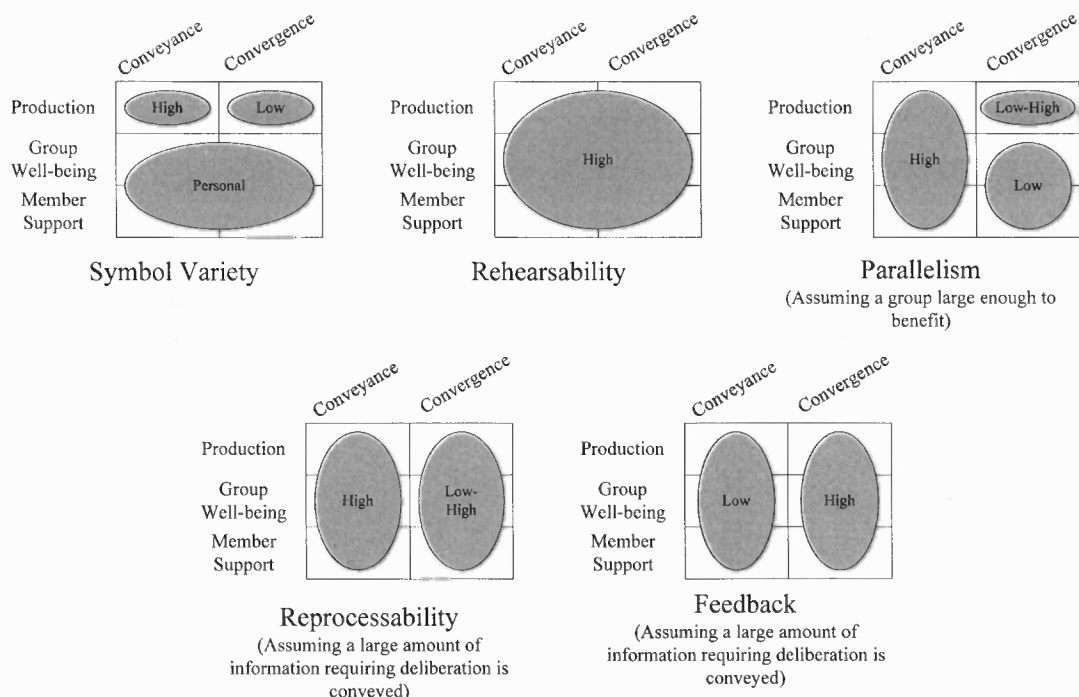
#### **5.4.2 Communication Aspect of Voting**

Alternatively, voting can be seen as a concise form of communication about one's preference. This kind of communication is with predefined format and very lean. The communication effect of voting will be more apparent when a group uses multiple rounds of voting to reach a decision. Media Synchronicity Theory (Dennis & Valacich, 1999) classifies communication media in five dimensions: immediacy of feedback, symbol variety, parallelism, rehearsability, and reprocessability. Voting is low in symbol variety

and parallelism because it only allows a formal way to express one's preference and one session for one issue at the same time. It is high in reprocessability since message size is small and message format is fixed. The immediacy of feedback and rehearsability of voting may range from low to high by system design and/or procedure. According to Media Synchronicity Theory, convergence communication processes are best matched with low symbol variety and parallelism as well as high immediacy of feedback and rehearsability (Table 5.5 and Figure 5.2). Communication characteristics of voting make it very appropriate for convergence communication processes.

**Table 5.5 Media Characteristics of Voting as Communication**

Media Characteristics/Description	Desired Media Characteristics for Convergence Processes	Media Characteristics of GSS Voting
Immediacy of feedback <i>The extent to which a medium enables users to have rapid bi-directional communications.</i>	High	Depend on procedure
Symbol variety <i>The number of ways in which information can be communicated.</i>	Low (Production) Personal (Group well-being, Member support)	Low
Parallelism <i>The number of simultaneous conversations that can exist effectively.</i>	Low-High (Production) Low (Group well-being, Member support)	Low
Rehearsability <i>The extent to which the media enables the sender to rehearse or fine tune the message before sending.</i>	High	Depend on user interface
Reprocessability <i>The extent to which a message can be reexamined or processed again within the context of the communication event.</i>	Low-High	High



**Figure 5.2** Desired media characteristics for group processes.  
(Adapted from Dennis & Valacich, 1999)

The group can explore the reason(s) for agreement/disagreement based on the result of voting. Consensus Building Theory (CBT) (Briggs, Kolfschoten, & De Vreede, 2005) suggests steps for evaluating the willingness to commit and diagnosing causes for conflict in the consensus building process. Voting can be very effective in the evaluating activity and enhance the effectiveness of diagnosis. More detailed discussion on voting as communication will be in the subsequent section that addresses information exchange of voting.

## 5.5 Input Factors and GSS Voting

*Proposition 6:* Factors in voting, such as task support, voting procedure, and voting method, act as inputs that will affect processes and outcomes of group decision making.

There are many factors related to use of voting in GSS. These factors will affect the decision making process and outcome. There is also the possibility of interaction effect among these input factors. The rest of this section will identify factors and discuss their effects based on theories, experiments, and field observations.

*Proposition 7: Outcomes from previous voting will affect later use of voting.*

Because voting can be and should be used multiple times for group decision making, the outcome of the previous voting will have an effect on the following round of voting. In other words, the outputs of GSS voting will become inputs for the subsequent rounds of voting. Thus the relationship between input and output in the framework is not a simple static mapping but a dynamic one. In addition to the initial setting of voting, the history of using voting will also determine the process and outcome.

### **5.5.1 Task Support**

Task support in GSS can interact with the use of voting. For example, anonymity, which reduces the personal influence of dominant individuals, may also reduce the possibility that people can form alliances in voting. Voting can be conducted with the voter's identity revealed (open vote) or concealed (secret ballots). An open vote is used when it is important to record individual positions on an issue. However, there are issues with open ballots. Powerful people can influence other voters by casting their votes with their identities revealed. A voter may not express his or her true preference if the supported alternative is considered radical or is against the dominant member. Furthermore, people are reluctant to change position in an open vote situation because of cognitive dissonance (Frenkel & Doob, 1976; Knox & Inkster, 1968). Because of these reasons, members may hesitate to express themselves or disclose information supporting their true positions



during discussions. Secret ballots, or anonymity in voting, can reduce this problem associated with open voting. Anonymity makes it harder for members to identify others with compatible preferences so they may swap votes. It also makes it harder for people to verify if an ally has kept his or her promises.

As there are different levels of anonymity in discussion (Valacich, Dennis, & Nunamaker, 1992), there can be different levels of anonymity in voting. The membership of the group can be known or unknown to members. Members can have no identity associated with them or can be identified with pen names or aliases. The last approach can trace the position change of a member but not reveal the true identity of the individual.

The effect of anonymity in group discussion has been studied in GSS research for a long time. Researchers have found that anonymity can lead to positive effects such as more objective evaluation, more equal participation, and better decision quality (Jessup, Connolly, & Galegher, 1990; Nunamaker, 1997; Nunamaker et al., 1994). Anonymity also has negative impacts like increasing free riding. Nevertheless, while most of the analysis and findings about anonymity in group discussion may also be pertinent to voting, there is little experimental data validating the effect of anonymity in GSS voting. In addition, people are accustomed to thinking that identities should be kept secret in voting since this is the norm in most free elections, a more interesting question might be to ask what is the effect of open balloting. Would people spend more time before casting their votes to ponder the alternatives? Or, would people wait and then follow the majority fearing that they might become ostracized if they cast an unpopular vote? Clearly, these questions make relevant and interesting research topics.

Moreover, the level of anonymity in discussion and voting can be different. Members can have a discussion session using their true identities or aliases to avoid free riding, yet vote anonymously to eliminate influence of powerful members. Or, the group can have their discussions anonymously to enable the expression of unpopular options, but have members' formal positions recorded in an open vote. There are many possible combinations of anonymity in discussion and voting. The interplay between anonymity in discussion and voting warrants future research.

### **5.5.2 Task Characteristics**

The optimal use of voting tools in GSS will depend on the type of task. For example, for a type 3 intellectual task in McGrath's task circumplex (McGrath, 1984), it may be more suitable to use voting tools to determine the decision criteria rather than to decide the final choice because the task has a correct answer based on the criteria. On the other hand, it may be more appropriate to use voting tools to discover the viewpoints of participants in a type 5 cognitive-conflict task, which is to resolve conflicting viewpoints.

Task complexity also affects voting. Voting with few alternatives requires less effort. The difference among voting methods is less prominent when there are few alternatives. The number of alternatives can also affect the possibility for members to estimate the group preference profile and manipulate the voting outcome by voting insincerely. When choosing an appropriate voting method for a task on hand, the group should also take the task complexity into account. A large number of alternatives coupled with a voting method that requires a lot of effort can easily cause information overload and render the voting process unproductive.

The output of the task also dictates what kind of voting method is more appropriate. A voting method that allows members to vote for more than one alternative would be more suitable for a task requiring members to choose several alternatives instead of only one (Gavish & Gerdes, 1997).

### **5.5.3 Group Characteristics**

Winniford (1991) has shown that group size affects the use of voting in GSS. Large groups need more rounds of votes to reach decision than small groups do. However, there is no significant difference in decision time for large and small groups. In addition, the decision quality is higher for large groups. Since large groups usually suffer more group process losses (Nunamaker et al., 1991), the use of voting tools seems to reduce group process losses more effectively in large groups. Nevertheless, studies are needed to verify this hypothesis and to explore the effects of other group characteristics on voting in GSS.

### **5.5.4 Process Structure**

The use of voting and the features of voting tools should be designed to match the process structure. For example, a decision session based on Delphi process (Linstone & Turoff, 1975) could be matched with dynamic voting tools to enable members to explore their differences and speed up consensus building without the need to wait until all opinions are collected and tallied as in the traditional Delphi process. Voting tools can also change the process structure. It was found in a field study that voting before discussing may result in higher agreement among members and higher satisfaction with the interaction. The voting before discussion approach may be useful when group

agreement is important. It can also be employed when interpersonal conflict might cause problems in meetings (Whitworth & McQueen, 2003).

### **5.5.5 Voting Procedures**

The time to invoke voting, length of the poll, stop conditions, and rules to interpret the results are all parts of the voting procedure. Variations in procedures may lead the group to emphasize certain aspects of the decision processes. The procedures may be designed to speed up consensus building, to achieve higher decision quality, or to prompt information exchange. One should consider the context when choosing among voting procedures due to the variations in the method of combining preferences. Clearly, a contingency theory is needed to match the procedures with task support and task characteristics.

### **5.5.6 Voting Methods**

Researchers in SCT have proposed many conditions for an ideal voting method. When a voting method fails to meet a desired condition, it may make members feel the method is unfair or it might choose a less appropriate alternative under certain situations. For example, the universal criterion (Arrow, 1951) states that a method should produce a result (with the possibility of ties) no matter how members voted. If a voting method can not produce a winner then voters will question the usefulness of the voting method. Considering the independence of clones criterion (Tideman, 1987), i.e., the voting outcome is unaffected by the addition or removal of alternatives that are the same or very similar. If a method failed independence of clones criterion, it might select a less preferred alternative rather than stronger preferred alternatives when supports for stronger

preferred alternatives are divided among similar alternatives. These deficiencies may limit the application of a voting method in GSS. Knowing which voting method exhibits what properties can help a group choose a more appropriate voting method if the group recognizes a voting method may fail under that circumstance.

Voting methods can also affect how information is used in the decision making process. In a study of rank-order effects (Hollingshead, 1996), groups in which members had to rank order alternatives exchanged more information than groups in which members only needed to choose the best alternative. Voting methods, such as the plurality method, approval voting, or Borda count, require a person to choose only one alternative, select several acceptable alternatives, or rank order all alternatives, put different information processing loads onto individuals and yield different amounts of information exchanged among members. The difference may make the group contemplate more information or process the information more deeply before making the final decision.

On the other hand, how the alternatives are compared and selected may also have an effect on individuals. For example, certain voting methods, such as approval voting and Borda count, allow an individual to endorse not only the most preferable alternative but also other acceptable alternatives at the same time. This may reduce post-decision regrets if an individual's most preferable alternative is not chosen. However, very little has been done to examine the effect of voting methods on processes and outcomes in GSS.

**5.5.6.1 Individual Efforts in Voting.** To come up with a vote, an individual has to make comparisons among alternatives. In a more complex voting method the voter will

need to process more information in making comparisons. Gavish and Gerdes (1997) have suggested a five-level classification of ballot complexity that can be seen as a combination of mental and physical efforts at an individual level. The first level is simply marking the highest valued alternative. The second level is to partition the alternatives into two sets and mark all alternatives in the acceptable set. The third level is to rank alternatives in the acceptable set and allocate limited votes. The fourth level requires the voter to rank the entire alternative set. The voter has to quantify the whole preference profile in the fifth level. Table 5.6 is a summary of the ballot complexity.

**Table 5.6 Ballot Complexity**

Ballot Complexity Level	Description of Efforts	Example
1	Mark highest valued alternative	Plurality Method
2	Separate alternatives into two sets, mark all alternatives in the acceptable set	Approval Voting
3	Rank alternatives in the acceptable set to allocate limited votes	Multiple Vote
4	Rank whole preference profile	Borda Count
5	Quantify whole preference profile	Average Score Rating

Source: (Gavish & Gerdes, 1997)

Deeper processing of information by individuals can lead to better decision quality because an individual can integrate more information into his or her decision framework (Hilmer & Dennis, 1999). The individual has to put in more effort and there is more information to be discussed in a complex voting method. Each round of voting may take longer to complete. This may make the group spend more time before it reaches a final decision.

**5.5.6.2 Exchange of Task-related Information.** Coombs (1964) proposed a “Searchingness structure,” which arranges data collection procedures on two general

dimensions: the number of items presented at a time (from 1 to  $n$ ) and whether the respondent has the task of choosing some items (pick  $k$ ), or rank ordering two or more of the items (order  $k$ ). According to Coombs, the data collection procedures in the searchingness structure vary in “channel capacity” and “redundancy.” Channel capacity reflects how much information a procedure yields and provides a measure of the relative power of the method. Redundancy indicates how much of the capacity is used in measuring and controlling inconsistency in the procedure. Voting methods, like data collection procedures, expects the voters to either pick or rank order some alternatives. Thus it is possible to apply techniques in the searchingness structure to analyze these voting methods. The channel capacity will indicate information contributed by the voter.

The channel capacity is based on information theory (Shannon, 1948). The information value of a vote can be estimated from all possible presentations of votes. We start with the formula for entropy (in bits)  $H = -\sum_i p_i \log_2 p_i$ , where  $p_i$  is the probability for the  $i^{th}$  presentation. To calculate the maximum theoretical channel capacity for a voting method, we assume that all combinations have equal probability of occurring, and then probability for a presentation becomes  $1/k$ , where  $k$  is the number of all possible combinations. The channel capacity  $C$  for a voting method is  $C = -\sum_{i=1}^k \frac{1}{k} \log_2 \frac{1}{k}$ , or, after simplification,  $\log_2 k$ .

Based on an  $n$ -alternatives voting scenario, we can compute the channel capacity for some voting methods. For the Plurality Method, because the voter can only pick one from all the alternatives, the possible number of combinations is  $P_1^n = n$  (Pick 1 from  $n$ ). There are  $2^n$  possible combinations for Approval Voting as a voter can either vote for or

not vote for each alternative. In Borda Count, the voter has  $n!$  ways of ordering all the alternatives. A voter has  $H_n^m = C_{n-1}^{m+n-1}$  different ways to allocate  $m$  points to  $n$  alternatives in the Average Score Method. Table 4 is a summary and sample calculation of the channel capacity for several voting methods.

**Table 5.7 Channel Capacity of Voting Methods**

Voting Method	Possible Number Of Combinations	Channel Capacity	Capacity for a 10-alternative Case
Plurality Method	$n$	$\log_2 n$	3.32
Approval Voting	$2^n$	$n$	10
Borda Count	$n!$	$\log_2 n!$	21.79
Average Score Method with $m$ points	$H_n^m = C_{n-1}^{m+n-1}$	$\log_2 C_{n-1}^{m+n-1}$	With 50 points: 33.55 With 100 points: 41.96

Difference in channel capacity does not only mean a member can express more or less in one's vote; it can also lead the group to exchange different amount of information in discussion. A high bandwidth voting method allows more precise expression of members' preferences. The group may be able to discover uncommon information because some members make very different votes. A group is likely to find similarities and disparities in members' preference profiles in a high bandwidth voting method and then it can explore the underlying reasons more deeply. The exploration will lead the group to exchange even more information.

Interaction among members makes members feel more confident about their decision (Heath & Gonzalez, 1995). Since a high bandwidth voting method prompts interaction among members, it will lead to higher confidence about the decision. The expressive power of a high bandwidth voting method should enable a group to use less rounds of voting to reach a decision. Thus using a high bandwidth voting method might



reduce the time for a group to reach a decision. However, high bandwidth voting methods tend to be complex voting methods, which may require more time for each round of voting. The net effect of complexity and bandwidth of voting method on time to reach a decision is not clear.

**5.5.6.3 Exchange of Social Information.** Although voting is a very lean and formal communication, it is still possible for the group to exchange some social information, that is, members' preferences. A member can learn about other members' preferences over a series of voting sessions. This exchange of social information will make a group member more familiar with other members and create the feeling of belonging in the group. More complex voting methods give out more information about a member's preference. In spite of this, this kind of social information exchange is very weak compared to other media that allows more freedom in expressing one's feelings. This social information exchange may also be nullified by anonymous voting. Thus, the effect of social information exchange with voting might hardly be noticeable.

### **5.5.7 Access to Voting Results**

A group can have access to the voting result earlier or later. There are different degrees of accessibility similar to anonymity. The most unrestricted access is the type where a member can see the result at any time, even before casting his or her vote. The most restricted access would be that the group cannot see the results even after the voting session. It is difficult to find a real-world example for this kind of restricted access. Between the extremes, a member might have some restrictions in viewing the results. The most common restriction is that the results will only be made available after the voting session. A less restrictive access to the results might be that one can see those

after a voter has cast his or her vote. Other variations may include showing the result after a certain percentage of members have voted or promulgating the result after a certain time period.

Researchers have long confirmed the “bandwagon effect” in election (Marsh, 1985; Simon, 1954; Zech, 1975). A candidate who wins early primaries can influence the people who were previously committed to other candidates. When those people get a chance to vote later, a lot of people change their position to support the early winner. Although the scale of voting in group decision making is smaller compared to the scale of elections, it is also possible that people will change their position simply because they have viewed the partial voting result before casting their votes. Early access to partial results may also dissuade people who see their preferred alternative lose by a wide margin from expressing their true opinions. Some people might also free ride on other people’s effort so they wait until there is a winning alternative then vote in order to be on the winning side if they have access to partial voting result.

Early access to voting results is not without its merits. People may feel more satisfied with the process because they can go on with their discussion without the need for waiting until all other members have voted. It may also prompt a quicker consensus building process. However, the consensus building process should only start after all parties’ views have been considered. This may require a carefully designed procedure that balances discussion and voting sessions.

### **5.5.8 Frequency of Voting**

Researchers in GSS have suggested that voting should not be used as a one-time mechanism to signal the end of discussion. Instead, they suggest that there should be

multiple rounds of voting to foster discussion (Kraemer & King, 1988; Nunamaker, 1997; Nunamaker et al., 1994). Nonetheless, there are no guidelines for how often a group should vote. Will long discussions with fewer rounds of votes do better, or will short discussions with more rounds of votes do better? The issue might be even more complex than matter of rounds of votes because the best approach might be contingent on other factors such as task type and member ability. Action Regulation Theory (Hacker, 1994, 2003) which is about modes and sequences of task may offer hints in designing the voting process. In any case, there is very little empirical data to predict which approach would be better.

Alternatively, if we treat the frequency of votes as a dependent variable, then what factors affect it? Winniford (1991) has identified two factors, communication mode (Face-to-Face vs. GSS) and group size, that impact on the number of voting rounds needed. The complexity of voting method might also have an effect on how many rounds of voting a group needs in order to reach a decision. A complex voting method requires more effort from individual members. Group members may feel exhausted and vote less often. On the other hand, people can exchange more information with a complex voting method, thus they might be able to reach a decision in less rounds of votes.

### **5.5.9 Dynamic Listing of Alternatives**

As voting selects one alternative from a set of alternatives, a voting procedure cannot divine a good decision among a list of poorly formulated alternatives. If a voting procedure allows dynamic addition and deletion of alternatives, it might be able to improve the quality of decision, especially if the new alternative is an improvement on old alternatives and/or synergy of old alternatives generated during discussion. People

will be able to eliminate those alternatives that are obsolete so the group does not have to spend time and energy to discuss them.

In order for dynamic listing of alternatives to function, the system needs to provide additional support. The system should notify members that the alternatives have changed. Either people will have a chance to change their votes or the system will invalidate the previous vote and start a new round of vote with new alternatives. In either case, the frequency of re-vote should be carefully controlled, otherwise people will get frustrated and become dissatisfied with the voting process.

#### **5.5.10 Representation of Voting Result**

The representation format of data can influence the decision making process (Benbasat, Dexter, & Todd, 1986; Davis, 1989; Hoadley, 1990; Lusk & Kersnick, 1979). The design of voting systems in GSS has to consider the output format because it will affect the final outcome. It is possible for the system to show the voting results in different formats such as text or graphic formats. The system should allow the flexibility for its users to choose among output formats. Some voting methods can be used to produce additional information if members' preferences satisfy certain conditions. Three possible methods for providing additional outputs are briefly discussed here. The extra information can be very useful for the group to make further analysis if members want to spend extra effort to understand this information.

**5.5.10.1 The Law of Comparative Judgments.** A pairwise comparison matrix between all the alternatives can be used to compute a group scale based on the Law of Comparative Judgments<sup>2</sup>. The pairwise comparison matrix can be constructed by asking

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<sup>2</sup> For description and review of this method, the Law of Comparative Judgment, see Appendix B.

members to do comparisons of two alternatives at a time or a rank order of several alternatives (Easley & Mackay, 1995; Li, Cheng, Wang, Hiltz, & Turoff, 2001). Each alternative will be assigned a value on an interval scale. With this scale, the group can see the strength of each alternative based on its scale value. The group can also discover if some alternatives are similar in certain attributes because their values are clustered together in the scale. Although the scale computed by the Law of Comparative Judgments is easy to interpret, there are several restrictions, such as the minimum number of alternatives or minimum number of comparisons that must be met for the scale to be meaningful.

**5.5.10.2 Kemeny-Snell Median.** A well-known method for finding consensus in Social Choice is the Kemeny-Snell median (Kemeny & Snell, 1962; Roberts, 1976), which finds a ranking that minimizes the sum of Kemeny-Snell distances to other rankings. Each member in the group holds a ranking on the alternatives. A Kemeny-Snell distance  $d(a, b)$  can be computed between two rankings  $a$  and  $b$  by counting the agreements and disagreements of ordering of alternatives in the two rankings. Given all the rankings  $a_1, a_2, \dots, a_n$  by group members, the Kemeny-Snell median is the ranking  $x$ , so that  $\sum_{i=1}^n d(a_i, x)$  is minimized. Similar to the voting paradox, there could be more than one Kemeny-Snell medians for a set of rankings. A related concept is the Kemeny-Snell mean, which is a ranking that minimizes the sum of square of distances among rankings, i.e.,  $x$  is the Kemeny-Snell mean, so that  $\sum_{i=1}^n d(a_i, x)^2$  is minimized.

A GSS voting tool can compute and display the Kemeny-Snell median or mean for the group. The median or mean ranking represents current consensus of the group on

alternatives. In the case when there are more than one Kemeny-Snell medians or means, the group members can still benefit by this method by identifying what was in agreement and what is not in agreement, thus concentrate their discussion in either confirming the agreement or exploring the reason for disagreement.

One problem of the Kemeny-Snell median method is its computational complexity is NP-complete (Bartholdi, Tovey, & Trick, 1989), there is no efficient algorithm to find the median in polynomial time. If the number of alternatives or the number of rankings by voting members become large, it will be impossible to find the Kemeny-Snell median in a reasonable time for decision making.

**5.5.10.3 Consensus Index by Fuzzy Analysis.** There are times that a member can only give a rough idea about his or her preference between two alternatives, e.g., he or she might be 80% toward choosing the first alternative and 20% toward choosing the second alternative when comparing two alternatives. This imprecise preference can be modeled as a fuzzy relation. The whole preference profile for a single member can be represented as a fuzzy preference matrix. If each member's fuzzy preference matrix is known, then a consensus index for the group can be computed by aggregating all the fuzzy preference matrices (Spillman, Spillman, & Bezdek, 1980). Although there is practical difficulty in building each member's fuzzy preference matrix with only voting results, information about fuzzy preference matrix can be deduced from voting results or gathered with other procedures or tools during the voting process then used to compute a group consensus index. It will require some research before GSS voting tools can use fuzzy analysis to display a group consensus index during decision making.

## **5.6 Process Factors in Voting in GSS**

It is not clear how the input factors of voting affect process factors, such as, the pattern of communication, participation, and process gains or losses due to limited research on this area. How users adopt voting tools for their own use also complicates the study of the effect of voting on process factors. Although the designers of the GSS may have a specific intention for a certain design feature, the group may adapt and use the feature in its own way, rather than in the way the GSS designers expected (DeSanctis, Poole, Dickson, & Jackson, 1993). For example, voting tools can equalize the influence of members, but what will the dominant members do to counter this effect? Will “logrolling,” that is, members forming alliance to support each others’ agendas, still happen in GSS voting? Can anonymity in voting reduce or prevent logrolling in GSS? All of these make interesting research topics when studying voting in GSS. Given the dynamic nature of the voting process, there will be many research opportunities in this area.

## **5.7 Output Factors in Voting in GSS**

There are two kinds of outcomes: task-related outcomes and group-related outcomes. These outcomes will also affect future use of voting in GSS especially if the group uses more than one round of voting before reaching a conclusion. All these should be considered when studying voting in GSS.

### **5.7.1 Task-related Outcomes**

From the report by Nunamaker and his coworkers, the use of voting tools, coupled with the right procedure, can improve decision quality (Nunamaker et al., 1994). While most

groups reduced the time to reach decisions using voting tools, some groups spent more time to reach decisions. Dufner and her colleagues (1995) have also reported that groups with voting tools had higher perceived discussion quality. However, there is no theory on how to match voting tools and procedures to achieve better task-related outcomes.

### **5.7.2 Group-related Outcomes**

Research regarding group-related outcomes when the groups use of voting tools is limited. There are many open research questions in the area. For instance, will group members be more satisfied with the group when they utilize voting tools? The satisfaction level possibly will be related to the member's status. An influential member may be less satisfied because voting tools take away some of his or her power in the group. On the other hand, a less influential member may have a higher satisfaction level with the voting tools, as the voting tools remove the status difference.

## **5.8 The Need for Research on GSS Voting**

Because of the scarcity of theory and empirical data, new research investigating the relationship between voting factors, group processes, and decision outcomes under a GSS is strongly needed. This chapter presents a framework to study voting by expanding existing frameworks of GSS. Factors about voting have been reviewed and examined. In addition, several ways to classify voting methods were reviewed or proposed. This framework can provide the theoretical background for building and using voting tools in GSS. Experiments to validate the framework are the next critical steps in studying voting in GSS. Organizations and groups can benefit from better understanding of voting in GSS by using voting more effectively and efficiently.



## CHAPTER 6

### DESIGNING VOTING TOOLS IN GSS

There are many factors that can affect the use of voting in GSS. This topic has not been systematically studied by researchers. In order to use voting to support group collaboration effectively, we should contemplate the requirements of voting tools based on theories and reviews of existing GSS voting tools.

#### 6.1 Possible Benefits of Voting Tools in GSS

The implementation of voting tools in a computer system can assist a group in many ways:

- **Improving efficiency:** A computerized system can tabulate the voting outcome faster and more accurately than a manual system. Thus, it enables people to vote more often and/or use more complicated voting schemes.
- **Dynamic voting:** the computer system can keep track of members' votes yet allow them to change their votes and show the most current results to the group while the group is still deliberating the decision.
- **Providing help:** A computerized voting system can give the user on-line help about the voting schemes and also help the users to interpret the results.
- **Stored voting schemes:** The computer system can store many voting methods and predefined procedures at the disposal of a facilitator and may even make suggestions regarding which one should be used based on the context.
- **Choice between open or secret ballot:** The system can be used to remove identities to enable individuals to vote based on their true preferences rather than the socially desirable position; or the system can keep a record of one's votes to make members accountable for their votes.
- **Checking for consistency of preference:** The software can incorporate algorithms to detect inconsistency in an individual's preference. It can enable the individual to rethink his or her preference before finally casting the vote.

- Enforcing non-manipulability: It is possible to implement mechanisms, such as the Clarke tax mechanism (Ephrati & Rosenschein, 1996; Wang & Leung, 2004) or the Groves mechanism (Makowski & Ostroy, 1984), to prevent the manipulation of voting under certain situations.

In the following sections, theories and factors identified in the GSS voting framework will be examined as well as a simple survey of existing GSS voting tools to form the requirements of GSS voting tools.

## **6.2 Implications of Social Choice Theory in GSS Voting**

For almost two centuries, scholars have unsuccessfully tried to find a perfect social choice scheme that could meet all the desirable conditions reviewed in the preceding section of this paper. Arrow (1951) proved that it is impossible for a social choice rule to satisfy all five of the reasonable conditions (universality, monotonicity, IIA, no imposed preference, and no dictatorship) when making a choice among three or more alternatives. The Impossibility Theorem has had a profound impact on SCT, as it demonstrates that there is no single social choice rule that can always fairly decide an outcome that involves more than two alternatives. After Arrow published his Impossibility Theorem, researchers have discovered other impossibilities in social choice. However, this does not mean that people should abandon voting because there is no perfect choice scheme. If we allow some properties to be relaxed, good choice schemes still exist for choosing a reasonable alternative. In the GSS context, researchers and group facilitators should consider these two implications of Impossibility Theorem on voting: A GSS should not have only one voting method for all the situations and one should be aware of the limitation of available voting methods and choose a suitable method for the circumstance.

The discussion above is based on the assumption that group members cast their votes sincerely. The problem of voting becomes more complicated when some of the voters try to manipulate the outcome by expressing false preferences. Voters might cast bogus votes to help a preferred alternative win or to avoid an undesired alternative being chosen. Unfortunately, the Gibbard-Satterthwaite theorem (Gibbard, 1973; Satterthwaite, 1975) proves that any choice rule satisfy no-dictatorship criterion and universal criterion will be susceptible to manipulation when there are three or more alternatives. Two approaches might be able to alleviate the problem of manipulation in GSS voting. One is to use methods such as the Clarke tax mechanism (Ephrati & Rosenschein, 1996; Wang & Leung, 2004) to reduce the incentive for a voter to manipulate the voting outcome. However, this kind of mechanism is not available under all circumstances. A second method has been proposed by researchers who have observed field use of voting in GSS; these investigators recommend using voting as a means to promote discussion rather than reaching a final decision.

### **6.3 Implications of Media Synchronicity Theory in GSS Voting**

Voting in GSS might be able to gain greater benefits if the design and use of voting tools focuses on the communication characteristics of immediacy of feedback and rehearsability. The communication of voting can happen at two points: when a member can receive voting communications and when a member can respond to voting communications. To receive voting communication, a group can perceive high immediacy of feedback by allowing access to the voting result early or low immediacy of feedback by not allowing access to the voting result until later. There are different

degrees of accessibility. The most unrestricted access is that a member can see the result at any time even before casting his or her vote. The most restricted access would be that the group cannot see the results even after the voting session. Between the extremes, a member might have some restrictions in viewing the results. The most common restriction is that the results will only be made available after the end of the current voting session. A less restrictive access to the results might be that one can see those after a voter has cast his or her vote. Other variations may include showing the results after a certain percentage of members have voted or promulgating the results after a certain time period. Early access to voting results might prompt a quicker consensus building process because they can go on with their discussion without the need for waiting until all other members have voted. It may also lead to higher satisfaction with the process.

On the other hand, early access to partial results may dissuade people from expressing their true opinions when they see their preferred alternative has already lost by a wide margin. In situations when access to partial voting results is available, some people might wait until there is an obvious winning alternative before casting a vote in order to be on the winning side.

To respond to voting communications, a voting tool might be designed to give members the ability to modify their votes. A member can make a more informed decision by allowing changeable votes with display of intermediate results. A member can reallocate his or her vote to influence the group ranking after viewing the most up-to-date intermediate result. The group can reach equilibrium after several rounds of vote modifications (Gavish & Gerdes, 1997)

Voting methods that are complex might cause confusion to members. If a voting tool allows a user to review the outcome of voting before actually casting one's ballot, it can reduce the confusion caused by the complexity of the voting method. A voting tool with the capability to allow members to evaluate the outcomes of different allocations of one's vote under hypothetical circumstances of other members' allocations of votes before casting a final vote can also enable a group to converge to an equilibrium state more quickly because users can appraise different scenarios and thus reach a preference allocation that maximizes the expected benefit.

#### **6.4 Voting Tools and Group Process Gains and Losses**

Process and task support in GSS can interact with group process gains or losses (Nunamaker, Dennis, Valacich, Vogel, & George, 1991). Features in voting tools can enhance group process gains or reduce group process losses. The following section describes process gains and losses that should be considered when designing voting tools.

##### **6.4.1 Synergy**

Because the purpose of voting is to select one alternative from a set of alternatives, a voting procedure cannot produce a good decision among a list of poorly formulated alternatives. If a voting procedure allows the addition of alternatives during voting session, it might be able to improve the quality of decision. This is especially true if the new alternative is an improvement on old alternatives and/or a synergy of old alternatives generated during discussion because the new alternative can be discussed and voted on immediately without the need to wait until the end of current voting session.

### **6.4.2 Failure to Remember**

Although there still is an on-going debate concerning the structure and capacity of human memory, the general consensus by scholars is that humans have limited capacity in working memory (Cowan, 2000). If there are a large number of alternatives, a group member might not be able to recall information about alternatives when making comparisons for determining the order of alternatives. A voting tool can be designed to alleviate this problem by allow retrieval of information about each alternative. Cues can be displayed in voting tools to remind users about salient attributes of each alternative and links can be provided so group members can access detailed descriptions or arguments that have been communicated during discussions.

### **6.4.3 Conformance Pressure**

Researchers have long confirmed the “bandwagon effect” in elections (Marsh, 1985; Simon, 1954; Zech, 1975). A candidate who wins early primaries can influence the people who were previously committed to other candidates. When those people get a chance to vote later, many people will change their position to support the early winner. Although the scale of voting in group decision is smaller compared to the scale of elections, it is also possible that people will change their position simply because they have viewed the partial voting result before casting their votes. Early access to partial results may also dissuade people who see their preferred alternative losing by a wide margin from expressing their true opinions and contributing information in discussion.

#### **6.4.4 Free Riding**

Another problem with uncontrolled access to partial voting result is free riding. Some people might wait until there is a winning alternative then vote in order to be on the winning side if they have access to partial voting result. Voting tools should permit the flexibility in when to show voting results so facilitators can have control of the voting process in case there is a problem of conformance pressure or free riding.

#### **6.4.5 Domination**

Powerful people can influence other voters by casting their votes with their identities revealed. A voter may not express his or her true preference if the supported alternative is against the dominant member. Anonymity in voting can reduce the domination of powerful members. There are different levels of anonymity in discussion (Valacich, Dennis, & Nunamaker, 1992), and there can also be different levels of anonymity in voting. The membership of the group can be known or unknown to participants. Members can have no identity associated with them or can be identified with pen names or aliases. The voting with alias approach can trace the position change of a member but not reveal the true identity of that individual.

#### **6.4.6 Information Overload**

Voting tools can reduce the potential impact of information overload by allowing members to eliminate those alternatives that are obsolete or which have already reached consensus. This capacity of voting tools allows group members to focus their attention on fewer alternatives during voting. More advanced voting tools might provide functionality of comparison and sorting of alternatives based on attributes. Sophisticated

voting tools can integrate modeling and analytic technique such as Analytic Hierarchy Process (AHP) (Choi, Suh, & Suh, 1994) and sensitivity analysis (Mészáros & Rapcsák, 1996) to enable members to evaluate the merit of each alternative for individual decisions.

Voting tools can also reduce information overload by having flexibility in output format, especially graphic output. The output of voting should not be limited to only the tally of ballots, but can also include information generated by processing the tally, for example, the voting history of an individual, degree of agreement or disagreement on a single alternative, and status of consensus. These outputs can make group members focus their attentions on unsolved issues rather than going through all issues.

## **6.5 Integration with other GSS Tools**

Briggs and Romano have pointed out that “*one tool, no matter how fully featured, will not do it all*” (in Nunamaker, 1997 p. 378). Voting is only one part of the group collaboration process. To streamline the collaboration process and to achieve synergy, we should consider integration among tools.

### **6.5.1 Integration with Idea Generation Tools**

Alternatives for voting do not appear magically from thin air. Members can propose numerous alternatives during the idea generation stage. Alternatives generated during the idea generation session need to be organized because several alternatives might be similar and can be merged into one integrated item or an alternative can be a replacement of another alternative. The list of alternatives can be gathered and processed then imported



into voting tools (Chen, Hsu, Orwig, Hoopes, & Nunamaker, 1994; Turoff, Hiltz, Cho, Li, & Wang, 2002).

### **6.5.2 Integration with Discussion Tools**

To build consensus, a group may go through steps of articulating a proposal, evaluating willingness to commit, diagnosing causes of conflict, and invoking conflict resolution strategies (Briggs, Kolfschoten, & De Vreede, 2005). Using voting tools can help groups discover agreements/disagreements, but a group needs to explore causes of disagreements and resolve them. This process can be streamlined by integrating voting tools with discussion tools. The integration can go in either direction: from discussion tools to voting tools by embedding voting in discussions or from voting tools to discussion tools by linking voting to arguments in the discussion.

Idea generation tools, discussion tools and voting tools can morph into a system that represents the discourse of group decision-making as in Issue Based Information System (IBIS) (Conklin & Begeman, 1988), GRADD (Becker & Bacelo, 2000) or Social Decision Support Systems (SDSS) (Turoff et al., 2002). In such a system, items like issues, proposals, arguments and preferences are linked by relationship. An issue can have many proposals linked to it as possible solutions. A proposal can have arguments for or against it and members' preferences attached to it. Voting in this system can be done by tallying preferences attached to proposals that address a specific issue.

## **6.6 Survey of GSS Voting Tools**

A list of features for voting tools based on earlier discussion was compiled and is displayed in Table 6.1. While it is possible to do an in-depth review of a few selected

GSS voting tools, the purpose of this paper will be better served by a broad survey of features in GSS voting tools to determine if there is any feature not covered by earlier discussion. There are many voting tools to facilitate group collaboration that could be components of a full featured GSS or a standalone voting package. Some tools are commercial systems while others are open source projects. Because of the extensive number of voting tools and the availability of instruction manuals or demos, it is difficult to conduct a complete survey of all available voting tools. A simple survey of voting tools was conducted. Table 6.2 is a partial listing of voting tools examined.

**Table 6.1 Features of GSS Voting Tools Based on Earlier Discussion**

• Different degrees of access to intermediate results	• Links to arguments in discussion
• Changeable vote	• Different levels of anonymity
• Weighted vote	• Modeling/analytic tools for individual decision
• Multiple rounds voting	• Flexible in output formats
• Multiple voting methods	• Consensus/disagreement status
• Review result before actual vote	• Import alternative list from other tools
• Add/remove alternatives	• Embedded voting
• Explanations of voting alternatives	• Discourse structure of decision making

**Table 6.2 GSS Voting Tools Surveyed**

<b>Name</b>	<b>Reference</b>
AntiGroupWare	(Norton, DiMicco, Caneel, & Ariely, 2004)
CM <sup>3</sup>	(Gavish, Gerdes, & Sridhar, 1995)
eRoom	<a href="http://www.eroom.net">www.eroom.net</a>
eVote®/Clerk	<a href="http://www.deliberate.com">www.deliberate.com</a>
Drupal	<a href="http://groups.drupal.org">groups.drupal.org</a>
GroupSystems	<a href="http://www.groupsystems.com">www.groupsystems.com</a>
KOM2000/KOM2002	<a href="http://cmc.dsv.su.se/KOM2000">cmc.dsv.su.se/KOM2000</a>
Meetingworks	<a href="http://www.meetingworks.com">www.meetingworks.com</a>
phpESP	<a href="http://www.butterfat.net/wiki/Projects/phpESP">www.butterfat.net/wiki/Projects/phpESP</a>
SZTAKI Voting and Survey System	<a href="http://wwwold.sztaki.hu/services/voting">wwwold.sztaki.hu/services/voting</a>
WINGDSS	(Csáki, Rapcsák, Turchányi, & Vermes, 1995)

### **6.6.1 Delegation of Vote**

There is one feature found in AntiGroupWare, delegation of vote, which has not yet been discussed in this paper. The rationale behind this feature is that not every member is an expert in judging certain issues and may not be comfortable to cast a vote. With delegation of vote, an individual can assign his or her vote to others who are experts in this domain and their votes will gain greater weight. To maintain anonymity, individuals who were delegated with votes should not know that they have additional weight in their votes nor should they know the source(s) of delegation. It allows the voting process to utilize the organizational knowledge of distribution of expertise that is not reflected on the formal organization chart (Norton et al., 2004).

## **6.7 Building GSS Voting Tools**

### **6.7.1 Security**

The Association for Computing Machinery (ACM) has published a statement on computer-based electronic voting systems which states “*the Association recommends more attention to integrity, security, and usability in the design and use of all voting systems.*” (Grove, 2004, p. 70) Although voting in GSS is on a smaller scale than a voting system for elections, it is still essential to consider the issues of integrity and usability in GSS voting tools. However, voting tools in GSS may not require the same level of security as in a voting system for election. Nonetheless, voting tools in GSS can utilize security mechanisms developed for electronic election systems, especially for critical and sensitive decisions. For example, server and client can establish secure communication using encryption protocols, so a third party will not be able to eavesdrop on the content and response of ballots. In addition, voting tools can use methods beyond username/password authentication to verify a member’s identity. Members will have greater confidence in a voting tool that is secure, and better trust the voting process, which can lead to higher acceptance of the outcome.

### **6.7.2 Implementation Approaches**

While there are many GSS voting tools, the functionality of these voting tools usually are inadequate for a group to take full advantage of voting. The voting tools either provide few voting methods, limited multi-round voting support, or little control over accessibility to voting results. In such cases, redesigning the whole GSS may provide the best synergy for voting tools and other GSS tools. Nonetheless, there are simpler approaches that can incorporate enhanced voting functionality into an existing GSS. The

first approach is using a standalone voting package. The advantage of a standalone voting package is that it can be used with any GSS without any modification to either system. The drawback is very little integration between the main GSS and voting package. Members will have to log into the voting package as well as the original GSS. It may also become necessary for members to manually copy the voting results back into the main GSS because the voting package has no knowledge about the main GSS. There is also extra administrative work because the system has to maintain two copies of user information. The other approach requires customization of a voting package on the backend server that provides the core voting service and modification of the main GSS so that the voting package can piggyback onto the authentication routine of the main GSS. This approach provides a single login for members and less administrative work. It is possible to send data from the voting package to the main GSS because the voting package possesses information about the main GSS.

## **CHAPTER 7**

### **GSS VOTING TOOL PROTOTYPE**

A GSS voting tool was developed as a test of concept prototype. This prototype was also used in an experiment for group decision making with multiple rounds of voting. Due to limited resources, the method used to develop of this voting tool is the mixed approach as discussed in the previous chapter, a collection of programs serve as the backend of the voting function while utilizing the original group discussion system for user authentication. This chapter discusses the underlying program logic of the voting tool prototype. The program logic can be extended to include more advanced functionality. With a little modification, the implementation method can be applied to many existing GSS.

#### **7.1 Features Implemented in the Prototype**

The prototype implemented some vital features discussed in the previous chapter. The major ones are: multiple rounds of voting, multiple voting methods, accessibility, and modification of ballot for later rounds. Group members can vote in the current round and review voting results from previous rounds or partial result of the current round if the accessibility is set to allow viewing of partial results. Five voting methods are designed for the prototype. Due to time constraint, three methods are actually coded in the prototype. Additional voting methods can be easily added via the templates mechanism mentioned in a later section. The alternatives on the ballot can be changed between

voting rounds. The group leader can remove or add back alternatives when starting a new round of voting.

Other minor features in the voting tool are designed to reduce cognitive and labor loads for the users. When a user moves the mouse pointer on to the name of an alternative, the voting tool will show a short description of that alternative. If the user clicks on the name of an alternative, it will bring up a pop-up window with full description for the alternative. The user can copy the voting result in either graphic or tabular form to the group discussion by simply clicking a button in the voting tool. The voting tool also provides status about the voting session to the users. The user can see how many members in the group have voted in the current round. There is a count-down timer shows the time remaining until the group has to reach a final decision. Operation instruction and screen shots of the voting tool can be found at Appendix E.

## **7.2 Integration with Host Program**

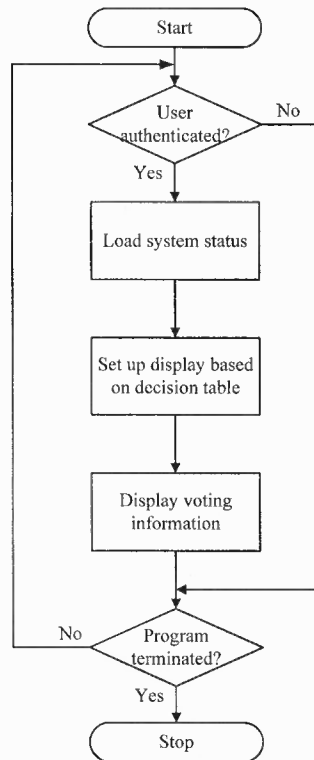
The voting tool was developed using the integration approach, that is, the voting tool taps into the authentication mechanism of a host system then provides voting functionality to the host. The host system in this implementation is phpBB, an open-source group discussion forum. The original voting function in phpBB was disabled and replaced with the more advanced voting function in the prototype. The voting prototype was written in PHP and client-side JavaScript, the same programming languages used in phpBB for interfacing with the authentication mechanism in phpBB.

In the first version of the prototype, the user has to click on a 'vote' button to display the voting tool in a separate window. The users had to invoke the voting tool and

switch between voting and discussion windows. Feedback from testing indicated people were confused by this design. The design was changed to display the voting tool in an embedded window with group discussion, which reduces confusion to the user.

### 7.3 Control Flow in the Prototype

The control flow in the voting tool is event driven. The voting tool runs a loop that checks for the user's authentication, loads status from the database, decides actions to perform based on system status and user action, displays appropriate information to the user, then waits for the user's input for the next iteration (Figure 7.1).



**Figure 7.1 Control flow of the voting tool prototype.**

The core of the voting tool control flow is a decision table that decides which actions to be taken and information to be shown based on the system status and user



action (Figure 7.2). The system status includes voting method used, voting result accessibility, member eligibility for new rounds of voting, member privilege to end the current round of voting, member participation in voting, number of people who have voted, round number for current voting, and completion status of the current round. The user's action can range from no action, vote, show result, show ballot, end the current round, or start a new round. The decision table dictates whether the voting tool performs any of the following tasks: display the ballot, show user's vote, show the results for a given round of voting, insert the user's vote into database, end current round of voting, or start a new round of voting. For example, if there is no user selected action, then the voting tool will display either the voting results if the current round of voting has ended, the user's vote in this round if the current round of voting is open and the user has voted, or the ballot for voting if the current round of voting is open and the user has not voted yet. Allowed user actions are checked and the control elements (buttons and/or drop-down list) for these actions are presented in the voting tool display.

#### **7.4 Templates for Voting Methods**

The voting tool implements several voting methods via templates. There are four templates associated with each voting method for displaying ballots, processing submitted votes, presenting voting results, and showing individual's votes. Each template is written in PHP for generating HTML and with JavaScript for checking the correctness of user input as well as for showing dynamic content. There is a second check of user input in the PHP code to catch illegal input just in case the user has disabled JavaScript in the browser.

**Table 7.1 Decision Table for Voting Tool System Actions**

User action	System status					Actions by the system
	Member voted	Accessibility	Voting ended	Member can end voting	Member can start voting	
-	-	-	Y	-	-	Set member as voted in this round Set user action to view result
-	N	-	N	-	-	Set user action to show ballot
-	Y	-	N	-	-	Set user action to show one's vote
Submit vote	N	-	N	-	-	Run submit vote template to record member's vote Set member as voted in this round if all the members voted then end the current voting round Set user action to show one's vote
New round	-	-	Y	-	-	Set up a new round of voting Set user action to show ballot
New round	N	-	N	-	-	Set user action to show ballot
New round	Y	-	N	-	-	Set user action to show one's vote
End round	-	-	-	-	-	End current round of voting Set user action to view result
-	-	-	N	Y	-	Display 'end current round' button
-	-	-	Y	-	Y	Display 'start new round' button
~Show ballot	N	-	-	-	-	Display 'show ballot' button
-	-	Full	-	-	-	Allow member to select up to this round of voting for result
-	Y	Partial	-	-	-	Allow member to select up to this round of voting for result
-	N	Partial	-	-	-	Allow member to select up to last round of voting for result
-	-	Restricted	Y	-	-	Allow member to member select up to this round of voting for result
-	-	Restricted	N	-	-	Allow member to member select up to last round of voting for result
View Result	-	-	-	-	-	Display voting result based on voting method
Show ballot	-	-	-	-	-	Display Ballot based on voting method
Show vote	-	-	-	-	-	Show member's vote based on voting method

The ballot template takes the list of alternatives and then formats them into an appropriate style according to the voting method. The user's input is checked to verify if it is correct for the voting method. For example, the total of points assigned to all the alternatives matches the points allocated in average score voting. The submission template checks the user's vote is as specified in the voting method then insert the data into the database. The result template aggregates users' votes into the group result and then presents it in graphic and tabular form. The individual vote template shows how the user casted his or her vote in the current round of voting. Together, the four templates provide complete functionality of one voting method.

### **7.5 Extending the Voting Tool Prototype**

The decision table and template in the voting tool prototype provide a relatively easy way of extending voting tool functionality by adding new system status, user actions, or templates. For instance, to implement weighted voting, a new system status 'weight' will be added in the system and modify the result template so each user's vote will be aggregate based on the weight assigned for each user.

The voting tool can also be incorporated into other group discussion systems. Although this voting tool is developed predominantly for phpBB, the only components in the voting tool that are tightly coupled to phpBB are the authentication mechanism that verifies the user can participate in voting and the JavaScript code that copies voting results to discussion. The control flow and templates of the voting tool can be adapted to other systems with minor modification.

## **CHAPTER 8**

### **EXPERIMENT DESIGN AND REVISIONS**

Voting in GSS is an extremely complex issue and currently there is a dearth of empirical data available. Due to the complexity of the framework, this experiment only addresses a portion of the whole framework. Because of its potential effect on group process and outcome, voting method bandwidth was selected as the focus for this exploratory experiment. The main research question is as follows: When groups vote with high or low bandwidth voting methods, what differences in objective and subjective outcomes can be detected. The design and implementation of the experiment had to overcome several obstacles. The original experiment design and subsequent changes due to these constraints are described in this chapter.

#### **8.1 The Original Experiment Design**

The original design of the experiment was a 2 by 2 factorial design (Table 8.1). One factor was voting method bandwidth with high and low conditions. The other factor was access to voting results with limited and full (unrestricted) treatments. Each cell had 10 groups. Each group had 5 members for a total of 200 subjects.

Unfortunately, once subject recruitment began, it became clear that it was difficult to meet the original planned enrollment goal with the limited resources on hand. It was decided at that time to focus on the voting method bandwidth factor only for this experimental session. The accessibility of voting results treatment is planned for

future research when there are increased resources for recruiting subjects. The difficulty in subject recruitment is documented in later sections of this chapter.

**Table 8.1 Experiment Design**

		Voting Method Bandwidth	
		High (Average Score Method)	Low (Plurality Method)
Access to Voting Results	Limited (Only after casting vote)	High Bandwidth-Limited Access (HL)	Low Bandwidth-Limited Access (LL)
	Full (Any Time)	High Bandwidth-Full Access (HF)	Low Bandwidth-Full Access (LF)

### 8.1.1 Selection of Task

Voting can be used for many different types of tasks. It can be used to prompt information exchange so the group can pick the right choice (Type III Intellectual task in McGrath's Group Task Circumplex). It can be used to come to a decision where there is no right answer (Type IV Decision-Making task). It can also be used to resolve conflict in viewpoints (Type V Cognitive-Conflict task). Although a Type III task with unique unshared information (hidden profile task) will make it easy to analyze whether a group makes a better decision or not, it is not the best task to study group interaction and members' feelings about the decision. Once the group members realize there is a correct answer, members will cease to exchange more information. Moreover, there are other decision support tools, such as modeling tools that might provide better help to the group in making this kind of decision with a right answer. This research chose tasks with no correct answer for the experiment.

One common problem in testing GSS tools is that data collected in experiments does not reflect the full potential of the tools. Subjects are still learning how to adapt the

GSS tools into their group process during the experiment, especially for new tools or innovative use of old tools. In order to minimize the effect of user inexperience, the original design of the experiment called for two tasks to be completed in the study. An introductory warm-up task familiarized subjects with the system and voting procedures. The warm-up task had to be interesting enough to engage the subject to spend time and energy learning the system and voting procedures. However, the task could not be too complex or overly time consuming. A modified University of Georgia Admission (UGA) Task (Dennis, 1993) was selected as the warm-up task. The group was asked to review three previously rejected applicants and then recommend an order of the candidates for admission into the university.

The second task, 'the hostage rescue task,' is a decision making task designed for this experiment. The group had to put together a list of eight hostages in order of who would be rescued first. Profiles of six hostages were designed so each hostage represented a pole in personal value as described by Allport, Vernon, and Lindzey (1960). Another hostage had a profile that was obviously inferior to all the other hostages. This hostage was used as a check. The last hostage had a profile with minimal information to represent uncertainty. The group had to resolve differences in their personal value to reach a final list. The instructions further pressure the subjects to complete the task within a strict timeframe.

### **8.1.2 System**

The discussion and voting system used for this experiment is a modified version of phpBB ([www.phpbb.org](http://www.phpbb.org)) as discussed in the previous chapter. Because the primary goal of this experiment was to study voting tools and the convergence process, the alternatives

were set by the experiment investigator so members would not go through the divergence process of generating alternatives in this experiment.

The whole system was setup on a server with dual Pentium III processors with 2 Gigabytes of RAM running Ubuntu Linux version 6.06 LTS ([www.ubuntu.com](http://www.ubuntu.com)) operation system. The servers were stress tested and fine-tuned so the Web and database services could handle at least 200 users, the anticipated number of subjects, on-line simultaneously. The server was connected to the school's network and a domain name was assigned to it for access via Internet.

### **8.1.3 Subjects**

In the original research design, subjects were students recruited from classes in the Information Systems, Computer Science, and Management programs. Students were invited to participate in the experiment as an alternative to a class assignment. Participation in the experiment was voluntary and subjects could withdraw from the experiment at any time.

### **8.1.4 Procedure**

The whole experiment took a total of three hours: one hour for orientation and two hours for the two tasks. The participants attended an orientation before they began the experiment. During the orientation, subjects were introduced to the purpose and procedure of the experiment then decided if they wanted to participate in the experiment. If a subject decided to take part in the experiment, he or she signed a consent form, filled out a pre-experiment questionnaire for background information, and chose the time slots that he or she was available for group discussion. Each participant received a package that contained a user's manual for the system, task description, and user name and

password. The experiment investigator assigned subjects into a group and chose a group leader when there were enough subjects for a scheduled time slot to start a session of group discussion.

The first hour of the discussion session was the warm-up task. The next hour was for the experimental task. There was no restriction on what procedure a group could use to reach the final decision except that members should use multiple rounds of voting as mentioned in the instruction. Each group was free to adopt the discussion and voting tools for the decision as they saw fit. The feedback from the participants, such as group report and post-task questionnaire, was submitted on-line, so the participants did not have to travel back to campus after the orientation. Each participant received a thank you message for his or her contribution to the study after completing the experiment. The message also provided links to debrief material such as theoretical background of the study and expected findings.

## **8.2 First Revision of Experiment Design**

The original design was presented to faculty members and fellow Ph.D. students in the Information Systems Department for comments. Their feedback and changes in Institutional Review Board (IRB) guidelines for recruiting human subjects for experiments led to the first revision of the experiment design.

### **8.2.1 Subjects and Incentive**

The IRB revised its guidelines on the use of human subjects. As a result, using class assignments for experimentations was prohibited. Volunteer subjects had to be recruited for the experiment. Incentives for participation in the experiment were originally planned



as a \$5 cash reward plus a chance of winning gift cards valued at \$200, \$100, and \$50. Even at this modest level of reward for the subject's time and effort, the experiment investigator lacked the financial means to provide such incentive for the targeted number of subjects. A fellow Ph.D. student suggested that the incentive for participation should be changed to a chance to win a game console in a raffle. The Nintendo Wii, priced at \$250, was selected as the raffle prize for participating in the experiment. One Nintendo Wii would be given out per every 50 subjects who had completed the experiment. The Nintendo Wii was in short supply and high demand at the time of the experiment, which added appeal to the targeted subjects, undergraduate students. Three Wii's were secured before starting the experiment.

Subjects were recruited individually by posting flyers on campus, giving presentations during classes, and sending out invitations on mailing lists. A plan for setting up a table in the Campus Center was also considered as a way to recruit subjects. A website with descriptions about the experiment was set up for subjects to sign up for the experiment. Subjects who visited the website and decided to sign up could fill out contact information and select a date and time to participate in the experiment.

### **8.2.2 Task**

One faculty member expressed the concern of lack of pre-test for the experimental task. It was impossible to control the composition of the group. It was possible that a group could form with members holding the same preferences thus after one round of voting or discussion, the group could reach its final decision. A pre-test would solve this problem by grouping subjects with dissimilar preferences together in one group. Although it was possible to use the Allport-Vernon-Lindzey values questionnaire (Allport et al., 1960) as

the pre-test, the correlation between the questionnaire and profiles in hostage rescue task had to be validated first. The validation of the questionnaire and task alone would require an extended time period and require numerous additional subjects, thus it was determined that the hostage rescue task will not be employed in this experiment. The hostage rescue task was not published with this dissertation because it will be validated and revised for future research. An alternative task, the State Budget Decision (see appendix G), modified from a published task, Legislative Dilemma (Valacich, Mennecke, Wachter, & Wheeler, 1994), was utilized for this experiment. The subjects were instructed to work on the task individually first as pre-test. The individual decisions were compared when subjects were assigned into groups so that each group would not have a dominated majority at the start of the discussion.

### **8.2.3 Procedure**

A faculty member recommended hosting subjects in the lab during the experiment for better control and observation. This suggestion was incorporated into the revised procedure. The total time for the experiment session including orientation, consent, pre-task questionnaire, individual decision, two experimental tasks, post-task questionnaire, and debriefing was estimated to be approximately 3.5 hours. It was determined that this was too long for an experiment because the incentive was not motivating enough or subjects would become fatigued prior to the main experimental task. Accordingly, the time of experiment session had to be reduced. The warm-up task was eliminated from the revised procedure since the experiment investigator would be present with the subjects in the lab to explaining how to use the system and answering questions during experimental tasks. The time on the main task was reduced and items in the post-task

questionnaire were also condensed from 60 questions to 35 questions. A post-discussion individual decision was added to determine the level of change in personal preferences after discussion or voting. The estimated time for all the activities in the revised procedure is about 1.5 hours, which was within acceptable time length for an experiment.

IRB application for this experiment setup was approved on December 23, 2006. Approval from University of Medicine and Dentistry of New Jersey (UMDNJ) IRB for posting flyers at UMDNJ campus was also obtained. Recruiting of subject was started at the beginning of 2007 Spring semester after the winter break. Two major difficulties encountered at the beginning of this experiment set up lead to another revision of the experiment design.

### **8.3 Second Revision of Experiment Design**

Although numerous people expressed their interest in the experiment, the sign up rate was dismal. One reason for the low sign up rate was that people did not want to travel to campus for the experiment, especially during weekends. With only a handful of people signed up for the experiment, it was difficult to gather together enough subjects for one experiment session because people signed up for different session times. There was a long wait before a subject could be scheduled for an experiment session. The waiting time for the experiment created two problems. First, some potential subjects lost interest in the experiment during the extended waiting period and then dropped out. Second, it was still unfeasible to control the composition of group members with the pre-test because most of the time there were just barely enough subjects to form one group during

one experimental session. There was no mean to mix and match subjects to form diverse groups.

The first experiment session of this revised procedure clearly exhibited the lack of commitment for the experiment by some subjects. Five subjects were scheduled for this session and only one showed up for the experiment. Two subjects sent messages saying they could not attend the experiment only hours beforehand. The other two subjects simply did not show up and left no message. Although the experiment investigator had anticipated the possibility of subjects' nonattendance, and arranged two back-up subjects, the session still had to be aborted due to shortage of subjects. This incident led to the second revision of the experiment procedure.

The difficulty of coordinating subjects to the same experiment session caused the group discussion to switch to asynchronous mode which allowed people with incompatible schedules to take part in the experiment. The orientation was also changed from face-to-face to on-line, so people who could not travel to campus could participate. This also allowed potential subjects who did not live near the campus to sign up for the experiment. Commitment from subjects was still a problem. With asynchronous discussions, it was possible to assign another subject into a group if someone did not post message or vote in the group discussion. This was not an ideal solution for the commitment problem, but it did keep the number of subjects in a group above a minimum level.

The revised procedure is shown in Figure 8.1. This figure was on the recruiting website to explain the asynchronous set up of group discussion. A person would sign up via a form on the recruiting website. The experiment investigator then sent the consent

form (Appendix D) as an attachment in an e-mail message. The subject would read the consent form and express his or her consent to participate in the experiment in a reply. Experiment instructions (Appendix E) would be sent to the subject after receiving the expressed consent. A subject would complete the pre-task questionnaire (Appendix F) and individual decision then wait until the experiment investigator matched five people into a group. The discussion would last for one week. Because the asynchronous nature of discussion, it was difficult to give an exact time a subject had to commit on the task. It was estimated that a subject might spend 1.5 to 3 hours for the experiment. The subjects would fill out the post-task questionnaire (Appendix H) and individual decision after the group discussion then receive a debriefing of the experiment (Appendix G).

This revised experiment protocol was approved by NJIT IRB on February 18, 2007 (Appendix C). Again, UMDNJ IRB approval for posting flyers at UMDNJ campus was obtained. In addition to posting flyers on campus, the investigator also made presentations in classes, sent invitations to mailing lists, and hosted an exhibition in Campus Center to recruit subjects.

Recruiting subjects was still a major constraint with this procedure. The impact of recruiting purely voluntary subjects is discussed in the limitation section of the results and discussions chapter.

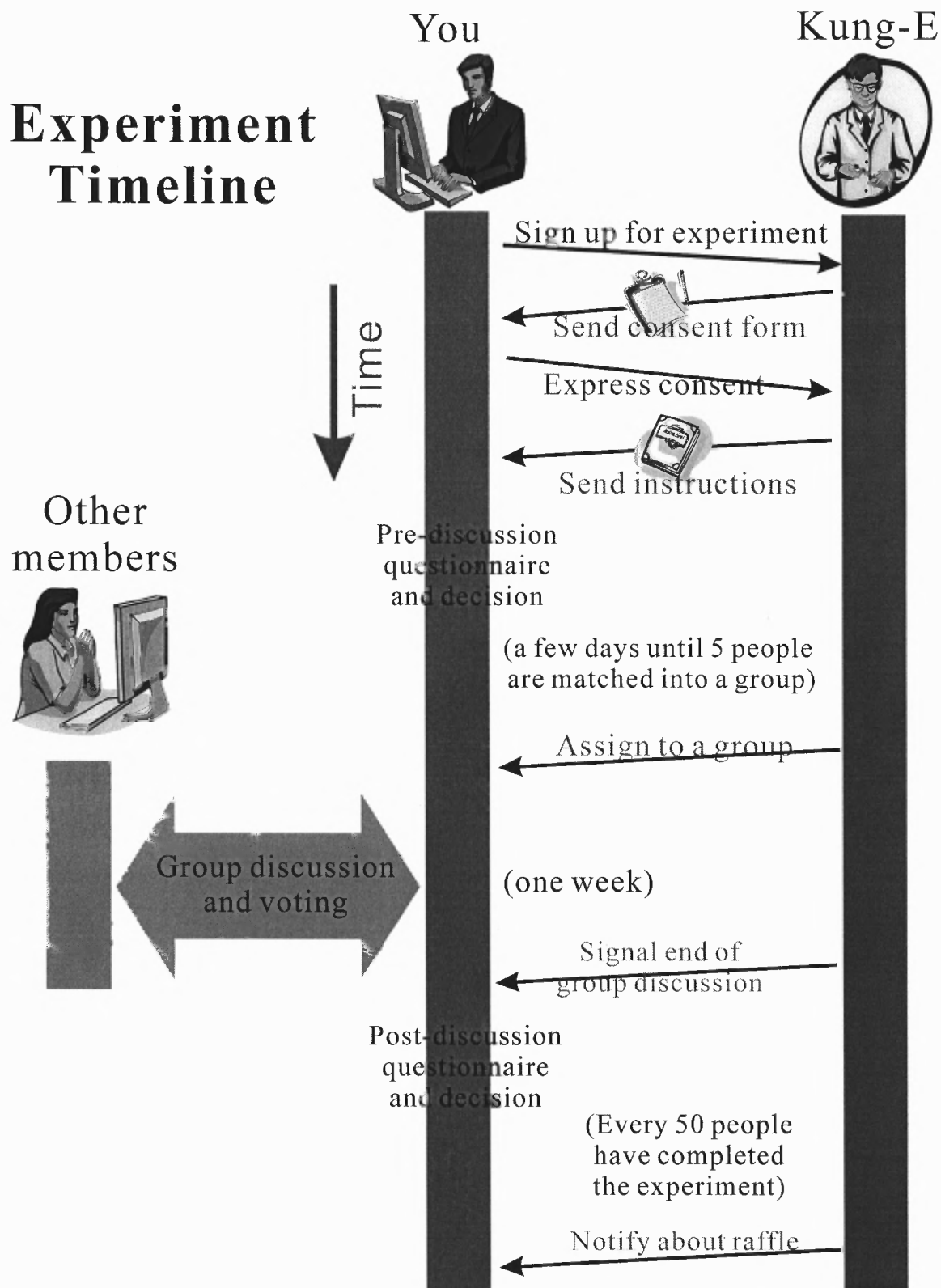


Figure 8.1 Timeline of events in the experiment.

## 8.4 Hypotheses to Be Tested in the Experiment

Although the experiment in this study is exploratory, hypotheses were still developed based on the framework for this experiment. Since it was decided that this experiment session would focus on voting method bandwidth, only hypotheses related to voting method bandwidth are discussed in this section. One should note that these hypotheses are constructed based on the context of the experiment setting. Due to the complexity and interaction among factors in GSS voting, some of the hypotheses might change in a different setting. For example, the groups in this experiment are newly formed without prior history, interactions among members will be different from what would happen in groups that have previously worked together. There is also a preset deadline for the final group decision instead of allowing groups to reach a final decision with no time limit. Group members might also act differently due to time pressure.

The hypotheses covered both objective and subjective measures. The objective measures to be tested were: level of consensus, rounds of voting, and number of messages posted. The subjective measures to be tested were: perceived process gains/losses, information use, perceived usefulness of the voting tool, perceived decision process quality, perceived decision quality, group cohesiveness, decision confidence, and general satisfaction.

### 8.4.1 Hypotheses for Objective Measures

**8.4.1.1 Level of Consensus.** The level of consensus measures the degree of agreement reached by group members. Because a greater amount of information about members' preferences was exchanged through voting in a high bandwidth method, the group can identify agreement and disagreement more easily. Members can concentrate more on

resolving disagreement instead of wasting time wading through inconsequential opinions in the discussion. The more time spent in resolving disagreement should lead to a higher level of consensus.

*H1: The level of consensus will be higher for groups using a high bandwidth voting method.*

**8.4.1.2 Rounds of Voting.** A high bandwidth voting method permits more precise expression of members' preferences. The expressive power of a high bandwidth voting method should enable a group to use less rounds of voting to discover members' preferences in order to reach a decision.

*H2: Groups will use less rounds of voting in a high bandwidth voting method to reach decision.*

**8.4.1.3 Number of Messages Posted.** As pointed out by Hollingshead (Hollingshead, 1996), a group is likely to find similarities and disparities in members' preference profiles in a high bandwidth voting method and then it can explore the underlying reasons for agreement/disagreement more deeply. The exploration will lead the group to exchange more information in discussion, i.e., members will post more messages with a high bandwidth voting method. In addition, a high bandwidth voting method allows members to cover more alternatives during one round of voting, members can start more discussion threads based on the result of a high bandwidth voting method.

*H3: Group members will post more messages during discussion with a high bandwidth voting method.*

## **8.4.2 Hypotheses for Subjective Measures**

**8.4.2.1 Perceived Process Gains/Losses.** Members perceive group process gains when the decision process is germane to the task and group process losses when the process is not connected to the task (Steiner, 1972). A high bandwidth voting method



provides more information related to alternatives being considered than a low bandwidth voting method does, thus group members will focus more on task related discussions. This will increase group process gains and reduce group process losses.

*H4: Group members will perceive more group process gains and less group process losses with a high bandwidth voting method.*

**8.4.2.2 Information use.** Information use is the degree one person considers information provided by other people when making his or her decision. The person may or may not change his or her position because of this information (Dennis, 1996). A voting high bandwidth method enables group members to classify and examine arguments by others more easily. A member can concentrate more of his or her attention on information provided by other people leading to agreement or disagreement in voting.

*H5: Group members will consider more information provided by other people with a high bandwidth voting method.*

**8.4.2.3 Perceive Usefulness for Voting Tool.** A high bandwidth voting method allows members more precision in expressing one's preferences. It also enables the group to identify agreement or disagreement more easily. Members should perceive the voting tool using a high bandwidth voting method as more useful.

*H6: Group members will perceive higher usefulness for voting tools with a high bandwidth voting method.*

**8.4.2.4 Perceived Decision Process Quality.** A voting tool with a high bandwidth voting method will allow group members to focus more on task-related and less irrelevant discussions than a voting tool with a low bandwidth voting method does. Members will perceive the decision process as having higher quality due to the impression that it is more efficient and well-structured.

*H7: Groups with a high bandwidth voting method will perceive higher decision process quality.*

**8.4.2.5 Perceive Decision Quality.** Group members will need to work harder and there is more information to be discussed in a high bandwidth voting method situation. Deeper processing of information by individuals can lead to better decision quality (Hilmer & Dennis, 1999). The group will also have a greater possibility in discovering critical unshared information by looking at unusual preference patterns among members. All these should make members in groups using a high bandwidth voting method perceive higher decision quality.

*H8: Groups with a high bandwidth voting method will perceive higher decision quality.*

**8.4.2.6 Group Cohesiveness.** Group cohesiveness is the degree to which members of a group desire to remain in the group. Voting with a high bandwidth voting method focuses members more on task-related information. As a result, individuals may feel the discussions to resolve differences are about issues rather than about the individuals personally. Members will feel that they have less personal conflicts with others in a high bandwidth voting method condition, thus creating higher group cohesiveness.

*H9: Groups with a high bandwidth voting method will have higher group cohesiveness.*

**8.4.2.7 Perceive Decision Confidence.** Interaction among members will make members feel more confident about their decision (Heath & Gonzalez, 1995). Since a high bandwidth voting method prompts interaction among members, it will lead to higher confidence with the decision.

*H10: Groups with a high bandwidth voting method will perceive higher decision confidence.*

**8.4.2.8 General Satisfaction.** Members should experience many positive effects: precise expression of preferences, ease in identifying disagreements, and better decision

process, utilizing a high bandwidth voting method. Members should have higher level of general satisfaction.

*H11: Groups utilizing a high bandwidth voting method will have higher general satisfaction.*

### 8.4.3 Summary of Hypotheses

Table 8.2 summarizes the hypotheses to be tested in this experiment.

**Table 8.2 Summary of Hypotheses**

		<b>Measures</b>	<b>Predictions by the Framework</b>
Objective Measures	H1	Level of Consensus	High Bandwidth > Low Bandwidth
	H2	Rounds of Voting	High Bandwidth < Low Bandwidth
	H3	Number of Messages Posted	High Bandwidth > Low Bandwidth
Subjective Measures	H4	Perceived Process Gains/Losses	High Bandwidth > Low Bandwidth
	H5	Information Use	High Bandwidth > Low Bandwidth
	H6	Perceived Usefulness of Voting Tool	High Bandwidth > Low Bandwidth
	H7	Perceived Decision Process Quality	High Bandwidth > Low Bandwidth
	H8	Perceived Decision Quality	High Bandwidth > Low Bandwidth
	H9	Group Cohesiveness	High Bandwidth > Low Bandwidth
	H10	Decision Confidence	High Bandwidth > Low Bandwidth
	H11	General Satisfaction	High Bandwidth > Low Bandwidth

## CHAPTER 9

### RESULTS AND DISCUSSION

#### 9.1 Background Information of Subjects

Subjects were recruited by posting flyers on campus, giving presentations during classes, sending out invitations on mailing lists, and setting up a recruiting table in the Campus Center. Although the effort for recruiting subject was focused at students in campus, the majority of people who signed up for the experiment were not students in school. Many subjects were people who responded to invitations on mailing lists or messages forwarded by their friends. A total of 12 groups, 6 groups in high voting method bandwidth condition (groups HF02 to HF07) and 6 in low voting method bandwidth condition (groups LF01 to LF06), have completed the experiment. The number of subjects that have completed the experiment was 53. There were 7 subjects who dropped out from the experiment during the group discussion.

Because a lot of non-NJIT subjects signed up, only 20 of the 53 subjects were students. The occupations of subjects included student, engineer, accountant, architect, data analyst, school administrator, director in a private company, programmer, manager, paralegal, biostatistician, researcher, pharmacist, controller, college professor, teacher, secretary, and stay at home mom. The ages of subjects ranged from 20 to 54, with an average of 35.76. The average of self reported working experience is 9.59 years, range from 0 to 25 years. The ages and working experience for each group are shown in Table 9.1. The subjects consisted of 36 females and 17 males. Two subjects in high voting method bandwidth condition did not report their education level. Thirteen subjects had

education at bachelor level. Fourteen subjects were with master level education. Twenty-four subjects had a Ph.D. level of education. Subject's experience level in using Web-based discussion forums was divided toward either frequently or seldom used such a tool. Tables 9.2 and 9.3 describe the distribution of gender, education level, and experience in using Web-based discussion forums for subjects in the experiment.

**Table 9.1 Ages and Working Experience of Subjects**

		Age (Years)			Work Experience (Years)		
		Minimum	Maximum	Mean	Minimum	Maximum	Mean
High Bandwidth Group	HF02	33	51	43.8	1	20	12.5
	HF03	28	36	32.0	2	5	3.7
	HF04	26	45	36.2	5	20	11.0
	HF05	25	46	38.4	3	23	13.2
	HF06	25	40	34.0	1	22	10.4
	HF07	33	43	37.2	5	15	9.2
	Subtotal	25	51	37.0	1	23	10.4
Low Bandwidth Group	LF01	22	46	30.7	0	25	11.8
	LF02	21	47	35.3	0	21	11.8
	LF03	32	54	40.0	1	10	6.0
	LF04	20	35	26.7	0	16	4.9
	LF05	31	44	36.2	4	24	11.0
	LF06	24	43	34.0	0	18	6.5
	Subtotal	20	54	34.3	0	25	8.7
<b>Total</b>		20	54	35.8	0	25	9.6

**Table 9.2 Gender and Education Level of Subjects**

		Gender		Education Level			
		Female	Male	Not Indicated	Bachelor	Master	Ph.D.
High Bandwidth Group	HF02	3	1	0	2	1	1
	HF03	3	1	0	1	1	2
	HF04	4	1	1	0	0	4
	HF05	2	3	0	0	4	1
	HF06	5	0	1	1	2	1
	HF07	2	3	0	0	2	3
	Subtotal	19	9	2	4	10	12
Low Bandwidth Group	LF01	2	2	0	3	0	1
	LF02	3	1	0	1	2	1
	LF03	3	1	0	1	0	3
	LF04	3	1	0	3	0	1
	LF05	3	2	0	1	1	3
	LF06	3	1	0	0	1	3
	Subtotal	17	8	0	9	4	12
<b>Total</b>	36	17	2	13	14	24	

**Table 9.3 Experience in Using Web-based Discussion Program**

		Web-based Discussion Program Usage				
		Never	Once or twice	Three to five times	Six to ten times	Frequently
High Bandwidth Group	HF02	2	0	0	1	1
	HF03	1	1	1	1	0
	HF04	0	2	1	0	2
	HF05	2	1	0	1	1
	HF06	2	1	0	0	2
	HF07	0	2	0	1	2
	Subtotal	7	7	2	4	8
Low Bandwidth Group	LF01	2	0	0	0	2
	LF02	1	1	0	0	2
	LF03	0	1	0	0	3
	LF04	0	1	1	1	1
	LF05	2	1	0	1	1
	LF06	0	2	1	0	1
	Subtotal	5	6	2	2	10
<b>Total</b>		12	13	4	6	18

The average time spent on the experiment task by subjects is 2.32 hours based on the after-task self report (Table 9.4). There was no significant difference between the low and high voting method bandwidth conditions for the self-reported time spend on task.

**Table 9.4 Self-reported Time Spend on Task by Subjects**

		Self-reported Time Spend on Task (Hours)		
		Minimum	Maximum	Mean
High Bandwidth Group	HF02	1.00	4.50	2.38
	HF03	.67	2.50	1.59
	HF04	1.00	4.08	2.22
	HF05	3.00	6.00	4.50
	HF06	.33	3.00	1.77
	HF07	.67	2.50	1.83
	Subtotal	.33	6.00	2.41
Low Bandwidth Group	LF01	2.50	5.33	3.71
	LF02	.67	2.00	1.29
	LF03	1.17	3.00	1.92
	LF04	1.00	6.50	3.38
	LF05	.50	3.00	2.05
	LF06	.50	1.33	1.00
	Subtotal	.50	6.50	2.22
<b>Total</b>		.33	6.50	2.32

## 9.2 Objective Measures

Table 9.5 depicts objective data from the 12 groups in this experiment. Three objective measures, level of consensus, rounds of voting, and number of messages posted, will be discussed in this section.

Table 9.5 Objective Data from Experiment Groups

Group	High Bandwidth							Low Bandwidth					
	HF02	HF03	HF04	HF05	HF06	HF07	LF01	LF02	LF03	LF04	LF05	LF06	
Date Started	3/6/2007	3/9/2007	3/28/2007	5/15/2007	5/29/2007	5/29/2007	3/16/2007	3/22/2007	4/10/2007	5/15/2007	5/29/2007	5/29/2007	
Date Ended	3/13/2007	3/16/2007	4/4/2007	5/22/2007	6/5/2007	6/5/2007	3/23/2007	3/29/2007	4/17/2007	5/22/2007	6/5/2007	6/5/2007	
Number of Subjects Completed Task	4	4	4	5	5	5	4	4	5	4	5	4	
Number of Dropped Out	1	1	1	0	0	0	1	1	0	1	0	1	
Reached Full Ranking	N	N	N	N	Y	N	Y	N	N	Y	N	N	
Level of Consensus	3	4	3	5	6	4	6	3	3	6	1	2	
Rounds of Voting	2	3	2	4	2	2	3	4	3	4	2	3	
Number of Postings #1	1	5	1	2	1	1	4	3	3	8	1	3	
Number of Postings #2	2	5	2	3	1	1	4	3	4	8	2	4	
Number of Postings #3	2	6	3	3	3	2	5	4	6	10	3	4	
Number of Postings #4	5	7	4	5	5	3	11	8	6	21	4	6	
Number of Postings #5	.	.	.	8	5	3	.	.	8	.	4	.	
Total Posting	10	23	10	21	15	10	24	18	27	47	14	17	
Average Posting per Subject	2.5	5.75	2.5	4.2	3	2	6	4.5	5.4	11.75	2.8	4.25	



### 9.2.1 Level of Consensus

The level of consensus measures the degree of agreement reached by group members. Not every group reached a final ranking for all the six programs for the group decision. This could be caused by the lack of motivation in completing the experiment task or the lack of familiarity with asynchronous mode of communication. People were also not familiar with the concept of using multiple rounds of voting for making a decision, thus had difficulty in using the GSS voting tool. Because not every group reached a final total agreement on the order of the six programs, the level of consensus was measured as the group categorized the programs into tiers. An agreement on the order of all the six programs would get a consensus measurement of 6, while no agreement on the order of any program would get a consensus measurement of 1. If the group agreed on only one program, the consensus measurement would be 2, that is, one tier for the agreed program, another one tier for the other five unordered programs. Similarly, if a group agreed on two or more programs at the same level but had not yet resolved the tie among the programs, these programs would be counted as in one tier. The level of consensus should be considered only as a rough estimation because the tiers are constructed from posted messages and the results of voting. Some members did not post in the group discussion to express whether they agree with this intermediate decision. It was assumed those members accepted the final group decision implicitly.

Although the average consensus level for groups with high bandwidth voting methods (consensus level=4.17) is slightly higher than groups with low bandwidth voting methods (consensus level=3.50) as predicated in the framework, there is no significant difference in the level of consensus between the high and low bandwidth voting methods

condition by Wilcoxon Rank Sums test ( $W= 44.0$ ,  $p=0.2373$ , one-sided). However, groups reached roughly the same level of consensus with different amounts of communication via voting and discussion. The bandwidth of voting method leads to different communication patterns. This will be discussed in the next two sections.

### **9.2.2 Rounds of Voting**

The framework predicts that groups with low bandwidth voting methods would require more rounds of voting than groups with high bandwidth voting methods. The mean values of rounds of voting are 2.5 for the high bandwidth voting method condition and 3.167 for low bandwidth voting method condition, in line with the predicted direction by the framework. The non-parametric Wilcoxon Rank Sums test was used to check the significance of this prediction. The  $W$  statistics is 30.5 with one-sided  $p$  value 0.0998, which is significant at 0.1 level. However, this result should be looked upon with caution because many subjects were not used to multiple rounds of voting for decision making and some groups did make mistakes in the initial stage of using the voting tool.

### **9.2.3 Number of Messages Posted**

As shown in Table 9.5, a lot of subjects posted very few messages during the group discussion. It could be caused by the subjects' lack of commitment to the experiment or underestimation of the level of interaction required for reaching agreement in an asynchronous environment. The average number of messages posted by a member can be seen as an index of information exchanged among members. The framework predicts that groups with a high bandwidth voting method would exchange more information than groups with a low bandwidth voting method based on the experiment

results by Hollingshead (1996). Interestingly, the observed number of postings is in the opposite direction to this prediction. High bandwidth voting method groups, on average, posted 3.325 messages per member, while low bandwidth voting method groups, on average, posted 5.783 messages per member. The  $W$  statistics is 27.0 with one-sided  $p$  value 0.0461, which is significant at 0.05 level.

In addition to the difference in voting tools used in these two studies, possible reasons for the reverse direction on the amount of information exchange could be due to the differences in tasks and of these two experiments. Firstly, the task used in the study by Hollingshead is a type 3 intellective task (decision with a correct answer) in McGrath's task circumplex, while the task in this research is a type 4 preference task (decision with no right answer). Secondly, there are only three alternatives in Hollingshead's experiment compared to six alternatives in this study. Thirdly, subjects in Hollingshead's experiment only needed to choose one alternative for their final decision, but subjects in this research had to decide the order of six alternatives. The amount of information exchange required is much larger in this experiment. The information exchanged via voting alone is not enough for the task in this study so subjects had to rely on discussions to exchange information to reach agreement. The information exchange was contingent on more than voting method bandwidth alone.

#### **9.2.4 Summary of Findings from Objective Measures**

Table 9.6 summarizes findings about objective measures. The level of consensus and rounds of voting did show trends as predicted in the framework. The number of messages posted was in the opposite direction as predicted in the framework, which implies there are factors other than bandwidth of voting methods that affect the number

of messages posted by group members. Interactions between task type and voting method bandwidth may play a role in the amount of information exchanged. Further investigation on this subject is necessary to uncover factors and their interactions on voting and the amount of information exchange among members.

**Table 9.6 Summary of Findings of Objective Measures**

Outcome Measure	Prediction in the Framework	Observations	Wilcoxon Rank Sums Test <i>p</i> Value	Result
Level of Consensus	High Bandwidth > Low Bandwidth	High Bandwidth=4.17 Low Bandwidth=3.50	<i>W</i> =44.0 <i>p</i> =0.2373	High Bandwidth > Low Bandwidth, but no significant difference
Rounds of Voting	High Bandwidth < Low Bandwidth	High Bandwidth=3.167 Low Bandwidth=2.50	<i>W</i> =30.5 <i>p</i> =0.0998*	High Bandwidth < Low Bandwidth
Number of Messages Posted	High Bandwidth > Low Bandwidth	High Bandwidth=3.325 Low Bandwidth=5.783	<i>W</i> =27.0 <i>p</i> =0.0461**	High Bandwidth < Low Bandwidth, opposite as predicted in the framework

\* significant at 0.1 level    \*\* significant at 0.05 level

### 9.3 Subjective Measures

As Walczuch & Watson (2001) have pointed out, it is wrong to analyze data with individual subjects as the unit of analysis if the experiment is designed to investigate groups or there is significant interaction among group members. The argument holds true even if the group memberships are established randomly. Groups will become differentiated with interactions. The differentiation means the group and its members will influence and are influenced by this group membership (Goldstein, 1995, p. 2). The correct way for analyzing group data is to either aggregate individual data by groups then analyze at group level or to use a hierarchal model. It would be ideal if data from a group-based experiment could be analyzed with hierarchal models. The result for testing for significance of treatment effect is equivalent in both approaches. The hierarchal model also has the additional advantage of testing if there is a significant effect

of grouping. Unfortunately there were only a small number of groups and an unequal number of subjects in each group, the hierarchical ANOVA model presented by Walczuch & Watson (2001) is not suitable for analyzing data collected from this experiment. The subjective measures in this experiment were first aggregated by groups then tested with non-parametric Wilcoxon Rank Sums test to assess the differences between the low and high voting method bandwidth conditions.

Subjective measures were collected by post-experiment questionnaires. Those subjective measures include: perceived process gains and losses, perceived usefulness of voting tools, perceived decision process quality, group cohesiveness, perceived decision quality, and general satisfaction. The scores of these subjective measurements were transformed and normalized to the range of -3.0 to 3.0 before analysis. Table 8.7 shows the subjective measures aggregated at group level from each group. Reliabilities of all the subjective measurements were checked. The Cronbach's  $\alpha$  for all subjective measurements are greater than 0.75, the commonly accepted threshold for test of reliability.

Table 9.7 Subjective Measures, Aggregated at Group Level

Bandwidth	Group	Perceived Process Gains/Losses	Information Use	Perceived Usefulness of Voting Tool	Perceived Decision Process Quality	Perceived Decision Quality	Group Cohesiveness	Decision Confidence	General Satisfaction	
H i s h	HF02	1.7500	1.55556	1.54167	1.86667	2.33333	2.55556	2.20833	2.13333	
	HF03	0.5625	1.16667	1.20833	0.35000	1.75000	0.91667	1.62500	1.17500	
	HF04	0.9500	1.60000	1.56667	0.88000	1.55000	1.55000	1.26667	0.96000	
	HF05	1.1500	0.73333	0.96667	0.72000	1.25000	1.25000	0.50000	1.30000	
	HF06	0.7500	-1.33333	1.83333	1.90000	1.68750	1.68750	1.16667	0.79167	1.05000
	HF07	0.9500	0.60000	1.53333	0.96000	1.55000	1.55000	1.00000	0.90000	1.36000
	LF01	1.3125	-0.11111	1.37500	1.00000	1.43750	1.43750	0.75000	0.45833	1.35000
L o w	LF02	0.0000	0.50000	1.54167	0.50000	0.68750	1.41667	1.25000	0.85000	
	LF03	1.3125	0.91667	1.83333	1.05000	2.18750	1.00000	1.12500	0.55000	
	LF04	1.8125	1.33333	0.83333	1.25000	1.87500	0.91667	1.41667	1.05000	
	LF05	0.9000	0.33333	1.16667	1.04000	1.80000	0.80000	0.73333	1.08000	
	LF06	0.6875	0.00000	1.41667	1.85000	1.56250	0.83333	0.83333	1.35000	

### 9.3.1 Perceived Process Gains/Losses

Perceived process gains/losses were measured by 4 questions of 7-point semantic difference scale (Table 9.8). The questions were adapted from Watson (1987). Table 9.9 shows the analysis of perceived process gains/losses. There is no difference between high and low bandwidth voting method conditions in perceived process gains/losses ( $W=38.0$ ,  $p=0.469$ , one-sided).

**Table 9.8 Instrument for Perceived Process Gains/Losses**

3. The group members initiated the discussion on:		
Relevant issues	1-----2-----3-----4-----5-----6-----7	Irrelevant issues
4. The group members' contributions were:		
Well expressed	1-----2-----3-----4-----5-----6-----7	Poorly expressed
5. Participation in the discussion was:		
Evenly distributed	1-----2-----3-----4-----5-----6-----7	Unevenly distributed
6. The interpersonal relationships among the group members appeared to be:		
Healthy	1-----2-----3-----4-----5-----6-----7	Unhealthy

**Table 9.9 Result of Perceived Process Gains/Losses**

Perceived Process Gains/Losses		
Reliability Cronbach's $\alpha = 0.78$		
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	26	1.019
Low Bandwidth	25	1.004
Wilcoxon Rank Sums Test $W=38.0$ $p=0.469$ , one-sided		

### 9.3.2 Information Use

The questions for information use were adapted from Dennis (1996). It was measured by 3 questions of 7-point semantic difference scale (Table 9.10). The framework proposes that high bandwidth voting methods increase information use as more information was expressed via voting and multiple alternatives to be compared at the

same time. The high bandwidth voting method groups did show a little higher information use than low bandwidth voting method groups did (Table 9.11), however, the difference was not significant ( $W=46.0$ ,  $p=0.160$ , one-sided).

**Table 9.10 Instrument for Information Use**

12. To what extent did information contributed by others cause you to re-evaluate your choice (even if you did not change it)?	Very much	1-----2-----3-----4-----5-----6-----7	Not at all
13. To what extent did something someone else contributed make you take a second look at your choice (whether you changed your mind or not)?	Very much	1-----2-----3-----4-----5-----6-----7	Not at all
14. To what extent did the information contributed by others affect your decision (whether you changed your original decision or not)?	Very much	1-----2-----3-----4-----5-----6-----7	Not at all

**Table 9.11 Result of Information Use**

Information Use		
Reliability Cronbach's $\alpha = 0.92$		
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	26	0.720
Low Bandwidth	25	0.495
Wilcoxon Rank Sums Test $W=46.0$ $p=0.160$ , one-sided		

### 9.3.3 Perceived Usefulness of Voting Tool

Perceived usefulness of the voting tool was measured by 6 questions on a 7-point Likert scale (Table 9.12). The questions were adapted from Davis (1989). While groups in both conditions found that the voting tool was useful, the difference between the two conditions is not significant ( $W=43.0$ ,  $p=0.293$ , one-sided, Table 9.13).



**Table 9.12 Instrument for Perceived Usefulness of Voting Tool**

Strongly Agree	Agree	Somewhat Agree	Undecided	Somewhat Disagree	Disagree	Strongly Disagree
26. The voting tool helps me understand the positions of other members.						
1-----	2-----	3-----	4-----	5-----	6-----	7-----
27. The voting tool helps the group focused on the task.						
1-----	2-----	3-----	4-----	5-----	6-----	7-----
28. Using the voting tool enables the group to reach the decision more easily.						
1-----	2-----	3-----	4-----	5-----	6-----	7-----
29. The voting tool improves the group decision making process.						
1-----	2-----	3-----	4-----	5-----	6-----	7-----
30. The voting tool is ineffective in helping the group making the decision.						
1-----	2-----	3-----	4-----	5-----	6-----	7-----
31. I think the voting tool is useful for group making decisions.						
1-----	2-----	3-----	4-----	5-----	6-----	7-----

**Table 9.13 Result of Perceived Usefulness of Voting Tool**

Perceived Usefulness of Voting Tool		
Reliability Cronbach's $\alpha = 0.90$		
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	27	1.442
Low Bandwidth	25	1.361
Wilcoxon Rank Sums Test $W=43.0$ $p=0.293$ , one-sided		

### 9.3.4 Perceived Decision Process Quality

Perceived decision process quality was measured by 5 questions on a 7-point semantic difference scale (Table 9.14). The questions were adapted from Green & Taber (Green & Taber, 1980). As can be seen from the analysis shown in Table 9.15, there is virtually no difference between high and low bandwidth voting method groups ( $W=36.0$ ,  $p=0.348$ , one-sided), although the framework predicted high bandwidth voting method groups would have higher perceived decision process quality.

**Table 9.14 Instrument for Perceived Decision Process Quality**

7. How would you describe your group's problem solving approach?		
Efficient	1-----2-----3-----4-----5-----6-----7	Inefficient
Coordinated	1-----2-----3-----4-----5-----6-----7	Uncoordinated
Fair	1-----2-----3-----4-----5-----6-----7	Unfair
Understandable	1-----2-----3-----4-----5-----6-----7	Confusing
Satisfying	1-----2-----3-----4-----5-----6-----7	Unsatisfying

**Table 9.15 Result of Perceived Decision Process Quality**

Perceived Decision Process Quality		
Reliability Cronbach's $\alpha = 0.86$		
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	26	1.113
Low Bandwidth	25	1.115
Wilcoxon Rank Sums Test $W=36.0$ $p=0.348$ , one-sided		

### 9.3.5 Perceived Decision Quality

Perceived decision quality was measured by 4 questions on a 7-point semantic difference scale (Table 9.16). The questions were adapted from Davison (1997). The framework predicted high bandwidth voting method groups would have higher perceived decision quality, but there is no difference between the two bandwidth voting method conditions ( $W=38.0$ ,  $p=0.469$ , one-sided, Table 9.17).

**Table 9.16 Instrument for Perceived Decision Quality**

8. With regard to all group members as a whole, how would you rate the discussion for the task in terms of the following scales?		
Very meaningful	1-----2-----3-----4-----5-----6-----7	Totally meaningless
Vary appropriate	1-----2-----3-----4-----5-----6-----7	Totally inappropriate
Very free and open	1-----2-----3-----4-----5-----6-----7	Totally closed/restricted
Creative/imaginative	1-----2-----3-----4-----5-----6-----7	Familiar/unimaginative

**Table 9.17 Result of Perceived Decision Quality**

<b>Perceived Decision Quality</b>		
Reliability Cronbach's $\alpha = 0.79$		
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	26	1.687
Low Bandwidth	25	1.592
Wilcoxon Rank Sums Test $W=38.0$ $p=0.469$ , one-sided		

### 9.3.6 Group Cohesiveness

Perceived decision quality was measured by 4 questions on a 7-point semantic difference scale (Table 9.18). The data shows a trend for higher group cohesiveness in the high bandwidth voting groups as predicted in the framework, but the difference is not significant ( $W=44.5$ ,  $p=0.220$ , one-sided, Table 9.19).

**Table 9.18 Instrument for Group Cohesiveness**

9. To what extent were members in the group you worked with in this experiment helpful in getting the task done? Very helpful 1-----2-----3-----4-----5-----6-----7 Not at all
10. To what extent would you look forward to working with this group again? Definitely yes 1-----2-----3-----4-----5-----6-----7 Definitely no
11. To what extent did you trust members in the group you worked with in this experiment? Totally trusted 1-----2-----3-----4-----5-----6-----7 Not at all

**Table 9.19 Result of Group Cohesiveness**

<b>Group Cohesiveness</b>		
Reliability Cronbach's $\alpha = 0.77$		
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	25	1.234
Low Bandwidth	25	0.953
Wilcoxon Rank Sums Test $W=44.50$ $p=0.220$ , one-sided		

### 9.3.7 Decision Confidence

Decision confidence was measured by 6 questions on a 7-point Likert scale (Table 9.20). While groups with high bandwidth voting method expressed a little higher confidence in their decisions than groups with high bandwidth voting methods did, the difference between the two conditions is not significant ( $W=42.0$ ,  $p=0.348$ , one-sided, Table 9.21).

**Table 9.20 Instrument for Decision Confidence**

	Strongly Agree	Agree	Somewhat Agree	Undecided	Somewhat Disagree	Disagree	Strongly Disagree
20. I am confident that our group's decision is good.	1	2	3	4	5	6	7
21. I feel very committed to our group's decision.	1	2	3	4	5	6	7
22. I am not confident about the group's final decision.	1	2	3	4	5	6	7
23. The group made a good decision for this task.	1	2	3	4	5	6	7
24. I have doubts about the group's final decision.	1	2	3	4	5	6	7
25. I am confident that I can convince others that the group's decision is appropriate.	1	2	3	4	5	6	7

**Table 9.21 Result of Decision Confidence**

Decision Confidence		
Reliability	Cronbach's $\alpha = 0.91$	
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	27	1.132
Low Bandwidth	25	0.969
Wilcoxon Rank Sums Test $W=42.0$ $p=0.348$ , one-sided		

### 9.3.8 General Satisfaction

General satisfaction was measured by 5 questions on a 7-point semantic difference scale (Table 9.22). The questions were adapted from Dennis (1996). The framework predicted high bandwidth voting method groups would have higher general satisfaction

and data showing a trend in this direction, but the difference between the two bandwidth voting method conditions was not significant ( $W=45.5$ ,  $p=0.178$ , one-sided, Table 9.23).

**Table 9.22 Instrument for General Satisfaction**

1. To what extent did you enjoy participating in this discussion?	Very much	1-----2-----3-----4-----5-----6-----7	Not at all
2. How much fun was working on this task?	Very much	1-----2-----3-----4-----5-----6-----7	Not at all
15. How do you feel about the process by which the group made its decision?	Very satisfied	1-----2-----3-----4-----5-----6-----7	Very unsatisfied
16. How do you feel about your group's discussion?	Very satisfied	1-----2-----3-----4-----5-----6-----7	Very unsatisfied
17. All in all, how do you feel?	Very satisfied	1-----2-----3-----4-----5-----6-----7	Very unsatisfied

**Table 9.23 Result of General Satisfaction**

General Satisfaction		
Reliability	Cronbach's $\alpha = 0.85$	
	Valid Individual Response N	Mean of Group Responses
High Bandwidth	26	1.330
Low Bandwidth	25	1.038
Wilcoxon Rank Sums Test $W=45.5$ $p=0.178$ , one-sided		

### 9.3.9 Summary of Findings from Subjective Measures

Table 9.24 summarizes findings about subjective measures. Although the data showed some trends for factors such as information use, group cohesiveness, decision confidence and general satisfaction as predicted in the framework, none of the subjective measures were significant when tested with Wilcoxon rank sum method. The small sample size of only 6 groups in either treatment conditions was a major factor for the result of no significant differences in subjective measures. However, other factors might also play a

part in this experiment so the subjective measures did not show significant difference.

Those factors will be discussed in the limitation section later in this chapter.

**Table 9.24 Summary of Findings of Subjective Measures**

Outcome Measure	Prediction in the Framework	Observations	Wilcoxon Rank Sums Test $p$ Value	Result
Perceived Process Gains/Losses	High Bandwidth > Low Bandwidth	High Bandwidth=1.019 Low Bandwidth=1.004	$W=38.0$ $p=0.469$	No Difference
Information Use	High Bandwidth > Low Bandwidth	High Bandwidth=0.720 Low Bandwidth=0.495	$W=46.0$ $p=0.160$	High Bandwidth > Low Bandwidth, not significant
Perceived Usefulness of Voting Tool	High Bandwidth > Low Bandwidth	High Bandwidth=1.442 Low Bandwidth=1.361	$W=43.0$ $p=0.293$	No Difference
Perceived Decision Process Quality	High Bandwidth > Low Bandwidth	High Bandwidth=1.113 Low Bandwidth=1.115	$W=36.0$ $p=0.348$	No Difference
Perceived Decision Quality	High Bandwidth > Low Bandwidth	High Bandwidth=1.687 Low Bandwidth=1.592	$W=38.0$ $p=0.469$	No Difference
Group Cohesiveness	High Bandwidth > Low Bandwidth	High Bandwidth=1.234 Low Bandwidth=0.953	$W=44.5$ $p=0.220$	High Bandwidth > Low Bandwidth, not significant
Decision Confidence	High Bandwidth > Low Bandwidth	High Bandwidth=1.132 Low Bandwidth=0.969	$W=42.0$ $p=0.348$	High Bandwidth > Low Bandwidth, not significant
General Satisfaction	High Bandwidth > Low Bandwidth	High Bandwidth=1.330 Low Bandwidth=1.038	$W=45.5$ $p=0.178$	High Bandwidth > Low Bandwidth, not significant

#### 9.4 Group Interactions

The way a group adopts GSS tools could be a source for the difference in performance (Dennis, Wixom, & Vangerberg, 2001). This section will report some observations of interactions among group members for groups that reached a high level of consensus and those that reached a low level of consensus. Key factors for the difference in performance were explored. Four factors were observed to play important roles in group performance. The four factors are the early participation by members, leadership,

a well defined and announced procedure for voting, and using voting tool to identify agreements.

#### **9.4.1 Early Participation by Members**

It is important for members to start interacting with each other early on. The momentum of early interactions then will be carried over to the rest of the decision session. This reflects the concept of swift trust in virtual teams (Meyerson, Weick, & Kramer, 1996). Groups HF05 and LF04 clearly demonstrated the importance of this factor. Both groups reached high levels of consensus. The momentum of group interaction even lived on longer than the duration of the task as some members in these two groups posted messages to express their feelings about the task and the group after the final decision deadline.

#### **9.4.2 Leadership**

The group leaders in this experiment had a great control over the voting tool. They could decide when to start or end a voting session and which alternatives would be included in a round of voting. The power of the group leader over the voting procedure is best summarized by this comment from a subject in the post-task questionnaire:

*“The group leader made decisions on which choices to remove from the next round of voting, and I didn't see a whole lot of people concur with his choices. To be fair to the group leader, whom I thought did a good job, his choices did seem in line with the voting, and no one disagreed with his choices.”*

A group leader can shape the decision process by using the voting tool. It becomes critical for leaders not to wait for a slow or non-active member to end a voting session within a reasonable time, otherwise the group discussion will slow down and die

because there is no voting result to discuss. Group HF04 suffered from this kind of situation due to waiting for a member who never posted or voted.

#### **9.4.3 Well Defined and Announced Procedure for Voting**

The interactions in group HF06 are interesting and clearly showed the power of voting as an agreed procedure for reaching agreement. The group leader made an announcement in the beginning of the discussion that the group would reach its decision using the following procedures: the group will vote once in the beginning to discover the differences among members, discuss and resolve the differences, then a final vote in the end would be used as the group decision. The starting and ending time for both rounds of voting were also clearly stated in the announcement. No one in the group questioned the procedure. The group followed this procedure and accepted the result of the second round voting as its final decision.

#### **9.4.4 Using Voting Tools to Identify Agreements**

The advantage of comparing multiple alternatives at the same time and finding common middle ground with a high bandwidth voting method was evident when examining the interactions among members in groups HF07 and LF06. Both groups failed to reach a high level of consensus. However, group HF07 was able to find out that they could break the six programs into three tiers with the information in average score voting. On the other hand, group LF06 did not reach agreement on any program. A member posted messages declaring he could not accept the winning program from the first round of voting as the top program for the group decision. The group leader had to change the voting procedure by asking group members to choose the bottom program in the second



round of voting. Another member posted a strong message stating that he would not accept the program chosen in the second round of voting as the bottom program for the group decision. The discussion died because the group was deadlocked and members could not use the voting tool to find a middle ground to resolve their differences.

## **9.5 Limitations**

### **9.5.1 Recruitment of Subjects**

The experiment ran into several constraints, thus could not be completed as originally designed. The unit of analysis is group for group-related experiments. In order to achieve the desired statistical power, the required number of subjects has to be the required sample size multiplied by the number of members in one group. Because the IRB guidelines for human subject in research at the time the experiment was conducted would not allow participation in experiment as assignments in classes, subjects were recruited to the experiment by the possibility of winning a game console. Firstly, as could be seen in the case of recruiting subjects in the Campus Center, the incentive for participating in the experiment was not enough to attract large numbers of subjects. More than 40 people that expressed their interests in the experiment and took informational brochures, but only 3 people signed up for the experiment after the recruiting event ended. Secondly, the advertised 1 in 50 chance of winning the prize after completing the experiment was perceived as very small. There was evidence that subjects lost their interest and then dropped out from the experiment during the waiting period for matching them into a group. Some people who had signed up for the experiment did not respond to the messages requesting their consents for the experiment

or never completed the pre-group discussion questionnaires and individual decisions. For the people who did complete the experiment, it seemed their motivations were either interested in the research topic or to help the experiment investigator. The self-selection effect of purely voluntary subjects caused bias in the subjective data. The low possibility of winning the prize may have also contributed to the irregularity in responses in subject measures. The classical experiment on cognitive dissonance by Festinger (1957) has demonstrated that if a reward is perceived as much less value than the effort put into the task, people will judge the task as more interesting or more successful in order to justify the effort they have to spend on the task.

### 9.5.2 Artificial Task

Both artificial and real tasks are important in exploring the effect of voting. Although an artificial task provides better control in an experiment, subjects do not feel the task is related to them. Because performance and outcome satisfaction in a decision task are related to an individual's personal goal and vested interests (Briggs & de Vreede, 1997; Dennis et al., 2001), it becomes more difficult for the subjects to judge if they have made a good choice or are satisfied with the decision with an artificial task. This can be seen in one subject's comment in the post-task questionnaire:

*"Because some of the topics such as "Appeal Funding for Death Row Inmates" and "Abortion Subsidies for Low Income" are so far away from my life, its [sic] hard to say anything about it..."*

On the other hand, the lack of control in a real task would confound the effects of the factor being tested in the experiment. Thus, it will require experiments of both artificial and real tasks to fully explore the effects of factors in the GSS voting framework.

### 9.5.3 Unfamiliarity with Asynchronous Discussion and Voting Tools

Some subjects were not familiar with asynchronous discussion and how to use the voting for multiple rounds of voting. This was mentioned by several subjects in the post-task questionnaire:

*“It would be great if there is an example [sic] that can walk me through the process.”*

*“Lack of example. Don't know how to use it at the beginning.”*

*“I found it a little confusing to get the discussion going but once started we did OK.”*

*“Take a while learning to start the process - not uncommon to new task though.”*

This demonstrates that a practice task in the original experiment design would be very effective in addressing this limitation. The practice task planned had been eliminated due to an effort to keep the total time duration for the experiment reasonable. The practice task would have lengthened the one week experiment period. This length of time was deemed too long by many potential subjects and made recruiting difficult. Perhaps, a different reward system might provide enough incentive to make subjects willing to participate in both practice and experimental tasks.

## **CHAPTER 10**

### **SUMMARY AND CONCLUSION**

#### **10.1 Summary of Study**

The convergence to the final decision is an important and complex, yet a less studied, topic in GSS. Many researchers have proposed or observed that voting can be very useful in supporting the convergence process if it was used properly in the GSS context. Nonetheless, factors related to using voting in GSS have not been systematically researched. This research investigated theories, experiments, and field observations to form an integrated framework about voting in GSS. Various attributes of voting in GSS were identified as input factors. These input factors were linked to process and outcome factors by examining theories and experiments from previous research in GSS and other related fields such as decision science, political science, psychology, and communication research.

Voting tools and procedures in GSS should go beyond traditional paper-based voting by considering the computing and communication capability in GSS. In this research, functionalities for sophisticated voting tools in GSS were proposed by scrutinizing theories and reviewing existing GSS voting tools. Suggestions on how to implement advanced voting tools in existing GSS were also discussed.

A study was conducted to explore the effect of voting methods bandwidth proposed in the framework. Although the experiment had many restrictions, the results from objective measurements confirmed that voting methods bandwidth did affect the round of voting and amount of information exchanged by subjects. It also suggested that a contingency theory may be needed for future refinement of the framework because

interactions were found between task characteristics and voting methods bandwidth. Although results from subjective measures were not significant due to the small sample size in the study, many subjective measures did show a definitive trend in the predicted direction of the framework.

## **10.2 Contributions**

### **10.2.1 Contributions to Theory**

This research developed a framework for studying voting in GSS by examining both aggregation and communication aspects of voting. Bridging these two aspects is important because voting is primarily viewed as an aggregation activity while the communication effect has been overlooked in previous research. Many factors related to voting in GSS were identified and their effects were methodically analyzed in this study. In addition to reviewing the traditional ways of classifying voting methods, a new classification of voting methods was developed using the amount of information conveyed by casting a ballot. This new classification was partially tested in this research.

Results from the experiment demonstrated that the bandwidth of voting methods does make a difference in how groups make decisions. It confirms that the interactions among voting factors are vital in GSS voting. Moreover, task type appears to have strong influence in GSS voting. Additional theories for these interactions are necessary. The GSS voting framework provides a starting point for further theory building.

### **10.2.2 Contributions to Practices**

This research also contributes to the practical use of voting in GSS. It makes suggestions for functionalities to be considered by GSS designers in implementing

advanced GSS voting tools. Group facilitators can benefit by using the framework as a guideline when they use voting to emphasize certain aspects in the group processes and outcomes.

A GSS voting prototype was developed for this study. It proves that it is possible to integrate an advanced GSS voting tool into an existing system. The algorithm in the voting tool prototype can be used as a basis for developing more sophisticated GSS voting tools.

### **10.3 Directions for Future Studies**

Building a framework is only the first step in understanding the complexity of voting in GSS. Using this framework as a roadmap, there are many opportunities for future research. Listed below are four of the most prominent directions. There are many others to consider.

#### **10.3.1 Expanding and Validating the Framework**

The relationship between each input factor and each resulting process and outcome factor in the framework presents a research opportunity for theory building and validation. There will be even more potential research topics if the interactions among the input factors were also taken into account. Studies on the effect of long term use of voting could be another way to further refine the framework, as the history of using voting becomes feedback in the framework.

### **10.3.2 Designing of Sophisticated GSS Voting Tools**

The framework can be used as a guide on how to link group task goals through the effects of input factors to the functionality requirements of voting tools. Implementing sophisticated GSS voting tools and field testing these tools to collect actual usage data is a natural step for this research direction. This line of research could be extended into the area of Human Computer Interaction (HCI) by including topics like voting tools user interface design.

### **10.3.3 Matching GSS Voting to Specific Situations**

Special situations, such as emergency management or conflict resolution, may require special technology and process support in addition to the support for general group decision making. Identifying the requirements under these situations and then devising special and tailored voting tools and procedures that provide the necessary support is yet another line of possible future research.

### **10.3.4 Examining Organizational Issues in GSS Voting**

The last line of proposed future research is to expand the framework beyond its current scope. The use of voting in GSS may create organizational issues and ethical concerns. For instance, the possibility of power shifts in an organization or issues of confidentiality in voting. Rules to govern the acceptable use of voting in GSS should be considered. Some of these issues have been explored briefly when discussing possible effects of factors in the framework, but further securitization on this topic is necessary.

#### 10.4 Conclusion

In conclusion, voting is a common procedure in group decision making. Although voting was seen as a simple activity, it is a complex subject due to various factors and their interactions. In addition, GSS voting can be very different from traditional voting with the augmentation in computing and communication capability provided by GSS. Organizations and groups can benefit from better understanding of voting in GSS by using voting tools more effectively and efficiently. There is at present very little theory to guide the study and application of voting in GSS. Research investigating the relationship between voting, group processes, and decision making outcomes under a GSS is strongly needed. There remains much to explore and new directions to expand in GSS research. This framework will serve as a foundation for studying voting in GSS, an important subject that no doubt will become a rich and fruitful field for future GSS research.



## APPENDIX A

### THE SOCIAL CHOICE THEORY

Social choice theory (SCT) is the study of the aggregation of multiple preferences into a group choice. Craven (1992, p. 1) defines social choice theory as:

*“[Social choice theory] concerns the possibility of making a choice or a judgment that is in some way based on the views or preferences of a number of individuals, given that the views or preferences of different people may conflict with each other.”*

Nurmi (1987) suggests that SCT investigates the features of various methods used in aggregating individual preferences into collective decisions. Kenneth Arrow, one of the most influential scholars in SCT, considers that SCT provides a rational framework for making collective decisions (Arrow, 1997). However, SCT is not limited to determine collective choices. Multi-Criteria Decision Making (MCDM) shares many concepts with SCT. When an individual combines many dimensions of alternatives to make a decision, it can be viewed as an individualistic application of SCT (Nurmi, 2000).

#### A.1 Preferences

A brief explanation of key concepts in SCT is necessary before the analysis of attributes of various voting methods is presented. SCT is about combining individual preferences. Preference can be seen as the relative degree of desirability over a set of alternatives. Scholars in SCT have developed a set of notations to express preferences. Let's assume there are  $n$  individuals in a social choice system (e.g. a group, a committee, or a society). Each individual holds a preference (R) over a set of alternatives ( $T$ ). We can define relations  $P$  and  $I$  to express the preference. The relation  $P$  denotes that the alternative on

the left-hand side is strictly preferred to the alternative on the right-hand side. The relation  $I$  denotes that the individual is indifferent to these two alternatives. Usually a subscript index is used to indicate which person in the social choice system holds this preference. For example, given two alternatives  $a$  and  $b$ , the  $i^{\text{th}}$  person in the social choice system may prefer  $a$  to  $b$  (stated as  $aP_i b$ ), prefer  $b$  to  $a$  ( $bP_i a$ ), or be indifferent between these two ( $aI_i b$ ).

Another relation  $R$  is also commonly used in SCT to express that the alternative on the left-hand side is at least as preferable as the alternative on the right-hand side. We can think of  $R$  as a union of  $P$  and  $I$ . The expression  $aR_i b$  means that the  $i^{\text{th}}$  individual either prefers  $a$  to  $b$  or he/she is indifferent between  $a$  and  $b$  ( $aP_i b$  or  $aI_i b$ ).

There are two desired properties of preference: completeness and transitivity. A preference is complete if when giving any pair of alternatives,  $a$  and  $b$ , the individual can state either  $aP_i b$ ,  $bP_i a$ , or  $aI_i b$ . Transitivity is about the order of preference being preserved when more than two alternatives are compared. Giving three alternatives,  $a$ ,  $b$ , and  $c$ , we can have five types of transivities:

$aP_i b$  and  $bP_i c \Rightarrow aP_i c$  (PP Transitivity),

$aI_i b$  and  $bI_i c \Rightarrow aI_i c$  (II Transitivity),

$aP_i b$  and  $bI_i c \Rightarrow aP_i c$  (PI Transitivity),

$aI_i b$  and  $bP_i c \Rightarrow aP_i c$  (IP Transitivity), and

$aR_i b$  and  $bR_i c \Rightarrow aR_i c$  (RR Transitivity).

In reality a person may not be able to judge which alternative is preferred or if they are indifferent because he/she does not have enough information about the alternatives when

making a comparison. This results in an incomplete preference. Also, non-transitive preference can result when individuals use different criteria when judging alternatives.

## A.2 Choice

Choice expresses the acceptance of alternative(s) when one can only select a subset from all alternatives. An individual may choose one or more alternatives from a set of alternatives ( $T$ ). The choice set of the  $i^{\text{th}}$  individual from the set of available alternatives is denoted as  $C_i(T)$ . Condorcet suggested the following criterion for choice: people will choose their most preferred alternative(s) from the available alternatives (McLean & Urken, 1995). However, the Condorcet choice criterion is not universally true. A person may have cyclic preferences so the set of alternatives will contain no most preferred alternative. In addition, under various circumstances, individuals may choose a less preferred alternative.

### A.2.1 Rationality of Choice

The term “rationality” has a precise meaning in SCT. It means that the transitivity of preferences and the Condorcet choice criterion should hold true while an individual makes his/her choices. We can therefore construct four rationality conditions:

RC1 is based on PP transitivity. If one chooses  $a$  from  $a$  and  $b$  and chooses  $b$  from  $b$  and  $c$ , then he/she should choose  $a$  from  $a$  and  $c$  because  $a$  is preferable to  $b$  and  $b$  is preferable to  $c$ . (i.e.,  $C(a, b) = \{a\}$ ,  $C(b, c) = \{b\}$ ) then  $C(a, c) = \{a\}$ ).

RC2 is from II transitivity. If one chooses both  $a$  and  $b$  from  $a$  and  $b$  and chooses  $b$  and  $c$  from  $b$  and  $c$ , then  $a$  and  $c$  will be chosen when the individual has to choose from  $a$  and  $c$ ,

because  $a$ ,  $b$ , and  $c$  are indifferent. (i.e.,  $C(a, b) = \{a, b\}$ ,  $C(b, c) = \{b, c\}$ , then  $C(a, c) = \{a, c\}$ ).

RC3 and RC4 are based on Condorcet choice criterion. In RC3, if  $a$  is chosen from a set of alternatives that includes  $b$ ,  $a$  will be chosen when only  $a$  and  $b$  are provided as available alternatives. (If  $a \in C(T)$  and  $b \in T$ , then  $a \in C(a, b)$ ).

RC4 dictates that if  $a$  is chosen from  $a$  and  $b$ ,  $a$  is also chosen from a set of alternative. Then  $a$  will be chosen from the set of alternatives with  $b$  added as an available alternatives. (If  $a \in C(T)$  and  $a \in C(a, b)$ , then  $a \in C(T \cup \{b\})$ ).

RC3 and RC4 are very powerful as they enable us to build a complex set of alternatives from simple ones or to reduce a complex set of alternatives to a simple set.

### A.3 Choice Schemes

The procedure used to aggregate individual preferences (called a preference profile of the social choice system) into collective choices is called a choice rule or choice scheme or choice function ( $C$ ). A choice scheme is a function that maps the preference profile to the collective choices. There are probably infinite numbers of choice schemes as one can aggregate individual preferences into a collective choice by constructing any kind of function he/she would like. However, useful choice scheme must satisfy some restrictive properties.

#### A.3.1 Some Desired Properties of Choice Schemes

For a long time, scholars have been considered advantages and disadvantages of choices schemes. Several desired properties of choice schemes have been proposed.

**A.3.2.1 Condorcet Winning Criterion.** Condorcet, one of the pioneers in SCT, argued that a good choice scheme should select the alternative that beats every other alternative in pairwise comparisons. This alternative, called the Condorcet winner, is superior to any other alternative in one to one competitions. However, there may be no Condorcet winner in some situations. This is known as Condorcet Paradox. For example, with voters holding preferences as shown in table A.1, alternative  $a$  will beat alternative  $b$  in a pairwise comparison with a score of 70% to 30%. Alternative  $b$  will defeat alternative  $c$  because 70% of the voters prefer  $b$  to  $c$ . Yet alternative  $c$  will top alternative  $a$  because 60% of the voters prefer  $c$  to  $a$  while only 40% of the voters prefer  $a$  to  $c$ . There is no Condorcet winner in this case. The Condorcet winning criterion argues that a choice rule should pick the Condorcet winner if there is one. Conversely, we can also build a Condorcet loser criterion, an alternative that loses to every other alternative in pairwise comparisons should never be chosen by a choice scheme.

**Table A.1 Example of Condorcet Voting Paradox**

Percentage of Voters	Preference	
40%	$aPbPc$	$a$ vs. $b$ 70%:30%
30%	$bPcPa$	$b$ vs. $c$ 70%:30%
30%	$cPaPb$	$c$ vs. $a$ 60%:40%

**A.3.2.2 Universality Condition.** Using a social choice scheme, we should be able to aggregate any preference profile to a collective choice. The social choice scheme will produce a choice (with the possibility of ties) no matter what the preference profile may be. If a social choice scheme fails to find a winning alternative under certain situation, its usefulness is questionable.

**A.3.2.3 No Imposed Preference.** There should not be any restriction on an individual's preference imposed by the choice scheme. Everyone in the choice system should have the freedom to hold and to express any kind of preference. Arrow (1951) calls this property 'citizens' sovereignty' and links it to the foundations of democracy, since a democratic system should not place any constraint on any individual's preference.

**A.3.2.4 Monotonicity Criterion.** If an alternative already won under a choice scheme, it should remain the winner if some people change their preferences in favor of this alternative and nothing else was changed. In other words, an alternative should not be harmed by having more support. The strong form of the monotonicity criterion states that if an alternative is tied with other alternative(s), it will become the winner when it has more support and nothing else is changed in individuals' preferences.

**A.3.2.5 Independence of Irrelevant Alternatives (IIA).** If out of a set of alternatives,  $a$  is preferred to  $b$  under a choice scheme, then if any other alternative  $c$  is added to or removed from the set,  $a$  should still be preferred to  $b$  because  $c$  is irrelevant to the pair  $a$  and  $b$ . This property gives stability to the order of social choice. For instance, if the first choice becomes unavailable, the second choice will become the new winner without the need to vote again because the order between the original second choice and all the other alternatives will not change in the absence of the original winner. Although IIA seems to be a simple property, a lot of choice schemes failed this one.

**A.3.2.6 Pareto Condition (or Unanimity Condition).** The Pareto Condition deals with the unanimity in individual preference. The weak form of the Pareto condition is that if every one in the choice system ranks alternative  $a$  above  $b$ ,  $b$  should never become the winner if  $a$  is available. The strong form of the Pareto condition asserts that if

everybody think alternative  $a$  is at least as good as  $b$  and at least one member regards  $a$  as better than  $b$ , then  $b$  should not be chosen when  $a$  is available for choice.

**A.3.2.7 No Dictatorship.** A choice scheme is said to have a dictator if under that choice scheme, a certain individual prefers  $x$  to  $y$ , then the group prefers  $x$  to  $y$ , regardless of other individuals' preferences. In other words, the social choice is based on the preference of one person. There could be a hierarchy of dictators in the choice system. When the upper dictators are indifferent about two alternatives, then the next dictator's preference would decide the system's choice. Of course, for a fair choice scheme, we would like that no individual or a small group of individuals can dictate the outcome of a social choice, regardless of the preferences of other people.

### A.3.3 Commonly Used Choice Schemes

Only a handful of choice schemes are commonly used to aggregate individual preferences. Below are brief descriptions of some commonly used choice schemes. Some of these methods may produce more than one winner under certain condition. If there is more than one winner, usually an additional procedure (tie breaker) will be invoked to resolve the tie and choose a winner.

**A.3.3.1 Plurality Method or Simple Majority Voting Method.** This is the most widely used choice scheme. Everybody in the choice system has one vote. Each will endorse the most preferred alternative in the choice set. The alternative that has the most votes wins.

Example: Alternatives  $a$ ,  $b$ , and  $c$  are voted on by 9 people. If alternative  $a$  receives 4 votes,  $b$  has 3 votes, and  $c$  gets 2 votes, then  $a$  is the winner.

While it is simple and widely used, the plurality method does not always pick the Condorcet winner if there is one. In extreme case, it will even pick the Condorcet loser as the choice. It also fails to meet the independence of irrelevant alternatives criterion.

Like the plurality method, majority rule does not always pick the Condorcet winner and fails to meet the IIA criterion.

**A.3.3.2 Majority Rule.** Majority rule methods is a variation of the plurality method.

It requires the winning alternative must pass certain threshold to become the winner. The threshold can range from half of the votes to total support of the voters (unanimous support). Voters have to vote repetitively until one alternative surpasses the threshold.

Example: As in the previous example, alternatives  $a$ ,  $b$ , and  $c$  are voted on by 9 people.

If alternative  $a$  receives 4 votes,  $b$  has 3 votes, and  $c$  gets 2 votes, then there is no winner.

If in the second round of voting,  $a$  receives 4 votes,  $b$  gets 5 votes, and  $c$  has no vote, then  $b$  is the winner.

Like the plurality method, majority rule does not always pick the Condorcet winner and fails to meet the independence of irrelevant alternatives criterion.

**A.3.3.3 Majority with Run-off.** Similar to the majority rule method except that only

the two alternatives with the highest number of votes enter the second round of voting.

The vote repeats until one alternative pass certain threshold to become the winner. The threshold for percentage of votes needed for a winner can vary in this method as in the majority rule method.

Example: As in the previous example, alternatives  $a$ ,  $b$ , and  $c$  are voted on by 9 people.

If alternative  $a$  receives 4 votes,  $b$  has 3 votes, and  $c$  gets 2 votes, then there is no winner.



Only the two alternatives with highest number of votes ( $a$  and  $b$ ) enter the second round of voting. If  $a$  has 5 votes,  $b$  gets 4 votes, then  $a$  is the winner.

Majority rule with run-off does not always pick the Condorcet winner and fails to meet the independence of irrelevant alternatives criterion. However, it will not pick the Condorcet loser as the winner.

**A.3.3.4 Instant Run-off.** This is a multi-round voting method. Everybody in the choice system has one vote and endorses the most preferred alternative in the choice set just as in the plurality method. Start with all alternatives. Eliminate the alternative with the lowest number of vote in each round. Repeat the process until there is only one winning alternative left. When there are  $n$  alternatives, this method will take  $n-1$  rounds of votes to find the winner.

Example: Alternatives  $a$ ,  $b$ , and  $c$  are voted on by 9 people. If alternative  $a$  receives 4 votes,  $b$  has 3 votes, and  $c$  gets 2 votes, then  $c$  is dropped for the second round of voting. Alternatives  $a$  and  $b$  enter the second round of voting. If  $a$  has 4 votes and  $b$  gets 5 votes in the second round, then  $b$  is the winner.

**A.3.3.5 Amendment Procedure.** The amendment procedure is based on successive pairwise comparisons and serial eliminations. This method is usually found in legislative activities. Each alternative is treated as an amendment to the previous alternative. The first two alternatives will be considered as a pair. The winner is the alternative with more support. The winner then will compete against the next amendment. The last vote will be the winning alternative against the status quo (no change made).

The amendment procedure will choose the Condorcet winner if there is one. However, if there is no Condorcet winner, the outcome of the amendment procedure depends on the order of the pairwise comparisons.

#### **A.3.3.6 Borda Count or Preference Scores.**

The Borda count considers the entire ranking of individual preferences when making the choice. Each alternative is given a count based on its ranking in individual's preferences. For  $n$  alternatives, the most frequently used way to assign counts to alternatives is  $n-1$  points for each ballot on which it is ranked first,  $n-2$  for second, etc., down to 1 point for second to last, and 0 for last place. The alternative with the highest count wins. Variations of the Borda count method may assign different weights to different ranks.

For example, three persons hold the preferences as shown in table A.2. Alternative  $a$  gets 4 points (1 first place of 2 points and 2 second place for 1 point each). Alternative  $b$  has 3 points (1 first place of 2 points and 1 second place for 1 point). Alternative  $c$  receives 2 points (1 first place of 2 points). Alternative  $a$  is the winner under this procedure.

**Table A.2 Example of Borda Count**

Person	Preference	Alternative	Score
1	$aPbPc$	$a$	4
2	$bPaPc$	$b$	3
3	$cPaPb$	$c$	2

The Borda count method chooses a Borda winner which does not always coincide with the Condorcet winner. Although it has been debated by scholars for many years, there is no consensus on which winner is the "better" one.

#### **A.3.3.7 Average Score Method or Chip Allocation Method.**

Each voter has a fixed amount of scores (chips) that can be assigned to alternatives. Each alternative is given some number of scores (chips) by each voter. The alternative with the highest total

scores wins. Average score method can be seen as a variation of Borda Count. Instead of assigning scores based on the alternatives' ranking in the voter's preferences, voter assign the scores themselves. Neither the Average score method nor the Borda count method meet the independence of irrelevant alternatives criterion.

**A.3.3.8 Approval Voting.** Approval voting was conceived to overcome the problem that only the topmost alternative in an individual's preference list is considered in the plurality voting procedure. In the approval voting procedure, every voter in the choice system can cast one vote for any number of alternative(s) he/she approves. The alternative with the most votes is declared as the winner.

Example: Five persons vote on alternatives  $a$ ,  $b$ , and  $c$  on the ballot. Their votes are shown in table A.3. Alternative  $a$  is the winner because it has 4 votes while  $b$  has 3 votes and  $c$  has 2 votes.

**Table A.3 Example of Approval Voting**

Person	Approved alternative(s)
1	$a$
2	$a, b$
3	$a, c$
4	$b$
5	$a, b, c$

Alternative	Votes received
$a$	4
$b$	3
$c$	2

**A.3.3.9 Condorcet Method.** In order to find the Condorcet winner, we need to do pairwise comparisons between each pair of alternatives. The Condorcet method will yield a binary comparison matrix and the Condorcet winner can be identified if there is one. In the case of no Condorcet winner, scholars have developed procedures, such as the Schwartz and Dodgson procedures, to identify a winner that is the best approximation of the Condorcet winner. The pairwise comparisons can be a time consuming task if the

number of alternatives is large. For  $n$  alternatives, there will be  $n*(n-1)$  pairwise comparisons.

#### A.4 Arrow's Impossibility Theorem

Table A.4 is a listing of some voting methods that indicates whether they meet the desired properties. As we can see, no single voting method meets all the properties here. For almost two centuries, people have tried to find a social choice scheme that could meet all the desirable properties. One question emerges: is there a perfect choice scheme that can meet all the desirable properties? This question remained unanswered until Arrow (1951) proved that it is impossible for a social choice rule to satisfy all the five reasonable conditions (universality, monotonicity, independence of irrelevant alternatives, no imposed preference, and no dictatorship) when making a choice among three or more alternatives. The Impossibility Theorem has had a profound impact on social choice, as it demonstrates that there is no single social choice rule that can always fairly decide an outcome that involves more than two alternatives.

**Table A.4 Voting Methods and Desired Properties**

	<b>Condorcet Winning Criterion</b>	<b>Monotonicity Criteria</b>	<b>Independence of Irrelevant Alternatives</b>	<b>Pareto Conditions</b>
Plurality Method	Fail	Success	Fail	Success
Majority with Run-off	Fail	Fail	Fail	Success
Instant Run-off	Fail	Fail	Fail	Success
Amendment procedure	Success	Success	Fail	Fail
Borda Count	Fail	Success	Fail	Success
Chip allocation method	Fail	Success	Fail	Success
Approval voting	Fail	Success	Success	Fail

After Arrow published his Impossibility Theorem, many other impossibilities in social choice have also been discovered. This does not mean that people should abandon voting

because there is no perfect choice scheme. If we allow some properties to be relaxed, there are still close to perfect choice schemes available for making social choice. Researchers in SCT have discussed which properties can be relaxed and still yield a reasonable social choice scheme.

### A.5 Strategic Manipulation

All the above discussion is based on the assumption of voters' sincere presentation of their preferences. However, voters may find incentives to hide their true preferences. In SCT terminology, given a social choice rule,  $C(T)$  and  $C'(T)$  are choice sets when an individual  $j$  stating his/her preferences are  $R_j$  (true preference) or  $R'_j$  (fake preference). If the individual is better off with  $C'(T)$ , he/she would state his preference as  $R'_j$  rather than  $R_j$ . We will say this social choice rule is open to manipulation by person  $j$  on  $T$ . The same situation also applies to a group of individuals working together to manipulate the outcome.

There are different types of strategic Manipulation:

- **Compromising:** A voter votes for a less preferred alternative instead of the most preferred alternative because the most preferred alternative is perceived unlikely to win while the least preferred alternative is most likely to win. By voting for a less preferred alternative, the voter might be able to avoid the least preferred alternative.
- **Burying:** A voter dishonestly ranks an alternative lower in the hopes of defeating it. For example, a voter may rank a strong alternative last in order to help their preferred alternative to win.
- **Push-over:** a voter ranks a weak alternative higher, not in the hopes of getting it chosen but to push the most preferred alternative to win. For example, in a run-off method where multiple rounds of votes are required, a voter may vote for an alternative they perceive as unlikely to win, in order to eliminate a strong alternative and to help the preferred alternative win.

Non-manipulability can be viewed as a higher-order desirable property of a choice scheme. All previous mentioned desirable properties are based on truthful presentation of voters' preferences, but non-manipulability is needed to prevent voters misrepresent themselves. Some choice rules only require a rough knowledge (e.g., the distribution of top ranking alternatives) of the preference profile for an individual to manipulate the choice, while other choice rules may require detailed knowledge of preference profile if they are to be manipulated (table A.5). Unfortunately, the Gibbard-Satterthwaite theorem (Gibbard, 1973; Satterthwaite, 1975) proves that any choice rule satisfy no dictatorship and universal criterion will be susceptible to manipulation when there are three or more alternatives. In order to prevent manipulation, mechanisms outside of the choice scheme have to be used.

**Table A.5 Information Required for Successful Manipulation**

<b>Level</b>	<b>Procedure</b>	<b>Information required for successful manipulation</b>
1st level	plurality	distribution of first preferences over alternatives
2nd level	approval voting	distribution of approvals over alternatives
3rd level	amendment, Borda	binary comparison matrix
4th level	plurality runoff	entire preference profile

Source: (Nurmi, 1987, p. 124)

### **A.6 Choosing More Than One Winner**

Sometimes it is necessary to choose more than one alternative. If a method generates an order of the alternatives, an easy way to select  $n$  winners is to choose the top  $n$  alternatives in the order as winners. It will not require another round of voting to choose more than one winner. However, because many choice schemes do not satisfy the

Independence of Irrelevant Alternatives criterion, the rank order of the alternatives might be different if the topmost winner is removed from the set of available alternatives. The winners might be different if the choice is done in one round of voting or in many rounds of voting. Which way is the right way to choose more than one winner?

There are also issues of manipulation. Since an alternative does not to be the topmost winner to be chosen, it is possible for a group of people to divide their votes among their preferred alternatives to get more than one of their preferred alternatives chosen. It is also possible for two groups of people to work together to push both of their preferred alternatives to become winners. Groups of people can trade votes to achieve their preferable outcomes. This kind of manipulation is not necessary bad. For example, an alternative that receives overwhelming support may deplete the support of other similar alternatives, and a radical alternative with only minority support might be chosen. If a group of people divide their votes among preferred alternatives, it might have an outcome that is closer to the majority's preference. However, where is the line between acceptable and unacceptable manipulations? There are no easy answers to these questions.

### **A.7 Implications of SCT In GSS Voting**

SCT is mostly concerns about the characteristics of methods in combining individual preferences into a group choice, it can offer insights in using voting in group decision making. In the GSS context, researchers should consider these two implications of Impossibility Theorem on voting: A GSS should not have only one voting method for all the situations and GSS facilitators should be aware of the limitation of available voting methods and choose a suitable method for the circumstance.

Two approaches might be able to alleviate the problem of manipulation in GSS voting. One is to use some method such as the Clarke tax mechanism (Wang & Leung, 2004) to reduce the incentive for a voter to manipulate the voting outcome. The other one is to use voting as a mean to promote discussion rather than forming the final decision.

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## **APPENDIX B**

### **THE LAW OF COMPARATIVE JUDGMENT**

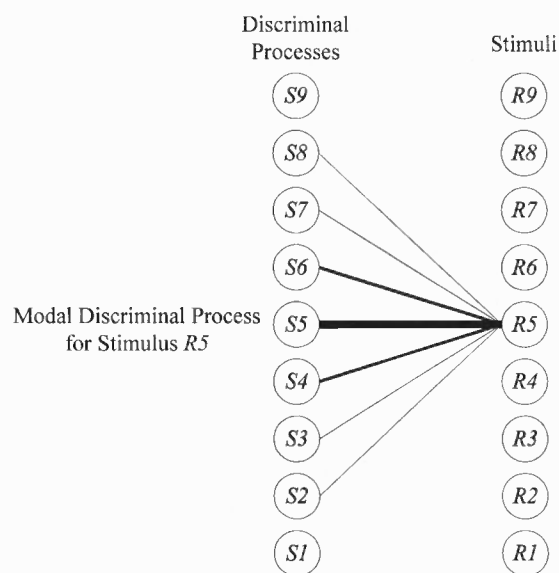
Psychologists are interested in mapping stimuli to psychological judgments. Thurstone (1927a, 1927b, 1927c, 1928, 1931) has published extensively on the method for constructing scales of psychological values from a series of binary comparisons starting in the late 1920s to the early 1930s. These papers were republished posthumously in the collection *The Measurement of Values* (Thurstone, 1959). His method, known as “the law of comparative judgment”, has been used in areas such as value study and marketing research.

The theory behind the law of comparative judgment is based on random distribution of judgments and overlapping of distributions. Thurstone’s writing on this topic was done before the terminology of random variable became universally adapted, the symbols used in his original papers may cause some confusion and, thus, we have replaced the symbols used in his original papers with modern symbols in this review to avoid such confusion.

#### **B.1 Mapping from Stimuli to Judgments**

As a psychologist, Thurstone began his discussion with mapping stimuli to psychology judgments. When a person is facing the problem of comparing a series of stimuli, (e.g., better-worse, heavier-lighter, or more-less judgments), he suggested that there is a psychological continuum formed by “discriminal processes” for these stimuli. Thurstone chose the term “discriminal processes” so he would not have to commit himself to any

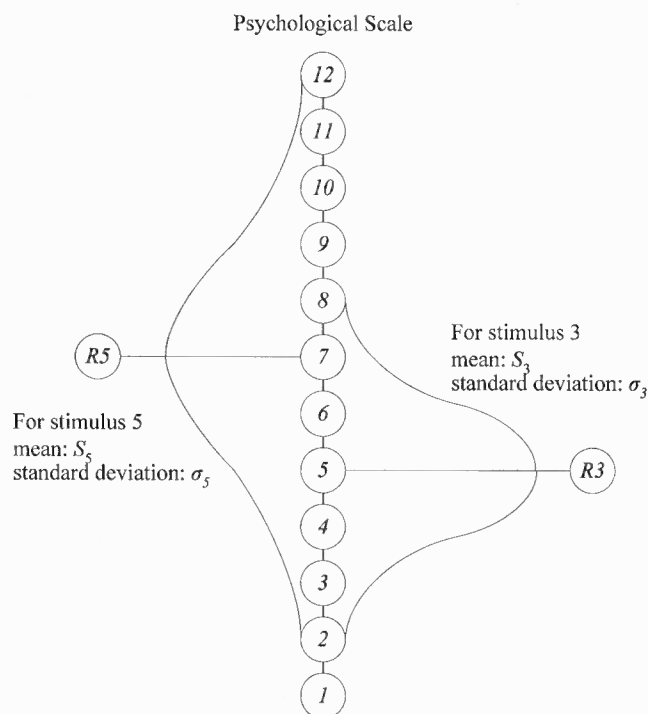
possible explanation of the underlying differentiating processes for the stimuli. Each stimulus will invoke a discriminational process. When a person is comparing two stimuli, two discriminational processes will be invoked. The judgment between the two stimuli is based on the rank produced by the discriminational process associated with each stimulus. However, because of fluctuations in processing sensory input, the discriminational process invoked by a certain stimulus is not fixed. For each stimulus, there is a most frequented discriminational process, the modal discriminational process, associated with a given stimulus. The same stimulus might also invoke other discriminational processes. The probability of a discriminational process being invoked by the stimulus will be less when the distance of that discriminational process is further away from the modal discriminational process (Figure B.1).



**Figure B.1** Mapping between discriminational processes and stimuli.  
(Adapted from Thurstone, 1959, p. 23)

Thurstone declared that although we do not know the real distribution of discriminational processes invoked by a stimulus around its modal discriminational process, an artificial psychological scale can be constructed so that the probability distribution of

discriminal processes for each stimulus is normal (Figure B.2). Thurstone argued that the scale does not require any assumption about the distribution of discriminative processes. The scale is defined in terms of the frequencies of the discriminative processes for any stimulus.



**Figure B.2** Psychological scale and distribution of discriminative processes.  
(Adapted from Thurstone, 1959, p. 27)

Since the discriminative processes for a stimulus are normally distributed around the modal discriminative process, the scale value of the modal discriminative process ( $S$ ) is the mean of the scale values of the discriminative processes for that stimulus. The standard deviation of the distribution of discriminative processes or standard error for a given stimulus is called its discriminative dispersion ( $\sigma$ ). Another term “discriminative difference” is used to describe the difference on the psychological scale between two stimuli of a particular judgment. If  $a$  is judged better than  $b$ , then the discriminative difference ( $a-b$ ) is

positive. On the other hand, if  $a$  is judged worse than  $b$ , then the discriminial difference ( $a-b$ ) is negative.

The difference between two modal discriminial processes on the psychological scale can be calculated by the probability that a stimulus is judged as more or less than the other stimulus. Since the difference between two means is the mean of differences, the difference of two discriminial processes can be written as  $S_1 - S_2 = S_{1-2}$ . Furthermore since  $S_{1-2} = x_{12}\sigma_{1-2}$  and also substituting  $\sigma_{1-2}$  with  $\sqrt{\sigma_1^2 + \sigma_2^2 - 2r\sigma_1\sigma_2}$ , the equation becomes  $S_1 - S_2 = x_{12} \cdot \sqrt{\sigma_1^2 + \sigma_2^2 - 2r\sigma_1\sigma_2}$ , this is what Thurstone called the complete form of the law of comparative judgment. Where

- $S_1$  and  $S_2$  are the value of the two stimuli in the psychological scale;
- $x_{12}$  is the sigma ( $z$  score) value of the proportion of stimulus 1 is judged better than stimulus 2,  $p_{1>2}$ . If  $p_{1>2}$  is greater than .5 then  $x_{12}$  is positive. If  $p_{1>2}$  is less than .5 then  $x_{12}$  is negative;
- $\sigma_1$  and  $\sigma_2$  are the discriminial dispersions of the two stimuli;
- $r$  is the correlation between the discriminial dispersions in the judgment.

Because Thurstone's paper was written before the terminology of random variable becomes universally adapted, his idea can be restated using random variable terminology. A stimulus will form a normally distributed random variable with mean  $\mu$  and standard deviation  $\sigma$  in the psychological scale continuum. The center (or mean) of the random variable is what Thurstone called the modal discriminial process and the standard deviation of the random variable is the discriminial dispersion. The  $x$  used by Thurstone can also be replaced with  $z$  to represent the  $z$  score value of normal unit distribution and  $\rho$  instead of  $r$  for correlation, then rewrite the law of comparative judgment as

$\mu_1 - \mu_2 = z_{12} \cdot \sqrt{\sigma_1^2 + \sigma_2^2 - 2\rho_{12}\sigma_1\sigma_2}$  . This form of the law of comparative judgment with random variable terminology will be used for later discussion.

Consider each alternative as a stimulus to a person, with enough comparisons between alternatives by participants in group decision making, the law of comparative judgment can be used to construct a scale of opinion on those alternatives. This scale provides more information than the result by traditional polling/voting because it shows not only the order of alternatives, but also the distance between alternatives.

## B.2 Computation Considerations

To apply the law of comparative judgment, Thurstone suggested that five cases should be considered. These five cases differ in assumptions, approximations, and simplifications. The first case uses the complete form of the equation for paired comparison data from a single subject judging pairs of stimuli several times. The scale value for each stimulus can be obtained by solving a system of simultaneous equations of the form  $\mu_i - \mu_j - z_{ij} \cdot \sqrt{\sigma_i^2 + \sigma_j^2 - 2\rho_{ij}\sigma_i\sigma_j} = 0$ . For  $n$  stimulus there will be  $n(n-1)/2$  equations and  $n(n+3)/2$  unknowns. The scale value is unsolvable because the number of unknowns is greater than the number of equations. Thurstone proposed an assumption to makes the simultaneous equations solvable by assuming the correlation  $\rho$  is constant for a single observer for the entire comparison session. By assigning the value of one stimulus as origin (0) and using its discriminial dispersion as unit of the scale, with the constant correlation assumption, there will be  $2n-1$  unknowns. The minimum solvable condition is 5 stimuli, for which there will be 10 equations and 9 unknowns (4 scale values, 4

discriminal dispersions, and 1 correlation). Since the system of equations is over-determined, some numerical methods should be used to fit the solutions.

Case 2 is for comparisons of stimuli made by a group of people. Thurstone argued that it is safe to assume the distribution of discriminial processes for each stimulus is normal for a group of people, rather than defining it as normal as was done in case 1. With the same assumption of constant correlation, the law of comparative judgment can be extended to a group of people comparing each pair of stimuli once.

Case 3, case 4, and case 5 simplifications are about reducing the labor of computation. They were proposed due to the limited computation power available at Thurstone's time. They are less important today. However, they are briefly discussed here for completeness. In case 3, Thurstone proposed that the equation can be simplified if the correlation can be assumed to be zero. A correlation of zero means that observing one stimulus will not affect the perceived value of the other stimulus. The formula for the law of comparative judgment can be simplified to  $\mu_i - \mu_j - z_{ij} \cdot \sqrt{\sigma_i^2 + \sigma_j^2} = 0$ .

The discriminial dispersions are assumed to be small and linear in case 4, that is,  $\sigma_2 = \sigma_1 + d$ . After expanding the equation and dropping terms containing  $d^2$  then substituting  $\sigma_2$  back, the law of comparative judgment formula can be simplified to

$$\mu_i - \mu_j - \frac{z_{ij}(\sigma_1 + \sigma_2)}{\sqrt{2}} = 0.$$

Case 5 is simplest of all. In addition to the assumption of correlation equals zero, the discriminial dispersions ( $\sigma$ ) are also assumed to be equal. The equation for the law of comparative judgment then becomes  $\mu_i - \mu_j - \sqrt{2}z_{ij}\sigma = 0$ .

Torgerson (1958) has presented a two-way classification of classes and conditions for the law of comparative judgment. The classes are based on replication type and the conditions are based on simplifying assumptions. In the first class, replication is within a single individual. The second case, an individual in a group compares each pair of stimuli only once. The third case, replication is mixed over individuals and trials. The first simplifying condition assumes constant covariance for all pairs of stimuli. The second simplifying condition in addition to the constant correlation also assumes a small difference between discriminial dispersions. The third condition assumes constant variance of distributions of discriminial differences. Table B.1 summarizes Torgerson's classification.

**Table B.1 Torgerson's Classification of The Law of Comparative Judgment**

	Condition A (assume constant covariance)	Condition B (constant correlation and small difference between discriminial dispersions)	Condition C (constant variance of distributions of discrimial differences)
Class I (within individual)	$\mu_i - \mu_j = z_{ij} \cdot \sqrt{a_i^2 + a_j^2}$	$\mu_i - \mu_j = z_{ij} \sqrt{\frac{1-r}{2}} (\sigma_i + \sigma_j)$	$\mu_i - \mu_j = cz_{ij}$
Class II (between individuals)	$\mu_i - \mu_j = z_{ij} \cdot \sqrt{a_i^2 + a_j^2}$	$\mu_i - \mu_j = z_{ij} \sqrt{\frac{1-r}{2}} (\sigma_i + \sigma_j)$	$\mu_i - \mu_j = cz_{ij}$
Class III (mixed)	$\mu_i - \mu_j = z_{ij} \cdot \sqrt{a_i^2 + a_j^2}$	$\mu_i - \mu_j = z_{ij} \sqrt{\frac{1-r}{2}} (\sigma_i + \sigma_j)$	$\mu_i - \mu_j = cz_{ij}$

(Adapted from Torgerson, 1958)

### B.3 An Example of Scale Building

This section illustrates how the law of comparative judgment can be used to construct its scale. The example is based on Thurstone's experiments on seriousness of offenses (Thurstone, 1927b). However, the focus here is not the underlying computation

technique (For an in depth discussion on the technique for computing the scale value, please see chapter 9 in (Torgerson, 1958).

One of Thurstone's experiments compared the subjective seriousness of several offences. Nineteen offences were included in this study (abortion, adultery, arson, assault, bootlegging, burglary, counterfeiting, embezzlement, forgery, homicide, kidnapping, larceny, libel, perjury, rape, receiving stolen goods, seduction, smuggling, and vagrancy). The 19 offences formed total 171 pairs of comparisons to be judged by 266 college students. Each student would answer the questionnaire by underlining the more serious crime. For example, for the pair Burglary-Assault, if the judge thinks assault is more serious than burglary, then his or her answer will be Burglary-Assault. If the subject cannot decide which offence is more serious, he or she will still need to underline one of them even if it is a tie. Definitions of the offences were also supplied to the students.

After the students completed the questionnaire, the answers were tabulated. Ratios of the numbers of answers for each pair were computed (Table B.2). The number in the table shows the proportion of students who thought the offence in the column was more serious than the one in the row. For example, 22.6% (51 out of 266) of the students in the experiment judged burglary as more offensive than arson.

Thurstone assumed that the standard errors for each pair of comparisons were equal. This is case 5 in Thurstone's classification. By assigning the scale value of vagrancy as zero and using the common standard error as unit of the scale, and solving a system of simultaneous equations, the scale value for each offence can be calculated (Table B.3). The zero point and unit size of scale is arbitrary. The whole scale can be shifted by choosing another zero point or scaled up/down by selecting a different unit size.

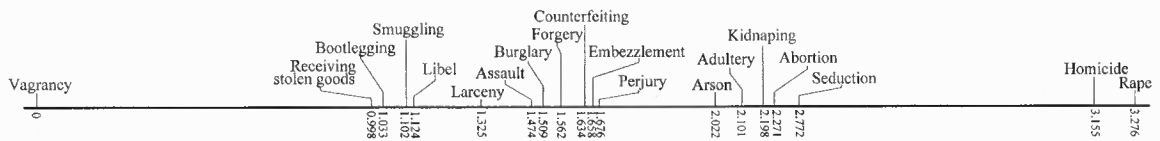


Table B.2 Proportion of One Offence Was Judged as More Serious Than Others

Abortion	0.323	0.338	0.211	0.128	0.238	0.244	0.245	0.212	0.760	0.318	0.222	0.191	0.256	0.822	0.143	0.419	0.174	0.045
Adultery	0.677	0.415	0.243	0.172	0.281	0.285	0.253	0.274	0.863	0.365	0.207	0.182	0.245	0.925	0.143	0.589	0.204	0.034
Arson	0.662	0.585	0.260	0.136	0.226	0.321	0.348	0.254	0.917	0.563	0.215	0.145	0.349	0.944	0.140	0.716	0.170	0.019
Assault	0.789	0.757	0.740	0.379	0.515	0.556	0.485	0.534	0.970	0.743	0.385	0.385	0.587	0.947	0.344	0.785	0.346	0.072
Bootlegging	0.872	0.828	0.864	0.621	0.764	0.745	0.738	0.754	0.955	0.924	0.678	0.506	0.728	0.985	0.527	0.871	0.576	0.116
Burglary	0.762	0.719	0.774	0.485	0.236	0.593	0.605	0.580	0.981	0.856	0.333	0.322	0.478	0.981	0.221	0.769	0.284	0.027
Counterfeiting	0.756	0.715	0.679	0.444	0.255	0.407	0.540	0.488	0.947	0.804	0.303	0.284	0.533	0.963	0.199	0.756	0.215	0.042
Embezzlement	0.755	0.747	0.652	0.262	0.395	0.460	0.350	0.958	0.951	0.752	0.305	0.248	0.474	0.977	0.141	0.774	0.251	0.049
Forgery	0.788	0.726	0.746	0.246	0.420	0.512	0.650	0.951	0.819	0.343	0.320	0.320	0.534	0.966	0.195	0.820	0.260	0.035
Homicide	0.240	0.137	0.083	0.045	0.019	0.053	0.042	0.049	0.917	0.083	0.030	0.034	0.079	0.441	0.027	0.181	0.026	0.011
Kidnapping	0.682	0.635	0.437	0.257	0.144	0.196	0.248	0.181	0.917	0.170	0.170	0.106	0.288	0.902	0.098	0.595	0.086	0.026
Larceny	0.778	0.793	0.785	0.322	0.667	0.697	0.695	0.657	0.970	0.830	0.652	0.348	0.648	0.970	0.268	0.848	0.365	0.053
Libel	0.809	0.818	0.855	0.494	0.678	0.716	0.752	0.680	0.966	0.894	0.652	0.702	0.981	0.981	0.530	0.886	0.456	0.067
Perjury	0.744	0.755	0.651	0.272	0.522	0.467	0.526	0.466	0.921	0.712	0.352	0.298	0.951	0.951	0.204	0.767	0.222	0.015
Rape	0.178	0.075	0.056	0.015	0.019	0.037	0.023	0.034	0.559	0.098	0.030	0.019	0.049	0.049	0.019	0.076	0.023	0.015
Receiving stolen goods	0.857	0.857	0.860	0.473	0.779	0.801	0.859	0.805	0.973	0.902	0.732	0.470	0.796	0.981	0.875	0.525	0.061	0.061
Seduction	0.581	0.411	0.284	0.215	0.231	0.244	0.226	0.180	0.819	0.405	0.152	0.114	0.233	0.924	0.125	0.121	0.023	0.023
Smuggling	0.826	0.796	0.830	0.424	0.716	0.785	0.749	0.740	0.974	0.914	0.635	0.544	0.778	0.977	0.475	0.879	0.037	0.037
Vagrancy	0.955	0.966	0.981	0.884	0.973	0.958	0.951	0.965	0.989	0.974	0.947	0.933	0.985	0.985	0.939	0.977	0.963	0.963

**Table B.3 Scale Value of Seriousness of Offenses**

Vagrancy	0
Smuggling	1.102
Seduction	2.272
Receiving stolen goods	0.998
Rape	3.276
Perjury	1.676
Libel	1.124
Larceny	1.325
Kidnapping	2.198
Homicide	3.155
Forgery	1.562
Embezzlement	1.658
Counterfeiting	1.634
Burglary	1.509
Bootlegging	1.033
Assault	1.474
Arson	2.022
Adultery	2.101
Abortion	2.271



#### B.4 Extensions of the Law of Comparative Judgment

The basic element of the law of comparative judgment is binary comparison between pairs of stimuli. However, it can easily be extended to rank order data. Thurstone (1931) authored a paper that constructed a scale based on rank order data. In the paper, instead of extracting all the possible pairs of comparisons from individuals' rank order data, Thurstone also gave a direct way to compute the proportion of by which a stimulus was judged more than others.

Later Thurstone (1945) realized that the scale could be calculated from choices made from more than two alternatives. Although this paper was not widely noticed, Luce (1994) noted that the model described by Thurstone is very similar to the simplest form of the random utility model in economics.

Thurstone and Jones (1957) also suggested that it is possible to find a natural origin (zero point) in the scale, so that the scale values become a ratio scale. Their method of finding the zero point is by grouping two alternatives and matching the scale value of the grouped alternatives to the sum of the two individual alternative's scale

values. If the zero point is stable then it is possible to calculate the zero point by averaging all the zeros found by grouped alternatives.

### **B.5 Limitations on the Law of Comparative Judgment**

There are a number of limitations to be mindful of when applying the law of comparative judgment. The number of equations needed to solve for the unknowns means that the law can only be applied for at least five alternatives in Thurstone's case 1 and 2 and at least three alternatives in case 5. This may not be a significant problem because additional alternatives can easily be created just for the purpose of doing comparisons. The normal distribution assumption about the discriminial processes would require a substantial number of comparisons for each pair of stimuli to make the scale meaningful (Dawes, 1994). If the comparisons are obtained from a small number of people, it also would be unreasonable to ask them the same question several times and hope that they will make an independent comparison each time. Anyhow, if there is a large number of participants in a Web based community, each person would not have to do a lot of comparisons before a meaningful scale can be computed.

The most problematic assumption in Thurstone's formation of the law of comparative judgment is that he ignored the response criteria (Luce, 1994). Thurstone assumed that a positive discriminial difference ( $a > b$ ) will always be judged as stimulus  $a$  is greater (or better, more beautiful, and so on) than  $b$ . There is no provision made for time-error tradeoff or for change in performance due to fatigue (Torgerson, 1958). Luce also points out that the motivational factors, such as instructions, rewards, and signal presentations, also affect the subject's judgment.

Another limitation is that the law of comparative judgment relies on the overlap of judgments to calculate the scale value. If an item is judged as greater than another item all the time, then it is impossible to compute the difference because the  $z$  score value would be infinite when the proportion of the first item judged greater than the other item is 1. One way to overcome this limitation is to compute the difference between these two items indirectly by way of a third item which is overlapped with the first two items. If there is no such item in between the items being compared, then it is impossible to construct a scale by the law of comparative judgment.

#### **B.6 Applying the Law of Comparative Judgment to Groups Decision Making**

Turoff and his colleagues (Li, Cheng, Wang, Hiltz, & Turoff, 2001; Turoff, Hiltz, Cho, Li, & Wang, 2002) have suggested a way to utilize the law of comparative judgment in group decision making. Instead of using traditional voting, a group will do paired comparisons or rank order of alternatives to come up with a scale for alternatives. Although it is not mentioned in their papers, it is also possible to use choices made among more than two alternatives to compute a scale as discussed by Thurstone (1945). Turoff and his colleagues argue that a scaling method can provide information to the group that voting methods can not. The information that can be provided by a scaling method includes the degree of consensus on given items, the degree of disagreement, current position of the whole group, an individual's position relative to the group and so on. The numerical scale values of alternatives are also easier for group members to visualize. They suggest using multiple instruments (voting and scaling) in group decision

making environments to help groups look at problems and solutions from different perspectives.

Easley and Mackay (1995) have proposed using the law of comparative judgment with multi-dimensional scaling (MDS) to help group members visualize the decision problem in a probabilistic geometric space. Preliminary result from a case study with engineers has shown that this approach helps groups to understand the problem better and find better solutions. However, group members may need some background knowledge to interpret the diagram of geometric space, although Easley and Mackay claim that it is reasonable to expect group members, even those without a sophisticated knowledge of probability distributions, to be able to comprehend the probabilistic geometric displays.

The results of using the law of comparative judgment in small groups are mixed. In Li's study (Li, 2003), the hypotheses that groups using scaling method would have a better outcome were not supported in most cases. Although it is not mentioned in the possible explanations, the inherent limitation that a large number of observation data points are needed to form a meaningful scale might also play a role. Li also found that the users' ability to understand the meaning of the outcomes from the scaling method seems to be crucial in successfully using the scaling tools because graduate students have higher acceptance of the scaling method than undergraduate students do. Thus training users to understand the scaling method is very important. Nevertheless, whether the scaling method could have significant outcomes in large groups is not known yet.

## B.7 Conclusion

The law of comparative judgment can be a powerful method in building an interval scale of alternatives. This allows more precise presentation of the collective opinion of the community and enables its members to view the same set of items from a different perspective. An important issue to the acceptance of the law of comparative judgment is to let users understand how the scale is constructed because some may raise question about the validity of the scale especially when the result does not agree with their view. If the method of constructing the scale is not clear, people will not trust the end result. A polling tool for group decision making based on the law of comparative judgment should provide explanation of the method, perform the computation, and display an easy to interpret scale to participants. In addition, successful use of the law of comparative judgment in would also require knowing the law's limitations to avoid using it erroneously. There are several limitations need to be considered when applying the law of comparative judgment to poll the opinion of members in a group. Firstly, there must be a minimum number of alternatives to be compared. Secondly, the number of comparisons between items has to be large enough for the final scale to be meaningful. Thirdly, there has to be overlap in judgments between items to compute a scale. Lastly, the instruction on how to judge the alternatives should be clear and consistent, so that everyone will judge the alternative with the same criteria to form a meaningful scale.

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## **APPENDIX C**

### **INSTITUTIONAL REVIEW BOARD APPROVAL**

The section contains the approvals of the revised experiment protocol by NJIT Institutional Review Board (IRB) and posting of recruitment flyers at University of Medicine and Dentistry of New Jersey (UMDNJ) by UMDNJ IRB. The initial experiment protocol was approved on December 22, 2006. The revised experiment protocol was approved by IRB on February 19, 2007.





**Institutional Review Board: HHS FWA 00003246**  
**Notice of Approval**  
**IRB Protocol Number: E78-06**

Principal Investigators: Fadi Deek/Kung-E Cheng  
 Information Systems

Title: Voting Group Support Systems: Testing the Effects of Voting Methods and Accessibility

Performance Site(s): NJIT/Off-Campus Sponsor Protocol Number (if applicable):

Type of Review: FULL  EXPEDITED

Type of Approval: NEW  RENEWAL  MAJOR REVISION

Approval Date: February 19, 2007

Expiration Date: February 18, 2008

1. **ADVERSE EVENTS:** Any adverse event(s) or unexpected event(s) that occur in conjunction with this study must be reported to the IRB Office immediately (973) 642-7616.
2. **RENEWAL:** Approval is valid until the expiration date on the protocol. You are required to apply to the IRB for a renewal prior to your expiration date for as long as the study is active. Renewal forms will be sent to you; but it is your responsibility to ensure that you receive and submit the renewal in a timely manner.
3. **CONSENT:** All subjects must receive a copy of the consent form as submitted. Copies of the signed consent forms must be kept on file with the principal investigator.
4. **SUBJECTS:** Number of subjects approved: 250.
5. The investigator(s) did not participate in the review, discussion, or vote of this protocol.
6. **APPROVAL IS GRANTED ON THE CONDITION THAT ANY DEVIATION FROM THE PROTOCOL WILL BE SUBMITTED, IN WRITING, TO THE IRB FOR SEPARATE REVIEW AND APPROVAL.**

*Dawn Hall Apgar*

Dawn Hall Apgar, PhD, LSW, ACSW, Chair IRB

February 13, 2007



Office of the Institutional Review Board  
Newark Campus

**NOTICE OF APPROVAL OF MODIFICATION**

**IRB PROTOCOL NUMBER: 0120070029**

(Refer to this number when making inquiries)

**PRINCIPAL INVESTIGATOR/DEPT:** **Niem-Tzu Chen, M.S., M.Ed.**  
Family Medicine  
New Jersey Medical School  
Medical Science Building  
183 South Orange Avenue B-648  
Newark, New Jersey

**CO-INVESTIGATOR(S):** Kung-E Cheng, Ph.D.

**TITLE:** Voting in Group Support Systems: Testing the Effects of Voting Methods and Accessibility.

**PERFORMANCE SITE(S):** New Jersey Institute of Technology

**SPONSOR/PROTOCOL NUMBER:** N/A

**TYPE OF REVIEW:** Expedited

**RISK DETERMINATION LEVEL:** Minimal Risk

**DEVICE DETERMINATION:** Not Applicable

**TYPE OF APPROVAL:** MODIFICATION

**MODIFICATION ITEMS:** Advertisements

**Document Versions Approved with this Modification:**

- Protocol Version:  
 Investigator Brochure:  
 Consent Version:

- Advertisement:  
 Educational Materials:  
 Other items:

**Currently Approved Documents:**

Protocol Version: -  
Investigator Brochure: -  
Consent Version: -

Advertisement: -  
Educational Materials: -  
Other items:

**Vulnerable Population Code(s):** No Children As Subjects; 45CFR46.204; No Prisoners As Subjects

**APPROVAL DATE:** 2/9/2007

**EXPIRATION DATE:** 1/28/2008

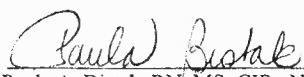
**EFFECTIVE DATE:** 2/15/2007

1. **Adverse Events:** Any on-site serious adverse events, or any unanticipated problems involving risk to subjects or others, or any serious or continuing non-compliance that occurs in relation to this study must be reported to the IRB Office (45 CFR 46, 21 CFR 50, 56) as outlined in the investigator instructions for adverse event reporting. For further guidance, please refer to [http://www2.umdni.edu/irbweb/forms/AErepform\\_instr.pdf](http://www2.umdni.edu/irbweb/forms/AErepform_instr.pdf)



Office of the Institutional Review Board  
Newark Campus

2. **Continuing Review:** Approval is valid until the protocol expiration date shown above. The IRB must review and approve all human subject research studies at intervals appropriate to the degree of risk, but not less than once per year, as required by 45 CFR 46 and 21 CFR 50, 56. In order to avoid lapses in approval of your research and the suspension of subject enrollment, please submit your continuation application at least eight weeks before the study expiration date.
3. **Consent:** The IRB has reviewed and approved the attached date-stamped consent/assent/parental consent form(s) for this study, as required by 45 CFR 46 and 21 CFR 50, 56, if applicable. Only the attached date-stamped consent/assent form(s) may be used to document informed consent of study subjects. All subjects must receive a copy of the approved date-stamped consent/assent form(s); a copy of the signed consent/assent form must also be filed in a secure place in the subject's medical/patient/research record.  
**Number of consent forms approved: 1 (NJIT)**
4. **Subjects: Number of subjects approved at this site: 250**
5. The investigator(s) did not participate in the review, discussion, or vote of this protocol.
6. **Amendments/Modifications/Revisions:** If you wish to change any aspect of this study, including but not limited to study procedures, consent form(s), principal investigator, co-investigator(s), advertisements, the protocol document or procedures, the investigator drug brochure, or accrual goals, you are required to obtain IRB review and approval under 45 CFR 46 and 21 CFR 50, 56. Implementation of these changes may not occur until you receive notice of IRB review and approval.
7. **Completion of Study:** Please notify the IRB when your study has been stopped for any reason. Include the following information in the written notification using a continuing review/final report form: number of subjects enrolled; number of subjects withdrawn from the study; and reason for study termination. Neither study closure by the sponsor or the investigator removes the obligation for timely continuing review or a final report.
8. **Wards of the state: Not applicable**
9. **Minor change in recruitment flyer to inform participants to carry out the task online during a one-week period instead of being in a computer lab at the same time for 1.5 hours. The only actual change being made is to change the words 'one and half hour' to 'some time.'**

  
Paula A. Bistak, RN, MS, CIP - Newark IRB Director

Date: 2/17/07

DHHS Federal Wide Assurance Identifier: FWA00000036

**APPENDIX D**  
**STUDY CONSENT FORM**

This section is the consent form approved by NJIT Institutional Review Board (IRB) for the revised experiment protocol. It contains important information such as purpose of the study, study duration, procedures, participants, risk, reward for participation, confidentiality, and contact information of the investigator about the study. All subjects participated in the experiment were requested to read consent form then express their consent of participating in the study by either returning a signed copy of this form or sending an email message to the study investigator.

**NEW JERSEY INSTITUTE OF TECHNOLOGY**  
**323 MARTIN LUTHER KING BLVD.**  
**NEWARK, NJ 07102**

**CONSENT TO PARTICIPATE IN A RESEARCH STUDY**

**TITLE OF STUDY:**

Voting in Group Support Systems: Testing the Effects of Voting Methods and Accessibility

**RESEARCH STUDY:**

I, \_\_\_\_\_, have been asked to participate in a research study under the direction of Dr. Fadi Deek. Other professional persons who work with him as study staff may assist to act for him.

**PURPOSE:**

This study intends to investigate the effects of voting in a group of people who use a group support system program to reach a decision.

**DURATION:**

My participation in this study will require 2-4 hours over one week.

**PROCEDURES:**

Once I agree to participate, I will sign the consent form, and complete a questionnaire (pre-test). I will be provided instruction on system operation prior to the experimental task. After signing in for the study, I will be asked to work on a hypothetical task individually. The investigator(s) will divide me and others into groups, and each group will have a group leader assigned. I will be asked to sign in to the system with the assigned user name and password at a specific time period for the study. I will be working on the task with my group for one week. The mode of interaction for the task is asynchronous, that is, people can work on the same task at different time. Other members may not be using the system at the same time when I am logged in the system. I will log into the system at least once a day. I can spend as much or as little time as I would like for the task each time I log into the system as long as my group can research a final decision before the one-week period. After completing the task as a group, a 2<sup>nd</sup> questionnaire, the post-test, will be used to gather data on my feedback. Then a debriefing on study purpose and its research question will be provided.

**PARTICIPANTS:**

I will be one of about 250 participants in this trial.

**EXCLUSIONS:**

I will inform the researcher if I am under 18 years of age, unable to use a computer with a mouse, and/or unable to read and/or understand the instructions.

**RISKS/DISCOMFORTS:**

This study does not ask for any information that's embarrassing, sensitive, or confidential. Participants will not be placed under any physical risk. No medical procedure is involved in the protocol. The risk of participation in this project is minimal.

There also may be risks and discomforts that are not yet known.

I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

**CONFIDENTIALITY:**

I understand confidential is not the same as anonymous. Confidential means that my name will not be disclosed if there exists a documented linkage between my identity and my responses as recorded in the research records. Every effort will be made to maintain the confidentiality of my study records. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

**PAYMENT FOR PARTICIPATION:**

I have been told that I will enter into open raffles for game consoles (Nintendo Wii). One open raffle will be held for every 50 people have completed the experiment procedure. Early participants will be qualified for later round of raffles. I will have the option to exchange the prize for a gift card of equivalent value if I won the prize.

**RIGHT TO REFUSE OR WITHDRAW:**

I understand that my participation is voluntary and I may refuse to participate, or may discontinue



Approved by the NJIT IRB on 2/19/07.

Modifications may not be made to this consent form without NJIT IRB approval.

my participation at any time with no adverse consequence. I also understand that the investigator(s) has the right to withdraw me from the study at any time.

**INDIVIDUAL TO CONTACT:**

If I have any questions about my treatment or research procedures, I understand that I should contact the principal investigator at:

Dr. Fadi Deek, Dean  
College of Science and Liberal Arts  
New Jersey Institute of Technology  
503 Cullimore Hall  
Phone: (973) 973-596-3677  
fadi.deek@njit.edu

If I have any addition questions about my rights as a research subject, I may contact:

Dawn Hall Apgar, PhD, IRB Chair  
New Jersey Institute of Technology  
323 Martin Luther King Boulevard  
Newark, NJ 07102  
(973) 642-7616  
dawn.apgar@njit.edu

**SIGNATURE OF PARTICIPANT**

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

Subject Name: \_\_\_\_\_  
Telephone: (\_\_\_\_) \_\_\_\_\_  
Email: \_\_\_\_\_  
Signature: \_\_\_\_\_  
Date: \_\_\_\_\_



Approved by the NJIT IRB on 2/19/07.

Modifications may not be made to this consent form without NJIT IRB approval.

**APPENDIX E**  
**INSTRUCTIONS TO SUBJECTS**

Instructions about the experiment procedure and system were sent to the subject in an email after receiving consent for participating in the experiment. The instructions were sent as an attachment in Adobe Acrobat portable document format (PDF). There is also an on-line version of the instructions on the experiment website. Link to the on-line instructions were also included in the email in case the subject could not view attached PDF file. Subjects can also download the instructions in Microsoft Word and Open Office Writer formats from the experiment Website.



## Instructions for Kung-E's Voting Experiment

The experiment is conducted on-line using a web site. The URL for the web site is <http://research.gss-voting.org:8080/>. Please do not omit the ':8080' part in the URL. It is needed due to firewall setting in NJIT's campus network.

Once you get on the web site, you will see this portal (figure 1) to the activities in the experiment. Please bookmark this page during the experiment because you will have to visit this portal several times during the experiment.

### Welcome to Kung-E 's Voting Experiment

1. Instructions for the experiment
2. Pre-task questionnaires
3. Task description
4. Pre-discussion individual decision
5. Discussion forum & voting tool
6. Post-discussion group and individual decision
7. Post-task questionnaires

Figure 1. Portal to activities in the experiment

The first item on the list of activities is the instructions about the experiment and the system. You can download and print the instructions in various formats.

The second item on the list 'Pre-task questionnaire' will take you to a survey system to let you fill out the before discussion questionnaire. Please use your experiment ID and password to login (figure 2). You will use the survey system again for the questionnaire at the end of the experiment.

**Survey System**

User Login

Please enter a username and password:

Username:  Password:

[\[ Main \]](#)

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Figure. 2 Survey system for questionnaires

The pre-task questionnaire is for gathering background information (figure 3).

**Survey System**

Survey: Pre-Task Questionnaire

Page 1 of 5

This is the pre-task questionnaire. The purpose of this questionnaire is to gather some background information.

1. [\*] Your ID for the experiment

[ Return to Main Menu ]

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Figure 3 Pre-task questionnaire

After finished the pre-task questionnaire, please choose the third item in the portal to read the description of the experiment task. You can download the task description using links at the bottom of this page (figure 4).

**Voting Experiment - State Budget Task**

**BACKGROUND**

A few months ago, the newly elected State Governor announced that the state was in deep financial trouble and had to balance the budget. Due to this budget crisis, the State Government eliminated several programs and also raised sales tax in order to increase revenue. Since the economic forecast has become better, the Office of Budget Planning has projected that state might be able to have a small financial surplus because of higher than expected sales tax revenue. The State Senate now has a chance to revise the budget and restore some of these eliminated programs. You, a State Senate, must decide which programs to restore. It is not clear how much the monetary surplus will be, so the Senate has to prioritize and determine which programs are to be restored. Programs will be restored according to their rank in the list based upon the final amount of available surplus dollars.

**DIRECTIONS**

Evaluate the competing programs and determine their relative merit. Many programs have merit, but limited resources require that you select the programs which you prefer to be restored. Your job is to prioritize those programs you believe deserve to be restored. Although many factors may influence the decisions regarding which programs to be restored, the most important factor is the degree to which a program agrees with your personal values. Your first task is to work on the list of programs individually. Next, discuss with other members via computer to form a group decision.

The mode of interaction for the task is asynchronous, that is, people can work on the same task at different time. Other members may not be using the system at the same time when you are logged in the system. You would have to collaborate with others across time through comments posted in the system and results of each round of voting. Please spend some time working on the task, voting, reading/responding comments by other members, and/or posing your own comments everyday. You can spend as much or as little time as you would like for the task each time you log into the system. The only requirement is that the group has to reach a final decision of the order of programs to be restored in one week. It is best to log in the system to check for comments and voting results several times a day so that you and other members can explore issues in the task more thoroughly. If you have any problem using the system or cannot continue participating in the experiment, please contact Kung-E Cheng (email: ke377@njit.edu or kunge.cheng@gss-voting.org; Tel: 862-596-2696) as soon as possible. The experiment investigator(s) will contact you if you do not log into the discussion system in the first day of the group discussion session to confirm whether you still want to participate in the experiment. If your group has reached a final decision before the one week deadline, congregate for a nice job done and please contact Kung-E Cheng.

You can work on the order of programs to be restored either way, from the program to be restored first or the program to be restored last. Use the voting tool to discover agreements/disagreements among group members, then discuss to confirm the agreements and to resolve the disagreements. Investigate the reason(s) for agreements and disagreements within the group. Persuade other members or make compromises based on the arguments for each program. The voting

Figure 4 Task description

The next step is to work on the task individually. You will use item 4 of the activities list to record your personal decision (figure 5).

### State Budget Restoration Order—Before Group Discussion

Experiment ID:

Program Name	You personal order to restore the programs (1 to 6, 1: first; 6: last)
Drug, Sex Education, & Contraceptive Programs (Grade 6-12)	<input type="checkbox"/>
Appeal Funding for Death Row Inmates	<input type="checkbox"/>
Toxic Waste Cleanup	<input type="checkbox"/>
Abortion Subsidies for Low Income	<input type="checkbox"/>
Housing for the Homeless Center	<input type="checkbox"/>
Job Training for Displaced Workers	<input type="checkbox"/>

Figure 5 Form for recording personal decision

After submitted your personal decision, you will be assigned to a group to work on the task with other members in your group. The system used for group discussion in this experiment is a modified version of phpBB (<http://www.phpbb.com>). Certain functionalities were removed from the system to avoid confusion in the experiment and a new voting tool replaced the original voting function of phpBB.

After choosing item 5 on the menu, you will see the starting page of phpBB (figure 6). Use your experiment ID and password to sign in by clicking the 'Log in' label on the upper-left side of the page. You can check the box 'Log me on automatically each visit' in the log in page (figure 7), then you do not have to log in using your experiment ID and password the next time when you use the same computer for the discussion forum.

**GSS-Voting.Org**  
Research of Voting in Group Support Systems

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[Profile](#)
[Log in to check your private messages](#)
[Log in](#)

The time now is Sat Feb 10, 2007 1:16 am  
GSS Voting Research Forum Index

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Forum	Topics	Posts	Last Post
<b>General</b>			
<a href="#">Discussion about the Research</a> Announcements and questions/answers about the research	1	1	Wed Nov 08, 2006 12:25 am Admin

All times are GMT - 5 Hours

**Who is Online**

Our users have posted a total of 8 articles  
We have 10 registered users  
The newest registered user is [tut1](#)

In total there is 1 user online :: 0 Registered, 0 Hidden and 1 Guest [ administrator ] [ Moderator ]  
Most users ever online was 4 on Tue Jan 31, 2006 7:37 pm  
Registered Users: None

This data is based on users active over the past five minutes

**Log in**

Username:  Password:  Log me on automatically each visit:

[New posts](#)
[No new posts](#)
[Forum is locked](#)

Figure 6 Starting page of phpBB

**GSS-Voting.Org**  
Research of Voting in Group Support Systems

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[Memberlist](#)
[Usergroups](#)
[Profile](#)
[Log in to check your private messages](#)
[Log in](#)

GSS Voting Research Forum Index

Please enter your username and password to log in.

Username:  Experiment ID

Password:  Password

Log me on automatically each visit:

[I forgot my password](#)

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Figure 7 Log in page of phpBB

Each group in the experiment was set up to have its own forum. Once you are signed in, you will see a forum with your group's name under experiments (figure 8).

You last visited on 09 Feb 2007 02:28  
 The time now is 10 Feb 2007 01:17  
[GSS Voting Research Forum Index](#)

View posts since last visit  
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Forum	Topics	Posts	Last Post
<b>General</b>			
Discussion about the Research Announcements and questions/answers about the research	1	1	08 Nov 2006 00:25 <a href="#">Admin</a>
<b>Experiments</b>			
Test Group 1 Discussion Forum for Test Group 1	2	2	No Posts

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All times are GMT - 5 Hours

**Who is Online**

Our users have posted a total of 6 articles  
 We have 10 registered users  
 The newest registered user is [test1](#)

In total there is 1 user online :: 1 Registered, 0 Hidden and 0 Guests [ [Administrator](#) ] [ [Moderator](#) ]  
 Most users ever online was 4 on 31 Jan 2006 19:37  
 Registered Users: [test1](#)

This data is based on users active over the past five minutes

New posts
 No new posts
 Forum is locked

Figure 8 Forum for group discussion

Click on the forum with your group's name, you will see a discussion topic for your group (figure 9).

Test Group 1

Moderators: None

Users browsing this forum: None

[GSS Voting Research Forum Index -> Test Group 1](#)

[Mark all topics read](#)

Topics	Replies	Author	Views	Last Post
Discussion for group Test Group 1	0	<a href="#">Admin</a>	23	15 Jan 2007 21:13 <a href="#">Admin</a>

Display topics from previous: [All Topics](#)

[GSS Voting Research Forum Index -> Test Group 1](#)

All times are GMT - 5 Hours

Page 1 of 1

Jump to:

New posts
 No new posts
 Announcement  
 New posts [ Popular ]
 No new posts [ Popular ]
 Sticky  
 New posts [ Locked ]
 No new posts [ Locked ]

You can post new topics in this forum  
 You can reply to topics in this forum  
 You can edit your posts in this forum  
 You can delete your posts in this forum  
 You cannot vote in polls in this forum

Figure 9 Topic for group discussion

After clicked on the topic for group discussion, you will see the voting tool (figure 10). The voting tool for your group might have a different look. There is a count down time in the voting tool to show you how much time remains for the discussion.

postreply GSS Voting Research Forum Index -> Group TEST1

**Voting topic: State Budget Restoration** Time remaining: 0 day 22 hour 45 minute

This is round 1 voting for State Budget Restoration.

Please choose one among the alternatives.

Points	Name	Description
<input type="radio"/>	Drug, Sex Education, & Contraceptive Programs (Grade 6-12)	<a href="#">Link to full description</a>
<input checked="" type="radio"/>	Appeal Funding for Death Row Inmates	<a href="#">Link to full description</a>
<input type="radio"/>	Toxic Waste Cleanup	<a href="#">Link to full description</a>
<input type="radio"/>	Abortion Subsidies for Low Income	<a href="#">Link to full description</a>
<input type="radio"/>	Housing for the Homeless Center	<a href="#">Link to full description</a>
<input type="radio"/>	Job Training for Displaced Workers	<a href="#">Link to full description</a>

Submit vote Reset

Figure 10 The voting tool

If you move the mouse cursor on one of the name of the programs, a window will pop out to show you a brief description about the program (figure 11).

GSS-Voting.Org

**GSS Voting Research**  
Research of Voting in Group Support Systems

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Discussion for group Test Group 1

postreply GSS Voting Research Forum Index -> Test Group 1

**Voting topic: State Budget Restoration** Time remaining: **Expired!**

This is round 1 voting for State Budget Restoration.  
Please assign 60 points among the alternatives.

Points	Name	Description
0	Drug, Sex Education, & Contraceptive Programs (Grade 6-12)	This program is designed to invest in the future by developing a drug and sex education curriculum for grades 6-12. It will include making contraceptives available to grades 6-12 without parental consent. Proponents of this project believe that society could greatly reduce the enormous social costs of drug abuse (crime, prisons, lost worker productivity, etc.) and unwanted pregnancies by educating young children and by continuing the educational process. Opponents argue that this is not the mission for primary and secondary education and that these personal and moral concerns belong to the choice of each family.
0	Appeal Funding for Death Row Inmates	
0	Toxic Waste Cleanup	
0	Abortion Subsidies for Low Income	
0	Housing for the Homeless Center	
0	Job Training for Displaced Workers	

There are 60 points left to be distributed.

Figure 11 Pop-up window showing program description

After you voted, the voting tool will show how you voted in this round of voting (figure 12). You might also see button(s) for possible action(s) in the voting tool. You can choose to view the result of a round of voting if there is one available for viewing. The leader of the group has a special privilege of ending the current round of voting.

postreply G55 Voting Research Forum Index -> Test Group 1

**Voting topic: State Budget Restoration** **Time remaining: Expired!**

End this round of voting

Select round to view

Vote submitted.

This is round 1 voting for State Budget Restoration.

you vote 7 points for Drug, Sex Education, & Contraceptive Programs (Grade 6-12).  
 you vote 10 points for Appeal Funding for Death Row Inmates.  
 you vote 12 points for Toxic Waste Cleanup.  
 you vote 8 points for Abortion Subsidies for Low Income.  
 you vote 9 points for Housing for the Homeless Center.  
 you vote 14 points for Job Training for Displaced Workers.

Figure 12 Voting tool display after voting

The result of a round of voting can be a partial result with only some of the members voted (figure 13), or a complete result with everyone voted (figure 14). The complete voting result will have a bar chart showing the final tally of all members' votes.

postreply G55 Voting Research Forum Index -> Test Group 1

**Voting topic: State Budget Restoration** **Time remaining: Expired!**

End this round of voting

Select round to view

Voting result for round 1

This round is open for voting.  
 1 of 3 members have voted in this round.  
 You have voted in this round.

Name	Total Votes	Description
Drug, Sex Education, & Contraceptive Programs (Grade 6-12)	7	<a href="#">Link to full description</a>
Appeal Funding for Death Row Inmates	10	<a href="#">Link to full description</a>
Toxic Waste Cleanup	12	<a href="#">Link to full description</a>
Abortion Subsidies for Low Income	8	<a href="#">Link to full description</a>
Housing for the Homeless Center	9	<a href="#">Link to full description</a>
Job Training for Displaced Workers	14	<a href="#">Link to full description</a>

Figure 13 Partial voting result

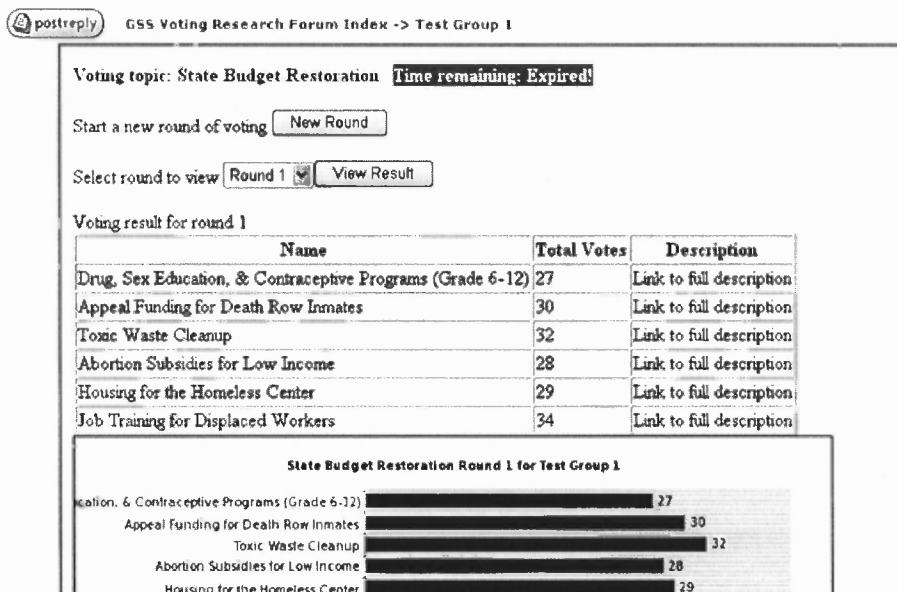


Figure 14 Voting result of completed voting round

The group leader can start a new round of voting after the end of the previous round of voting. After clicking on the 'New Round' button, the group leader can select which programs will be on the ballot of the next voting round (figure 15). If the group has already agreed on the order of a certain program, it can be removed from the next round of voting. Programs that are checked will appear in the next round of voting. Programs that are not checked will not show up in the next round of voting.

Voting topic: State Budget Restoration **Time remaining: Expired!**

Select round to view

Select alternatives for round 1 of voting for State Budget Restoration

Please choose the alternatives for next round of voting

<input checked="" type="checkbox"/>	Drug, Sex Education, & Contraceptive Programs (Grade 6-12)
<input checked="" type="checkbox"/>	Appeal Funding for Death Row Inmates
<input checked="" type="checkbox"/>	Toxic Waste Cleanup
<input checked="" type="checkbox"/>	Abortion Subsidies for Low Income
<input checked="" type="checkbox"/>	Housing for the Homeless Center
<input checked="" type="checkbox"/>	Job Training for Displaced Workers

Figure 15 Starting a new round of voting

Under the voting tool is where you can check comments posted by you or other people (figure 16). You can add your comment to the discussion by clicking the 'post reply' buttons on top-left or bottom-left. You can also reply (and quote the original text) to a specific comment by clicking the 'quote' button on the upper-right corner of each comment.



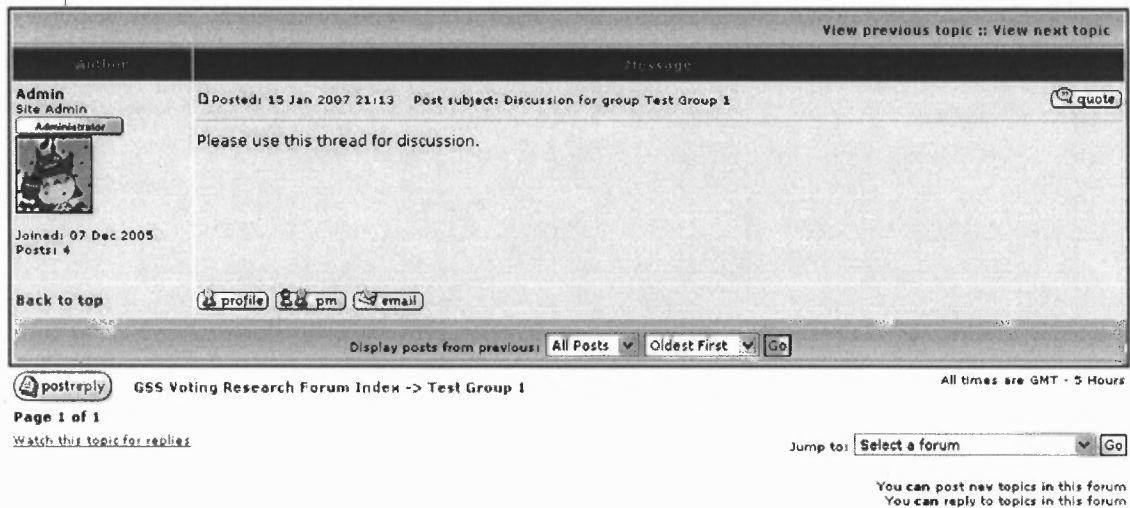


Figure 16 Comments in the discussion

You will see a post reply page when you posting a new comment or reply to another comment (figure 17). It is not necessary to type directly in the reply page. You can use a text editor or word processor program to compose your comment, then copy and paste the message to the reply page.

There are some special control codes (BBcodes) you can use to enhance the appearance of your message. Here is a simple list of BBcodes related to the display of text:

- To make a piece of text bold enclose it in [b][b], eg.  
[b>Hello[/b] will show as **Hello**
- For underlining use [u][u], for example:  
[u]Good Morning[/u] becomes Good Morning
- To italicise text use [i][i], eg.  
This is [i]Great![/i] would give This is *Great!*

You can also use icons to express your emotions by clicking the emoticons (small icons to express your emotions) on the left of the posting area. When you click an emoticon, the corresponding code for the emoticon will be add to the end of your text.

You can preview your message by clicking the 'Preview' button, or post your message by clicking the 'Submit' button. Don't worry if you find any mistake in your comment after posting it, you can edit your comment using the 'edit' button on the top-right of your comment.

GSS Voting Research Forum Index -> Test Group 1

Post a reply

Subject:

Message body

Emoticons

Font colour: Default Font size: Normal Close Tags

Tip: Styles can be applied quickly to selected text.

Options

HTML is OFF  
BBCode is ON  
Smilies are ON

Disable BBCode in this post  
 Disable Smilies in this post  
 Notify me when a reply is posted

Preview Submit

All times are GMT - 5 Hours

Figure 17 Posting comment

You can copy the result of a completed voting round to your comment. Two buttons 'Copy Text' and 'Copy Chart' will appear on the bottom of the voting tool when you are posting comment (figure 18). By clicking one of the buttons, the voting result (in either text or chart form) will be added to the end of your comment (figure 19). Currently, the text result is not aligned due to limitation in phpBB. The chart is added as a graph in the message using BBcode.

Housing for the Homeless Center	29	<a href="#">Link to full description</a>
Job Training for Displaced Workers	34	<a href="#">Link to full description</a>

**State Budget Restoration Round 1 for Test Group 1**

Copy result text to forum

Copy result chart to forum

Copy Text button  
Copy Chart button

GSS Voting Research Forum Index -> Test Group 1

Post a reply

Subject:

Message body

Emoticons

Font colour: Default Font size: Normal Close Tags

Tip: Styles can be applied quickly to selected text.

Figure 18 'Copy Text' and 'Copy Chart' buttons

0 10 20 30 40

Copy result text to forum

Copy result chart to forum

GSS Voting Research Forum Index -> Test Group 1

Post a reply

Subject:

Message body

Emoticons:

Options: HTML is OFF, BBCode is ON, Smilies are ON

Font colour: Default, Font size: Normal, Close Tags

List: [list]text[/list] (alt+I)

[b]State Budget Restoration round 1 for Test Group 1[/b]

Name	Votes
Drug, Sex Education, & Contraceptive Programs (Grade 6-12)	27
Appeal Funding for Death Row Inmates	30
Toxic Waste Cleanup	32
Abortion Subsidies for Low Income	28
Housing for the Homeless Center	29
Job Training for Displaced Workers	34

[img]http://localhost:8080/phpbb/images/chart/c121019c676.png[/img]

Disable BBCode in this post

Disable Smilies in this post

Notify me when a reply is posted

All times are GMT - 5 Hours

Figure 19 Adding voting result to a comment

The next step in the experiment is to report the group decision and your personal decision after the group discussion using item 6 on the activities list. Item 6 on the activities menu will take you to the form for reporting the group decision and your final personal decision (figure 20).

### State Budget Restoration Order—After Group Discussion

Group ID:

Experiment ID:

Program Name	The group's order to restore the programs (1 to 6, 1: first; 6: last)	Your final personal order to restore the programs after group discussion (1 to 6, 1: first; 6: last)
Drug, Sex Education, & Contraceptive Programs (Grade 6-12)	<input type="text"/>	<input type="text"/>
Appeal Funding for Death Row Inmates	<input type="text"/>	<input type="text"/>
Toxic Waste Cleanup	<input type="text"/>	<input type="text"/>
Abortion Subsidies for Low Income	<input type="text"/>	<input type="text"/>
Housing for the Homeless Center	<input type="text"/>	<input type="text"/>
Job Training for Displaced Workers	<input type="text"/>	<input type="text"/>

Figure 20 Group and final personal decision reporting form

The last step of the experiment procedure is to fill out the post-task questionnaire. Use your experiment ID and password to sign in the survey system again for the post-task questionnaire. After finishing the post-task questionnaire, you will be taken to a debriefing page that contains explanation about experiment such as purpose of the experiment, procedure, and expected finding. This debriefing page will only show up after finishing the post-task questionnaire. If you like to keep a copy of the debriefing, you can print the page or download a copy of the debriefing in various formats. Please do not discuss the experiment with people who has not completed the experiment yet, because doing so might create bias in the experiment data. You will be contacted for the time and place for the raffles of Nintendo Wii's. I will also send out message about the winners of the raffles.

**Thanks for participating in my experiment**

## **APPENDIX F**

### **PRE-DISCUSSION QUESTIONNAIRE**

All subjects participated in the experiment were requested to fill out this pre-discussion questionnaire before the experiment task. The questionnaire collects background information, such as age, education level, occupation, work experience, and attitude in working with groups from the subjects.

**Pre-Discussion Questionnaire**

Your Experiment ID: \_\_\_\_\_

The purpose of this questionnaire is to gather some background information.

1. Your Occupation \_\_\_\_\_
2. If you are a student, your degree program is:  Bachelor  Master  Ph.D.
  - 2.1. If Bachelor's, your year in school (circle one):  
Freshman/Sophomore/Junior/Senior/5<sup>th</sup>Year
  - 2.2. Your major: \_\_\_\_\_
3. If you are not a student, highest degree earned: \_\_\_\_\_
4. Is English your native or first language?  No  Yes  
If **No**, what is your first language? \_\_\_\_\_
5. Ethnic background:
  - African-American
  - American Indian/Pacific Islander
  - Asian
  - Hispanic
  - White
  - Other, please specify \_\_\_\_\_
6. What is your gender?  Female  Male
7. Your age at last birthday? \_\_\_\_\_
8. What is your level of experience in working in groups in general? (Circle a number).
 

Very high	high	medium	low	Very low
1-----	2-----	3-----	4-----	5
9. What is your level of experience in making actual business decisions?
 

Very high	high	medium	low	Very low
1-----	2-----	3-----	4-----	5

10. Have you used web-based discussion program (WebBoard, WebCT, on-line forum, etc.)?

	Six to ten times	Three to five times	Once or twice	Never
Frequently				
1-----	2-----	3-----	4-----	5-----

11. What is the total number of **years** you have been employed full-time? \_\_\_\_\_ years. (Do count summer or other vacation jobs if you work at them full-time.)
12. What is the most number of people you have supervised in a work setting?  
\_\_\_\_\_
13. Identify the industry (work area) that you have spent the **most** time working in (for example, banking, health care, food service, manufacturing, etc.):  
\_\_\_\_\_

**Directions:** Please respond to the following statements regarding communication with other people. Indicate after each statement the degree to which the statement applies to you by circling whether you strongly agree, agree, are undecided, disagree, or strongly disagree. There are no right or wrong answers. Work quickly and just record your first impression.

14. I dislike participating in group discussions.

Strongly Agree	1-----2-----3-----4-----5-----6-----7	Strongly Disagree
-------------------	---------------------------------------	----------------------

15. Generally, I am comfortable participating in group discussions.

Strongly Agree	1-----2-----3-----4-----5-----6-----7	Strongly Disagree
-------------------	---------------------------------------	----------------------

16. Engaging in group discussions with new people makes me tense and nervous.

Strongly Agree	1-----2-----3-----4-----5-----6-----7	Strongly Disagree
-------------------	---------------------------------------	----------------------

17. I am very calm and relaxed when I am called upon to express an opinion at a meeting.

Strongly Agree	1-----2-----3-----4-----5-----6-----7	Strongly Disagree
-------------------	---------------------------------------	----------------------

18. I am confident in contributing information and insight to a group.

Strongly Agree	1-----2-----3-----4-----5-----6-----7	Strongly Disagree
-------------------	---------------------------------------	----------------------

**When you have finished, return the questionnaire to the administrator.  
Please proceed to work on the task by yourself.**

## **APPENDIX G**

### **EXPERIMENTAL TASK**

The task “State Budget Decision” used for the experiment is adapted from “Legislative Dilemma” (Valacich, Mennecke, Wachter, & Wheeler, 1994). Modifications to the original task are:

1. changed the task from allocating funds among the six programs to deciding the order of the six programs;
2. removed amount of funding in the program descriptions;
3. rewrote the background information and instructions.



## State Budget Decision

### BACKGROUND

A few months ago, the newly elected State Governor announced that the state was in deep financial trouble and had to balance the budget. Due to this budget crisis, the State Government eliminated several programs and also raised sales tax in order to increase revenue. Since the economic forecast has become better, the Office of Budget Planning has projected that state might be able to have a small financial surplus because of higher than expected sales tax revenue. The State Senate now has a chance to revise the budget and restore some of these eliminated programs. You, a State Senate in the budget committee, have to work out an order of which programs to restore because the committee will recommend a proposal to the full Senate next week. It is not clear how much the monetary surplus will be, therefore you and other members in the budget committee have to prioritize and determine which programs are to be restored. Programs will be restored according to their rank in the list based upon the final amount of available surplus dollars.

### DIRECTIONS

Evaluate the competing programs and determine their relative merit. Many programs have merit, but limited resources require that you select the programs which you prefer to be restored. Your job is to prioritize those programs you believe deserve to be restored. Although many factors may influence the decisions regarding which programs to be restored, the most important factor is the degree to which a program agrees with your personal values. Your first task is to work on the list of programs individually. Next, discuss with other members via computer to form a group decision.

The mode of interaction for the task is asynchronous, that is, people can work on the same task at different time. Other members may not be using the system at the same time when you are logged in the system. You would have to collaborate with others across time through comments posted in the system and results of each round of voting. Please spend some time working on the task, voting, reading/responding comments by other members, and/or posting your own comments everyday. You can spend as much or as little time as you would like for the task each time you log into the system. The only requirement is that the group has to reach a final decision of the order of programs to be restored in one week. It is best to log in the system to check for comments and voting results several times a day so that you and other members can explore issues in the task more thoroughly. If you have any problem using the system or cannot continue participating in the experiment, please contact Kung-E Cheng (email: [kc37@njit.edu](mailto:kc37@njit.edu) or [kunge.cheng@gss-voting.org](mailto:kunge.cheng@gss-voting.org); Tel: 862-596-2696) as soon as possible. The experiment investigator(s) will contact you if you do not log into the discussion system in the first day of the group discussion session to confirm whether you still want to participate in the

experiment. If your group has reached a final decision before the one week deadline, congregate for a nice job done and please contact Kung-E Cheng.

You can work on the order of programs to be restored either way, from the program to be restored first or the program to be restored last. Use the voting tool to discover agreements/disagreements among group members, then discuss to confirm the agreements and to resolve the disagreements. Investigate the reason(s) for agreements and disagreements within the group. Persuade other members or make compromises based on the arguments for each program. The voting tool is designed so your group can vote multiple times during the task. Do not vote just once. Repeat the vote-discussion cycle until your group reaches a consensus on the order of programs to be restored.

## **THE PROGRAMS**

### Drug, Sex Education, & Contraceptive Programs (Grade 6-12)

This program is designed to invest in the future by developing a drug and sex education curriculum for grades 6-12. It will include making contraceptives available to grades 6-12 without parental consent. Proponents of this project believe that society could greatly reduce the enormous social costs of drug abuse (crime, prisons, lost worker productivity, etc.) and unwanted pregnancies by educating young children through the education process. Opponents argue that this is not their mission for primary and secondary education and that these personal and moral concerns are based upon choices family make. Since smaller and more limited programs in the past have not produced the anticipated results

### Appeal Funding for Death Row Inmates

Designed to provide legal appeal funds for death row inmates with cases that have special circumstances. These circumstances include: finding new evidence since their conviction; or civil liberty problems with their case. Proponents argue that the state must exhaust all important issues of justice before killing a person. Opponents argue that such judicial process errors are very rare and not an important social concern.

### Toxic Waste Cleanup

This program is designed to cleanup environmental hazards that threaten the local water supply of a major city. Currently, the company charged with creating the problem and the state have had a five year legal battle over who should pay for the damages (and the lawsuit is unlikely to be resolved in the next four years). A state funded cleanup effort would qualify for matching federal funds. Proponents of this project argue that the water supply (for a large area) could become contaminated if this project is not funded soon, and they fear this issue will drive away potential business investment in the state. Opponents argue that the seriousness of the threat is overestimated and that the company should be held responsible.

### Abortion Subsidies for Low Income

Designed to pay for an abortion if a woman cannot afford it. Proponents of the project argue that the cycle of poverty and its enormous social costs (welfare, childcare, medical) are perpetuated when poor women cannot choose to end an unwanted pregnancy. As a concession, proponents are willing to include a 24 hour waiting period. Inadequate funding for the project is unlikely to attain the project's objectives. Opponents argue that their tax dollars should not be used for this purpose.

### Housing for the Homeless Center

This program is designed to renovate a vacant downtown warehouse to provide shelter for the city's homeless population. Proponents of this project argue that over 40 people died last year from exposure and inadequate food. A local company has agreed to use part of the warehouse to employ some of the center's residents (on a one year basis), thus, they argue the homeless center would be partially self-sustaining. The resident's work would enable them to stay in the center and reduce the city's welfare expenses. For the project to proceed as planned significant renovations for the warehouse and work area are required, opponents argue that the project will not work and will become a burden on tax payers.

### Job Training for Displaced Workers

This program is designed to provide job training for workers who have been laid off due to their plant closing. The program would provide tuition to attend technical schools and childcare for workers. Proponents argue that such training is essential for the survival of many small towns. Opponents view the program as another form of welfare and believe that our economy already has ample ways for workers to find other jobs.

**State Budget Restoration Order – Before discussion**

**Your Experiment ID:** \_\_\_\_\_

<b>Program Name</b>	<b>Your personal order to restore the program (1 to 6, 1: first; 6: last)</b>
Drug, Sex Education, & Contraceptive Programs	
Appeal Funding for Death Row Inmates	
Toxic Waste Cleanup	
Abortion Subsidies for Low Income	
Housing for the Homeless Center	
Job Training for Displaced Workers	

**State Budget Restoration Order – After group discussion**

**Your Group ID:** \_\_\_\_\_

**Your Experiment ID:** \_\_\_\_\_

<b>Program Name</b>	<b>The group's order to restore the program (1 to 6, 1: first; 6: last)</b>	<b>Your final personal order to restore the program after group discussion (1 to 6, 1: first; 6: last)</b>
Drug, Sex Education, & Contraceptive Programs		
Appeal Funding for Death Row Inmates		
Toxic Waste Cleanup		
Abortion Subsidies for Low Income		
Housing for the Homeless Center		
Job Training for Displaced Workers		

## **APPENDIX H**

### **POST-DISCUSSION QUESTIONNAIRE**

A post-discussion questionnaire was used to obtain subjective data from subjects after completing the experiment task. Items in the questionnaire include measures for general satisfaction, decision process satisfaction, perceived decision quality, group cohesiveness, group process gains/losses, perceived usefulness of voting tool, information usage, and confidence of decision. Three open-ended questions were also in the questionnaire for feedbacks on the experiment material and system.

**Post-Discussion Questionnaire**

**Your Group ID:** \_\_\_\_\_  
**Your Experiment ID:** \_\_\_\_\_

After each statement, circle the answer that applies to you. There are no right or wrong answers. Work quickly; just record your first impression.

1. To what extent did you enjoy participating in this discussion?  
 Very much    1-----2-----3-----4-----5-----6-----7    Not at all
2. How much fun was working on this task?  
 Very much    1-----2-----3-----4-----5-----6-----7    Not at all
3. The group members initiated the discussion on:  
 Relevant issues    1-----2-----3-----4-----5-----6-----7    Irrelevant issues
4. The group members' contributions were:  
 Well expressed    1-----2-----3-----4-----5-----6-----7    Poorly expressed
5. Participation in the discussion was:  
 Evenly distributed    1-----2-----3-----4-----5-----6-----7    Unevenly distributed
6. The interpersonal relationships among the group members appeared to be:  
 Healthy    1-----2-----3-----4-----5-----6-----7    Unhealthy
7. How would you describe your group's problem solving approach?  
 Efficient    1-----2-----3-----4-----5-----6-----7    Inefficient  
 Coordinated    1-----2-----3-----4-----5-----6-----7    Uncoordinated  
 Fair    1-----2-----3-----4-----5-----6-----7    Unfair  
 Understandable    1-----2-----3-----4-----5-----6-----7    Confusing  
 Satisfying    1-----2-----3-----4-----5-----6-----7    Unsatisfying
8. With regard to all group members as a whole, how would you rate the discussion for the task in terms of the following scales?  
 Very meaningful    1-----2-----3-----4-----5-----6-----7    Totally meaningless  
 Vary appropriate    1-----2-----3-----4-----5-----6-----7    Totally inappropriate  
 Very free and open    1-----2-----3-----4-----5-----6-----7    Totally closed/restricted  
 Creative/imaginative    1-----2-----3-----4-----5-----6-----7    Familiar/unimaginative

9. To what extent were members in the group you worked with in this experiment helpful in getting the task done?  
 Very helpful 1-----2-----3-----4-----5-----6-----7 Not at all
10. To what extent would you look forward to work with this group again?  
 Definitely yes 1-----2-----3-----4-----5-----6-----7 Definitely no
11. To what extent did you trust members in the group you worked with in this experiment?  
 Totally trusted 1-----2-----3-----4-----5-----6-----7 Not at all
12. To what extent did information contributed by others cause you to re-evaluate your choice (even if you did not change it)?  
 Very much 1-----2-----3-----4-----5-----6-----7 Not at all
13. To what extent did something someone else contributed make you take a second look at your choice (whether you changed your mind or not)?  
 Very much 1-----2-----3-----4-----5-----6-----7 Not at all
14. To what extent did the information contributed by others affect your decision (whether you changed your original decision or not)?  
 Very much 1-----2-----3-----4-----5-----6-----7 Not at all
15. How do you feel about the process by which the group made its decision?  
 Very satisfied 1-----2-----3-----4-----5-----6-----7 Very unsatisfied
16. How do you feel about your group's discussion?  
 Very satisfied 1-----2-----3-----4-----5-----6-----7 Very unsatisfied
17. All in all, how do you feel?  
 Very satisfied 1-----2-----3-----4-----5-----6-----7 Very unsatisfied
- | <b>Strongly Agree</b> | <b>Agree</b> | <b>Somewhat Agree</b> | <b>Undecided</b> | <b>Somewhat Disagree</b> | <b>Disagree</b> | <b>Strongly Disagree</b> |
|-----------------------|--------------|-----------------------|------------------|--------------------------|-----------------|--------------------------|
| 1-----                | 2-----       | 3-----                | 4-----           | 5-----                   | 6-----          | 7-----                   |
18. The task description makes it clear what was to be accomplished.  
 1-----2-----3-----4-----5-----6-----7
19. I feel I have the background (education and/or experience) needed to carry out this task.  
 1-----2-----3-----4-----5-----6-----7
20. I am confident that our group's decision is good.  
 1-----2-----3-----4-----5-----6-----7
21. I feel very committed to our group's decision.  
 1-----2-----3-----4-----5-----6-----7



22. I am not confident about the group's final decision.  
1-----2-----3-----4-----5-----6-----7
23. The group made a good decision for this task.  
1-----2-----3-----4-----5-----6-----7
24. I have doubts about the group's final decision.  
1-----2-----3-----4-----5-----6-----7
25. I am confident that I can convince others that the group's decision is appropriate.  
1-----2-----3-----4-----5-----6-----7
26. The voting tool helps me understand the positions of other members.  
1-----2-----3-----4-----5-----6-----7
27. The voting tool helps the group focused on the task.  
1-----2-----3-----4-----5-----6-----7
28. Using the voting tool enables the group to reach the decision more easily.  
1-----2-----3-----4-----5-----6-----7
29. The voting tool improves the group decision making process.  
1-----2-----3-----4-----5-----6-----7
30. The voting tool is ineffective in helping the group making the decision.  
1-----2-----3-----4-----5-----6-----7
31. I think the voting tool is useful for group making decisions.  
1-----2-----3-----4-----5-----6-----7
32. Total time I have spent on the experiment task during the one week period is about \_\_\_\_\_  
hours \_\_\_\_\_ minutes.
33. Please identify any aspect of the task or the task materials that you found confusing or  
difficult to understand (for example, instructions, vocabulary, tables, etc.). PLEASE PRINT
- 
- 
- 
- 
34. What specific additional information would have given you greater confidence in making  
your decision?
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35. What changes would you recommend to make the system easier to use?

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**When you have finished, return the questionnaire to the administrator.  
Thank you very much for your participation.**

## **APPENDIX I**

### **AFTER EXPERIMENT DEBRIEFING**

Subjects will be able to view an on-line debriefing of the experiment after completing the post-discussion questionnaire. Subjects will also have a chance to download the debriefing in various formats while reading the on-line debriefing.

Thank you for participating in this study. You probably have some questions about the purpose of the study, the questionnaires that you completed, the State Budget task, the voting tools and the experiment procedure. The following should shed some light on some of these issues.

### **Motivation for the Study**

First of all, there is a large body of research that has been conducted in the area of Group Support Systems (GSS), which are computer systems that support group decision making and other tasks. The vast majority of these research studies have been focus on systems and procedures that aid groups for idea generation (brainstorming). Relatively few studies have been undertaken that help groups reach consensus. Based on field observation of GSS researchers, voting can be an important method to help groups reach consensus. Unfortunately, there were very few theories or experiments investigating the effects of various factors on group decision processes and outcomes in voting. This research study tries to address a small part of this deficiency in GSS research.

### **Experimental Research**

The activity you participated in is considered a laboratory experiment. Two variables are being manipulated in this study. One is the method of voting (simple major voting vs. average score voting) and the other is accessibility of the voting result (no restriction vs. after every member has voted). Taken together, the combination of these independent variables yields four conditions:

1. Simple major voting with unrestricted access to result
2. Simple major voting with restricted access to result
3. Average score voting with unrestricted access to result
4. Average score voting with restricted access to result

Based on your participation in this study you should be able to identify the condition you played a part in.

What are we attempting to learn from this experiment? You completed a number of questionnaires, the State Budget task individually, then in a group, and finally individual questionnaires conclude the process. In order to control personal differences in later analysis, the first questionnaires were administered to get some background information about you. The description of each program in the State Budget task was written in such a way as to accentuate certain personal values. First you complete the task individually so that we can record your initial personal preference. Then you work on the task in a group to reach a group decision. Finally, to measure the effect of GSS and voting, we asked for your after-group-discussion personal preference and your impression about the system and process.

Some of the variables that we are measuring include:

- Consensus change
- Decision process satisfaction
- Perceived Usefulness of voting tool

We are collecting data about these variables in order to test some of the following hypotheses:

**(a) Consensus Change**

H1 groups with average score voting will have a higher level of consensus change than groups with simple major voting.

**(b) Decision Process Satisfaction**

H2a groups with average score voting will have a higher level of decision process satisfaction than groups with simple major voting.

H2b groups with unrestricted access to result will have a higher level of decision process satisfaction than groups with restricted access to result.

**(c) Perceived Usefulness of Voting Tool**

H3a groups with average score voting will have a higher level of perceived usefulness of voting tool than groups with simple major voting.

H3b groups with unrestricted access to result will have a higher level of perceived usefulness of voting tool than groups with restricted access to result.

We will be collecting data from 40 groups (10 groups in each condition and 5 subjects per group), for a total of 200 subjects. When the experimental part of this study is completed, the data will be analyzed. We will then be able to determine if the hypotheses are supported by the data.

Please remember that all of your responses will be kept strictly confidential. Do not hesitate to contact me if you have any questions about this experiment.

Again, thank you for participating in this study!

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