Consideration of group information sharing behavior to guide map-mediated interface design in distributed collaborative spatial decision-making

S. HOPFER*
GeoVISTA Center, Department of Communication Arts and Sciences, Penn State University, 218 Sparks, University Park, PA 16802, USA

The Collective Information Sharing (CIS) Bias is considered in the context of distributed group collaboration for international humanitarian relief response. Information sharing conceptualized as sharing of unique (held by one group member) or shared (information held by at least two group members) information guides visual-spatial representation in interface design. Four theoretical explanations for why the information sharing bias might occur are offered. The implications of the CIS bias for map-mediated group communication is considered for collaborative spatial decision-making. Human dimensions of decision-making are the locus in defining the problem context (inefficient collaborative decision-making) and interface dimensions are considered for the locus of solutions to inefficient group information sharing and decision-making. Annotations might serve to attenuate the CIS bias by minimizing the repeat of information during group discussions.

Keywords: collective information sharing bias, visual communication, annotation, decision support systems, information visualization, distributed group work.

1. Introduction

Groups are composed frequently of members who bring to the table different skills, expertise, and roles. Diverse group members thus, work on tasks that require them to combine their efforts in a way that facilitates joint understanding of a complex problem. An underlying assumption residing in the notion of collaboration is that more heads are better than one when it comes to tackling a complex problem. Research by communication and psychology scholars spanning more than a decade has consistently shown that human communication behavior in small groups is likely to be biased toward discussing shared information (i.e., what group members have in common) rather than pooling the unique information that each group member possesses. This small group communication phenomenon is called the collective information sharing (CIS) bias (Stasser & Titus, 1985; Wittenbaum & Stasser, 1997). This human behavior bias can lead to sub-optimal decision-making when all options are not equally considered.

* email: sxh343@psu.edu

2. Attenuating the CIS discussion bias as a design goal when building tools for decision support

One important goal in designing visual analytical tools for spatial decision support is to attenuate the discussion bias toward shared information. Analytical discourse and reasoning is generally not a linear process (Thomas & Cook, 2005). Collaborating group members engage in convergent and divergent thinking, which involve ensuring that plausible alternatives have not been overlooked. The CIS bias has shown however, that group communication behavior often results in plausible alternatives being overlooked (Stasser & Titus, 1985). As stated by Thomas and Cook (2005), the key to good analytic discipline is early identification of competing explanations and chains of reasoning for the issue under study. Analytical reasoning tools thus, should be built with the goal of identifying early on competing explanations during the iterative, collaborative process of building knowledge structures. To improve upon this process however, tools themselves must not only be designed with the nature of tasks or problems in mind, but also group communicative processes that shape user behavior of visual analytical tools. How information is shared (e.g., the timing and sequence in which information sharing unfolds or the social communicative processes influencing information sharing) is directly related to how knowledge structures come into existence. Emerging knowledge structures lead to influencing how judgments are made about issues. Attenuation of the CIS discussion bias as a goal in developing visual analytical tools is in line then, with the second recommendation set forth in the research agenda on visual analytics to develop visually based methods that support the evaluation of alternatives during analytical reasoning (Thomas & Cook, 2005).

Context shapes the emergence of knowledge structures just as information sharing behavior does. Context should therefore be taken into consideration when designing tools. This paper examines the applied context of distributed spatial decision making for international humanitarian relief response. Experts and non-experts across the globe collaborate to share information, build knowledge structures, and make decisions when helping countries encountering a crisis.

3. Context of international humanitarian relief response

The context of international humanitarian relief response defines in part the conditions that shape visual analytical discourse and spatial decision making among distributed collaborators for this paper. At least four factors characterize the context of international humanitarian relief response: a) more than one possible solution to solving a problem in some instances, b) a high cost for poor decisions, c) time pressured decision making, and d) motivated decision-making (Andrienko & Andrienko, 2006; MacEachren & Cai, 2006).

When assessing a humanitarian crisis and making decisions about prioritizing tasks there is likely more than one way of solving a problem. Tasks with demonstrably correct answers are intellective tasks while tasks that call for group consensus are judgment tasks (Hollingshead, 1996). Group information pooling behavior differs depending on the framing of task type (Laughlin,1980; Laughlin & Ellis,1986). Both judgment and intellective tasks are likely to be made in international humanitarian relief efforts. More elaborate task typologies have been developed (Kelly & McGrath, 1985; MacEachren, 2005; Andrienko, Andrienko & Gatalasky, 2003) and are in need of being tested for their influence on group information pooling behavior. While further exploration on task type is encouraged, the suggestion should be noted from scholars of functional group decision theory that task type is likely to be a weaker predictor of group information sharing behavior than group member characteristics or member access to view or share information (Gouran & Hirokawa, 1983, 1996, 2003).

The cost of a poor group decision can be high when costs involve human suffering and loss of life such as in an international humanitarian disaster response. Time pressure also characterizes information sharing and decision making for international humanitarian relief response. Time shortage is not an optimal condition for increasing the pooling of unique information. Time pressured information sharing can however, lead to motivated information sharing. Motivation is presumed to influence the likelihood of mentioning information (Wittenbaum, Hubbell, & Zuckerman, 1999). Despite high motivation, collaborating groups existing across distance, time, organizational boundaries, and cultures encounter significant challenges to efficiently share information in a computer-mediated (let alone in an in-person) environment.

Visual tools thus, which are able to capture unique and shared information offer the advantage of minimizing the duplication or repeat of information during group discussion. Discussion that revolves around describing spatially complex and incomplete information and that can change rapidly such as in disaster response stands to benefit from visual analytical tools that prevent redundant information.

4. The Collective Information Sharing (CIS) Bias

A seminal study by Stasser and Titus (1985) revealed that groups often make suboptimal decisions for task information structured as hidden profiles because they tend to discuss and incorporate into their decisions, information that is shared (known to all members) at the expense of that which is unshared (known to a single member or unique). Hidden profiles involve group tasks in which a superior decision alternative exists, but its superiority is not obvious to individual members because they each have only a portion of information that supports

the superior alternative (Stasser & Stewart, 1992). Since the phenomenon was first noted, scholars in the field of communication and information science have overwhelmingly uncovered support for the presence of the discussion bias (Cruz, Boster, & Rodriguez, 1997; Hollingshead, 1996; Jefferson, Ferzandi & McNeese, 2004; Larson et al., 1994; Larson et al., 1996; Stasser & Stewart, 1992; Stasser, Stewart, & Wittenbaum, 1995; Stewart & Stewart, 2001; Wittenbaum, Hubbell, & Zuckerman, 1999; Wittenbaum, 2000; Wittenbaum, Hollingshead, & Botero, 2004).

The CIS bias has been studied in a number of ways including focusing on information type, task type, group member characteristics and, more recently, member access to information. To a large extent, research has focused on information type and group members' ability to recall information, as well as strategies to make unshared information salient. Group member characteristics have received equal attention in research efforts. The influence of member status and expertise have been explored, with both presumed to facilitate information pooling (Franz & Larson, 2002). The considerable evidence supporting the CIS bias indicates that it is an important communication construct to take into consideration when trying to understand how groups communicate for decision-making. Given that group collaboration and decision-making cross many domains, and that collaboration is often critical to tackling complex problems, work groups stand to benefit significantly from artifacts in a mediated system that effectively pool resources across all participating members. At least four theoretical explanations for why the CIS bias occurs are delineated in the discussion that follows. Approaches to interface design with the goal of attenuating the CIS bias will differ depending on which explanation is most credible.

5. Theoretical explanations for the CIS Bias

5.1 The Information Sampling Model (ISM)

The Information Sampling Model (ISM) rests on the view that group discussion is best conceptualized as an information sampling process. Stasser and Titus proposed the Information Sampling Model (1985), which treats information and mentioning a given piece of it as a matter of probability. Group discussion is thus, conceptualized as an information sampling process. The likelihood of a piece of information being mentioned and discussed collectively increases as the number of individual members who know that piece of information increases (assuming perfect recall ability). The theory of boundary objects similarly addresses the likelihood of a piece of information being discussed collectively (MacEachren & Cai, 2006). A blackboard or a map can sit in the middle of a group of experts many of whom have divergent viewpoints while the map acts as an object to talk with (or about). That is, visual representations or boundary objects can take on meaning through the dialogue carried on about them as the

object is discussed collectively even if from diverging viewpoints. Empirical research has supported the information sampling model (ISM) both in laboratory, controlled settings and in limited natural settings–one study of medical decision-making teams (Larson et al., 1996). Empirical research guided by the ISM has been further supported in computer-mediated environments (Hollingshead, 1996), thus in a context that corresponds to the focus in this paper -- web-based map-mediated collaboration to facilitate humanitarian relief logistics.

Privileging the information sampling model (a data-centric model) as a way of understanding group discussion directs the approach toward designing visual analytical tools to equalize the *number* and *timing* of opportunities to elicit unshared and shared information. An interface designed for geocollaboration (i.e., distributed, web-based map-mediated communication) could be equipped with annotation capabilities that encourage and elicit from each group member his or her unique knowledge (not only increase the *number* of opportunities, but integrate the elicitation of unique information *early* in the discussion).

Although the Information Sampling Model has explained significant variance in laboratory group experiments, it does have limitations. The model does not account for patterns of information pooling behavior in groups that violate certain "probability sampling" conditions. Three conditions include when a) members' expertise is known, b) members differ in status, and c) when shared information can be distinguished from unshared information. I turn, thus, to conceptualizations of group discussion that acknowledge social (connective-centric) aspects of group collaboration.

5.2 The Mutual Enhancement Effect (MEE)

Group information sharing can also be conceptualized as an inherently social process. In privileging a social rather than a purely informational perspective on information sharing, motivational reasons may in part explain variance in group information sharing behavior patterns. Wittenbaum et al. (1999) proposed that shared information is likely to have greater importance than unshared (i.e., unique) information because its exchange during discussion serves to validate members' task knowledge. When a piece of shared information is mentioned during discussion, other members can confirm its accuracy and relevance to the group task (Festinger, 1954). However, mentioning unique information (that only one group member knows) cannot be validated for accuracy or credibility by other group members. Evaluation of communicators' shared but not unique information is typically evaluated positively (Hollingshead, 1996). Communicators of shared information are perceived as competent and knowledgeable. Mutual enhancement, then, is a process whereby group members develop enhanced evaluations of each other's task

capabilities when shared information is mentioned. Mutual enhancement thus, promotes the prevalence of shared information during group discussion.

Group member characteristics typically become the focus of attention when privileging group discussion as a social process. Status is one member characteristic and is a characteristic around which differences in cognitions and evaluations of individuals or social types of them come to be organized (Berger & Zelditch, 1977). Status embodies those characteristics that lead groups to think about members in terms of their personal characteristics and what contributions they can make to the task at hand. Such characteristics might include expertise, tenure, gender, age, and ethnicity. It is particularly lower status, inexperienced group members who bias their discussion contributions toward shared information. Wittenbaum et al. (1999) have suggested that for low-status members, communicating unshared information is risky. Members who communicate unshared information are considered less knowledgeable and competent with respect to the task and less credible than members of equal status who communicate shared information. This is particularly the case when the group consists of strangers who have no means of validating accuracy and importance of contributions. The effects of mutual enhancement are likely to be limited to group members who are not well acquainted. This is likely to be the case for international, collaborative humanitarian relief response -- collaborators are unlikely to be well acquainted with each other prior to the collaboration. Therefore, communicating unshared information may be something that only members already high in status can afford to do. In the case of experienced members who are regarded as task competent, others may accept their communicated unshared information without question.

5.3 A Strong Commitment to Initial Preferences

Another theoretical explanation for why groups might prefer shared information during discussion is based on group members' pre-discussion preferences (i.e., their initial preferences, judgments, or beliefs; Gigone & Hastie, 1993, 1997). Many group members typically enter a discussion with preconceived decision preferences that they may be reluctant to revise. Studies of evidence use and its effects on evaluating information show a stable tendency for people to be conservative in revising their initial beliefs or reluctant that is, biased toward the first plausible hypothesis they develop (Anderson, Schum, & Twining, 2005; Morely, 1987; Morely & Walker, 1987; Wright & Drinkwater, 1997). Greitmeyer and Schulz-Hardt (2003) showed that group members evaluate preference-consistent information more favorably than preference-inconsistent information. One explanation for this is cognitively based. Information that is consistent with a person's beliefs is accepted more or less at face value, whereas inconsistent

information is tested more intensively and critically (which requires more cognitive effort). The evaluation bias in favor of preference-consistent information explains in part why group discussion favors shared information. Because shared information largely supports members' initial preferences, they evaluate it as more important and, therefore, more worthy of discussion than unshared information. In view of this tendency in human communication, the user interface could be designed to elicit and uncover group member initial preferences prior to group collaboration and make them explicit.

5.4 The Social Comparison Process

Social comparison processes offer a fourth theoretical explanation for why the discussion bias occurs (Festinger, 1954). In situations of great uncertainty (e.g., humanitarian relief collaboration), such as while working on an unfamiliar task, group members may look to others to evaluate the relative importance of their information. Hearing that others possess the same information may make that information appear to be more valuable, important, and relevant. Research supports the notion that shared information is evaluated more favorably, that is, as more important, valuable, and relevant than unshared information (Postmes, Spears, & Cihangir, 2001; Wittenbaum, Hubbell, & Zuckerman, 1999). Similar to the mutual enhancement effect, the social comparison effect draws on psychological motives of group members. Bolstering confidence of group members during situations of great uncertainty is likely to influence positively whether and how much unique information group members share.

6. Making Unique Information Salient

Strategies for making unique information salient are likely to differ depending on whether group communication patterns are more accurately explained by the information sampling model (ISM), which is data-centric or by the one of the three socially oriented information sharing models (MEE, initial preferences, social comparison), which are connective-centric.

Previous strategies to elicit the expression of unique information have included either suppressing shared information or making unique information salient (Hollingshead, 1996). A strategy for the latter has involved shifting the focus from shared to unshared information. One of the ways in which map-mediated group interfaces can function is to *coordinate* group interactions (MacEachren, 2005). Coordination strategies that promote the ability of group members to recall unique information might also likely to promote group members mentioning more unique than shared information.

Improving recall of information through the use of annotations in a visual display function as boundary objects (Henderson, 1991; MacEachren & Cai, 2006). Visual representations as boundary objects can facilitate group members' reading of alternative meanings (distinguishing between shared and unique information) when functioning as objects to "talk *about*". Coordination strategies of visual representations functioning as boundary objects therefore, could play a role in making unique information more salient by promoting the development of coordinated group recall.

7. Geo-spatial annotations

Digital web-accessible annotations are a form of conversion that can enrich group discussion around maps but also make unique information more salient. In-context digital annotations have been a relatively unexamined phenomenon (Cadiz, Gupta, Grudin, 2000). Annotations have the potential to fulfill several communication functions for synchronous and asynchronous group communication: augmenting organizational memory, documenting reasoning by other group members, drawing a viewer's attention to a location, generating ideas, facilitating rapid recollection of content (Ovsiannikov, Arbib, Mcneill,1999). Furthermore, for international humanitarian relief response, annotations could be promoted to draw other group members' attention to a) evidence, b) knowledge gaps, c) degrees of certainty about an issue, and e) alternatives. Annotations can take the form of text, spatial bookmark with a hyperlink, icon, or picture to name a few examples (Kolbe, Steinrucken, Plumer, 2003).

Strategies for visual tool design guided by the information sampling model (ISM) would focus on limiting or controlling the number and timing of annotation capabilities by group members so as to minimize repeat of information. Strategies for visual tool design guided by a socially oriented or connective-centric group communication model would focus on manipulating digital annotations to impart a psychological effect and encourage the sharing of unique information. One way annotations could take advantage of their digital affordances is to have them fade away or fade in color intensity after a period of time. Manipulating temporal aspects of visual tools was observed to reduce psychological inhibitions and increase participation of junior officers during military group discussions (Kerpedjiev & Roth, 2000). Private and public (i.e., public indicating access to all collaborators in this discussion and not necessarily interfaces accessible to the general public) annotations could be used in different layers. Annotation tool kits guided by information sharing principles with the goal of reducing redundant information among group members could be built to enhance collaborative activities. Like wikis annotations render what might initially be perceived as a hierarchical communication as more of a horizontal communication platform

for group discussion. Furthermore, annotations can be used to negotiate interpretations of situations acting as boundary objects to trigger collaborative discussion (Giacaardi, Eden, & Fischer, 2006; Kerpedjiev, Carenini, Green, Moore, Roth, 1998; MacEachren & Cai, 2006). Without annotations, groups are likely to repeat more information. Empirically investigating the utility of geo-spatial annotations to eliminate redundant sharing of information is a rich avenue for further study.

8. Ascertaining unshared information types

Group members most likely suspect that other members bring unique knowledge to the discussion, however there is frequently no mechanism for anticipating what types of information are unshared. The nature of unique knowledge is however, not always so obscure. Group members with a history of working together may develop a division of responsibility for obtaining, processing, and communicating certain types of information. Other groups are composed with the explicit goal of having certain areas of expertise represented. Therefore, members recognize expert roles within the group and associate these roles with specific domains of knowledge. In such cases, members undoubtedly have a sense of who is likely to be in possession of which type of unique knowledge. Groups function in this sense as transactive memory systems.

9. Transactive Memory Theory [a distributed spatio-temporal cognitive system]

Thus far, theoretical group discussion perspectives have focused attention on the potential of interface aspects to attenuate the CIS bias for distributed group contexts. This "context" will be elaborated here. Geocollaborative (i.e., distributed) groups using map-mediated communication can function as a *memory system*. Two major components of a transactive memory systems include a) individual memories of members and b) the transactive process (embodied in communication), which constructs, reconstructs, and uses these individual memories. What enables the group to function as an efficient memory system is the shared knowledge of who knows what types of information. As Wegner (1986) has noted, "The transactive memory begins when individuals learn something about each others' domains of expertise." (p. 191). Communication media have the potential to facilitate group members' becoming aware of which group member possesses what kind of information. McLuhan's (1963) famous slogan, "the medium is the message" (p. 7) has galvanized attention to the importance of the communication medium. McLuhan tended to distinguish media according to their perceptual demands on information processing. He was less concerned with message content.

Although not a specific model of tacit coordination, transactive memory theory articulates processes that involve tacit coordination. Tacit coordination is intricately linked with group discussion. Other group members function as sources of external memory storage. This notion is also in line with distributed spatio-temporal cognition (Tomaszewski & MacEachren, 2006), in which the communication medium, in addition to other members, takes on an active role in the functioning group communication *system*. Annotations can serve as memory off-loading devices lessening cognitive load of group members (MacEachren, 2005; Bilda & Gero, 2005). By shifting the focus of interaction and integration of information literally *onto* a map interface, the visual communication medium functions to make information salient. This, in turn, makes "visible" (both literally, and cognitively) in the minds of participating group members, what unshared information has been omitted from the interaction of collective group ideas unfolding *on* the map interface.

The cost of acquiring, storing, and retrieving information to share with others takes effort on the part of group collaborators. An efficient transactive memory system (i.e., spatio-temporal distributed cognitive system) is based on the principle of least collaborative effort. It costs, in time and effort, to acquire, store, and retrieve information from any source, and there is additional cost to disseminating information to others. Group members are, therefore, likely to communicate unique information strategically and selectively to other members. From this perspective, information can be regarded as a *resource* that is potentially a) valuable and b) costly to obtain and share. Having group members off-load their unique knowledge lessens cognitive load and hereby, encourages sharing of unique information. Little empirical research has been conducted on the role of geovisualization to support coordinated activity with a focus on augmenting the pooling of unique information in group discussions.

10. Discussion

In a deliberating group, shared information (information held by many or most) usually has a much greater effect than unshared information (information held by a few or just one). The result is that groups have "hidden profiles," in the form of information that does not get out, or that has less impact than it deserves. This phenomenon presumably leads to suboptimal decision-making. The argument is made, therefore, that the CIS bias is an important communication construct to take into account in understanding how discussion based group decision-making unfolds. Depending on which model of collaboration best characterizes a particular group discussion (ISM, MEE, commitment to initial preferences, social comparisons), approaches to attenuate the CIS bias will differ. One critical communication goal for group discussion is to elicit unshared information early in the process. Geo-spatial

annotations for distributed conversation support could take on a proportion of the collective group cognitive load of shared information. This might allow group members to focus on dissemination and pooling of unique information. Furthermore, geo-spatial annotations have the potential to take an active role as coordinating mechanism in the collective group *system*-to elicit, store, coordinate, and make salient unique information.

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References

Anderson, T., Schum, D. Twining, W. (2005). Fact investigation and the nature of evidence in *Analysis of Evidence*, Cambridge: Cambridge University Press.

Andrienko, N., Andrienko, G. (2006). Intelligent visualization and information presentation for civil crisis management. *9th AGILE conference on geographic information science*, Visegrad, Hungary.

Andrienko, N., Andrienko, G., Gatalasky, P. (2003). Exploring spatio-temporal visualization: an analytical review. *Journal of Visual Languages and Computing*, 14, 503-541.

Berger, J., Zelditch, M., Jr. (1977). Status characteristics and social interaction: The status organizing process. In J. Berger, M.H. Fisek, R.Z. Norman, & M. Zelditch, Jr. (Eds.) *Status characteristics and social interaction: an expectation-states approach* (pp.3-87). New York: Elsevier.

Bilda, Z., Gero, J. S. (2005). Does sketching off-load visuo-spatial working memory? Thesis, **Retrieved on May 3rd from** http://www.arch.usyd.edu.au/~zbil4930/

Cadiz, J., J., Gupta, A., Grudin, J. (2000). Using web annotations for asynchronous collaboration around documents. *CSCW* December 2-6, Philapdelphia, PA.

Conklin, J. E. (2006). *Dialogue Mapping*: *building shared understanding of wicked problems*. Wiley: Chichester, UK, pp. 242.

Cruz, M.G., Boster, F.J., & Rodriguez, J.I. (1997). The impact of group size and proportion of shared information on the exchange and integration of information in groups. *Communication Research*, 24, 291-313.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations*, 7, 117-140.

Franz, T.M., Larson, J.R., Jr. (2002). The impact of experts on information sharing during group discussion. *Small Group Research*, 33, 383-411.

Giaccardi, E., Eden, H., & Fischer, G. (2006). The silence of the lands: promoting the virtual museum as a place of cultural negotiation. *New Heritage Forum*, Hong Kong, 13-15 March, available at http://www.thesilence.org/documents/SOL_documents_NewHeritage.pdf

Gigone, D., Hastie, R. (1993). The common knowledge effect: information sharing and group judgment. *Journal of Personality and Social Psychology*, 65, 959-974.

Gigone, D., Hastie, R. (1997). The impact of information on small group choice. *Journal of Personality and Social Psychology*, 72, 132-140.

Gilliland, S.W., Schmitt, N., Wood, L. (1993). Cost-benefit determinants of decision process and accuracy. *Organizational Behavior and Human Decision Processes*, 56, 308-330.

Gouran, D.S., & Hirokawa, R.Y. (1983). The role of communication in decision-making groups: a functional perspective. In M.S. Mander (Ed.), *Communications in transition* (pp.168-185). New York: Praeger.

Gouran, D.S. & Hirokawa, R.Y. (1996). Functional theory and communication in decision-making and problem solving groups: An expanded view. In R.Y. Hirokawa & M.S. Poole (Eds), *Communication and group decision-making* (2nd ed., pp.55-80). Thousand Oaks, CA: Sage.

Gouran, D.S., & Hirokawa, R.Y. (2003). Effective decision making and problem solving in groups: a functional perspective. In R. Y. Hirokawa, R. S. Cathcart, L. A. Samovar, & L. D. Henman (Eds.), *Small group communication* (pp.27-38). Los Angeles, CA: Roxbury.

Greitmeyer, T. and Shulz-Hardt, S. (2003). Preference-consistent evaluation of information in the hidden profile paradigm: Beyond group-level explanations for the dominance of shared information in group decisions. *Journal of Personality and Social Psychology*, 84, 322-339.

Henderson, K. (1991). Flexible sketches and inflexible data bases: visual communication, conscription devices, and boundary objects in design engineering. *Science, Technology, and Human Values*, 16 (4), 448-473.

Hollingshead, A.B. (1996). Information suppression and status persistence in group decision-making: the effects of communication media. *Human Communication Research*, 23 (2), 193-219.

Jefferson, T. Jr., Ferzandi, L., McNeese, M. (2004). Impact of Hidden Profiles on Distributed Cognition in Spatially Distributed Decision-making Teams. *Proceedings of Human Factors and Ergonomics Society's 48th Annual Meeting*, New Orleans, Louisiana, September 20-24.

Kelly, J.R., McGrath, J.E. (1985). Effects of time limits and task types on task performance an dinteraction of four-person groups. *Journal of Personality and Social Psychology*, 49, 395-407.

Kerpedjiev, S., Carenini, G., Green, N., Moore, J., Roth, S. (1998). Saying it in graphics: from intentions to visualizations. In *Proceedings of Information Visualization IEEE*, Research Triangle, NC, October 19-20.

Kerpedjiev, S., Roth, S. F. (2000). Mapping communicative goals into conceptual tasks to generate graphics discourse. Proceedings of the 5th International Conference on Intelligent User Interfaces, New Orleans, Louisiana.

Kolbe, T. H., Steinrucken, J., Plumer, L. (2003). Cooperative Public Web Maps. *Proceedings of the International Cartographic Congress ICC* Durbin, South Africa.

Larson, J.R.Jr., Christensen, C., Abbott, S., Franz, T.M. (1996). Diagnosing groups: charting the flow of information in medical decision-making teams. *Journal of Personality and Social Psychology*, 71 (2), 315-330.

Larson, J.R.Jr., Foster-Fishman, P.G., Keys, C.B. (1994). Discussion of shared and unshared information in decision-making groups. *Journal of Personality and Social Psychology*, 67 (3), 446-461.

Laughlin, P.R. (1980). Social combination processes of cooperative problem solving groups on verbal intellective tasks. In M. Fishbein (Ed.) *Progress in Social* Psychology *(Vol. 1, pp.125-155)*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Laughlin, P.R., Ellis, A.L. (1986). Demonstrability and social combination processes on mathematical intellective tasks. *Journal of Experimental Social Psychology*, 22, 177 -189.

MacEachren, A. M. (2005). Moving geovisualization toward support for group work. In J. Dykes & A.M. MacEachren & M.J. Kraak (Eds.) *Exploring Geovisualization*. Amsterdam: Elsevier. pp.445-461.

MacEachren, A. M., Cai, G. (2006). Supporting group work in crisis management: visually mediated human-GIS-human dialogue. *Environment and Planning B: Planning and Design*, 33, 435-456.

MacEachren, A. M., Cai, G., Sharma, R., Rauschert, I., Brewer, I., Bolleli, K., Shaparenko, B., Fuhrmann, S., and Wang, H. (2005). Enabling collaborative geoinformation access and decision-making through a natural, multimodal interface. *International Journal of Geographical Information Science*, 19 (3), 293-317.

MacEachren, A. M., Gahegan, M., Pike, W. (2004). Visualization for Constructing and Sharing Geoscientific Concepts. In *Proceedings of the National Academy of Science*, 101 (supp. 1): 5279-5286.

McLuhan, M. (1963). *Understanding Media*. New York: Signet.

Mennecke, B.E., Valaciche, J.S. (1998). Information is what you make of it: The influence of group history and computer support on information sharing, decision quality, and member perception s. *Journal of Management Information Systems*, 15, 173-197.

Morely, D. D. (1987). Subjective message constructs: a theory of persuasion. *Communication Monographs*, 54, 183-203.

Morely, D. D., Walker, K. B. (1987). The role of importance, novelty, and plausibility in producing belief change. *Communication Monographs*, 54, 436-442.

Ovsiannikov, I.A., Arbib, M.A., McNeill, T.H. (1999). Annotation technology. *International Journal of Human-Computer Interactions*. 50, 329-362.

Postmes, T., Spears, R., Cihangir, S. (2001). Quality of decision-making and group norms. *Journal of Personality and Social Psychology*, 80, 918-930.

Stasser, G., Stewart, D.D. (1992). The discovery of hidden profiles of decision-making groups: solving a problem versus making a judgment. *Journal of Personality and Social Psychology*, 63, 426-434.

Stasser, G., Steward, D.D., Wittenbaum, G.M. (1995). Expert roles and information exchange during discussion: the importance of knowing who knows what. *Journal of Experimental Social Psychology*, 31, 244-265.

Stasser, G., Titus, W. (1985). Pooling of unshared information in group decision-making: Biased information sampling during discussion. *Journal of Personality and Social Psychology*, 48, 48-1467.

Stewart, D.D., Stewart, C.B. (2001). Group recall: the picture-superiority effect with shared and unshared information. *Group dynamics: theory, research, and practice*, 5, 5-48.

Tomaszewski, B.M., MacEachren, A.M. (2006). A distributed spatiotemporal cognition approach to visualization in support of coordinated group activity. *Proceedings of the 3rd International ISCRAM Conference*, Newark, NJ, May (submitted).

Thomas, J. J., Cook, K. A. (2005). The Science of Analytical Reasoning In *Illuminating the Path: The Research and Development Agenda for Visual Analytics*. Retrieved on November 2005 from http://nvac.pnl.gov/agenda.stm

Wegner, D.M. (1986). Transactive memory: a contemporary analysis of the group mind. In B. Mullen & G.R. Goethals (Eds.) *Theories of group behavior* (pp. 185-208). New York: Springer-Verlag.

Wittenbaum, G.M. (2000). The bias toward discussing shared information. *Communication Research*, 27 (3), 379-401.

Wittenbaum, G.M., Hubbell, A.P., and Zuckerman, C. (1999). Mutual enhancement: toward an understanding of the collective preference for shared information. *Journal of Personality and Social Psychology*, 77, 77-967.

Wittenbaum, G.M., Hollingshead, A.B., Botero, I.C. (2004). From cooperative to motivated information sharing in groups: moving beyond the hidden profile paradigm. *Communication Monographs*, 71 (3), 286-310.

Wittenbaum, G., Stasser, G. (1997, May). The role of group member status in collective information sampling: some psychological underpinnings. *Paper presented at the annual meeting of the Midwestern Psychological Association*, Chicago.

Wright, J.C., Drinkwater, M. (1997). Rationality versus accuracy of social judgment. *Social Cognition*, 15, 245-273.