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Massively Parallel Collaboration: A Literature Review

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Abstract

The present paper explores group dynamics and electronic communication, two components of wicked problem solving that are inherent to the national security environment (as well as many other business environments). First, because there can be no 'right' answer or solution without first having agreement about the definition of the problem and the social meaning of a 'right solution,' these problems (often) fundamentally relate to the social aspects of groups, an area with much empirical research and application still needed. Second, as computer networks have been increasingly used to conduct business with decreased costs, increased information accessibility, and rapid document, database, and message exchange, electronic communication enables a new form of problem solving group that has yet to be well understood, especially as it relates to solving wicked problems.

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"Wicked," or ill-defined problems, are at the very core of the national security mission; however, very little is empirically known or generally understood about how best to solve such challenges. In fact, "wicked" problems are those problems that by their very definition are so tangled that there is not agreement about their definitions, much less their solutions. The present paper explores two components of wicked problem solving that are inherent to the national security environment (as well as many other business environments): group dynamics and electronic communications. First, because there can be no 'right' answer or solution without first having agreement about the definition of the problem and the social meaning of a 'right solution,' these problems (often) fundamentally relate to the social aspects of groups (Allison, 2006). For the purposes of this paper, groups are defined as "two or more persons who share common goals, whose fates are interdependent, who have a stable relationship, and who recognize that they belong to a group" (Baron & Byrne, 1997, p. 471) [1]. Second, as computer networks have been increasingly used to conduct business with decreased costs, increased information accessibility, and rapid document, database, and message exchange (Siegel, Dubrovsky, Kiesler, & McGuire, 1986, as referenced by Baltes et al., 2002), electronic communication enables a new form of problem solving group that has yet to be well understood, especially as it relates to solving wicked problems.

As proposed by Rittel and Webber (1973), "wicked problems" stand in contrast to the more linear nature of "tame" problems and may therefore demand different, less linear-based, solution methods. Wicked problems have incomplete, changing, and contradictory requirements. Solutions to them are often difficult to recognize as such because of complex interdependencies. Classic examples of wicked problems include environmental, economic, and political issues (for an extreme case, consider what it would take to "solve" terrorism, where even the term terrorism is highly controversial and difficult to define). By contrast, tame problems are better structured, more linear challenges like those of mathematics, chess, or puzzle solving. Tame problems: "1) have a well-defined and stable problem statement, 2) have a definite stopping point, i.e. when the solution is reached, 3) have a solution which can be objectively evaluated as right or wrong, 4) belong to a class of similar problems which are all solved in the same similar way, 5) have solutions which can be easily tried and abandoned, and 6) come with a limited set of alternative solutions" (Conklin, 2005, p. 11). By contrast, wicked problems violate at least one of these characteristics, although this characteristic initially may not be apparent.

[1] In the present paper, "group decision making" includes groups of individuals with a relationship to one another, and does not include voting (sometimes referred to as the social aggregation of individual votes). We see this distinction as important because of the existing theory and process differences between group decision making and voting, as well as because of the increased time and effort investment required of the former (Greitemeyer, Brodbeck, Schulz-Hardt, Frey, 2006).

Group Dynamics

Although wicked problems are not constrained to groups (i.e., an individual may encounter a wicked problem), the two are often related (Conklin, 2005). For example, projects and problem solving are typically social in nature (Conklin, 2005). Groups are typically composed of members with variable levels of expertise and often work to solve problems that require them to combine their input and form some type of aggregate product or decision" (Bonner, 2004, p. 277). Moreover, problems whose solution(s) require large groups of individuals to change their mindsets and behaviors are likely to be a wicked problem in and of themselves. Thus, understanding group dynamics is a key component to understanding how to best solve wickedly difficult problems.

Anticipating how groups can best be utilized to solve wickedly difficult problems is a daunting task for (at least) two reasons. First, the relevant group literature is vast, spanning multiple psychological definitions, levels of granularity, academic disciplines, and countries. Second, group dynamics involves anticipating the complex interactions between potential group, individual, process, and contextual variables.

In terms of definition, group dynamics relate to decision-making, as well as problem solving. While both are related, the former is a choice among given alternatives, and the latter focuses more on correct problem identification in that it is a determination of how to proceed from a given state to a desired goal. Thus, the relevant knowledge base includes literatures examining group dynamics, problem solving, and decision-making. These literatures are vast, with the PsychInfo database alone noting 12,290 published works citing "group dynamics" as a key word string, 30,386 citing "problem solving" as a key word string, and 40,652 citing "decision making" as a key word string. A strong group research theme has also emerged within Europe and Japan (Davis, 1996), which further expands upon this literature.

A survey of group dyamincs is also complicated by its many levels of granularity, including sociological/cultural, psychological, and potentially, even biological. What was once primarily a social psychology emphasis has grown into an intraindividual emphasis, as well as a multidisciplinary study. Social psychology has experienced an inward paradigm shift focusing more upon the individual's effect upon the group, and less upon external causes (e.g., behavior sequences over time, multiple-person units, etc.; Steiner, 1986); whereas, group-level research topics have evolved into various specific, multidisciplinary problems (e.g., communication, organizational research, social decision making including social dilemmas, bargaining and negotiation, experimental games, and consensual decision making; Davis, 1996).

The study of groups is also complicated by a social psychology shift relating to a multi-disciplinary and more global literature. In 1974, Steiner posed his famous question, "Whatever happened to the group in social psychology?" According to Davis (1996), in the mid-1900's, when behaviorism began to lose its hold on psychology, there was an accompanying inward shift within social psychology such that questions about intraindividual life became the principal research interest. One possible reason for this

shift may relate to the multiplied subjects and related costs group level research requires over individual level research (Davis).

While Steiner (1986) concluded that paradigm shifts in social psychology favored the intraindividual emphasis at the expense of external causes (including sequences of behavior over time and multiple-person units), Davis has offered a contrasting hypothesis. Davis has suggested that group-level research topics have evolved from social psychology into various specific, multidisciplinary problems (e.g., communication, organizational research, social decision making including social dilemmas, bargaining and negotiation, experimental games, and consensual decision making). He further suggests that group research continues as a strong theme in European and Japanese social psychology, although the cause of this divergence from North American psychology remains unclear.

Our own literature search supports Davis's conclusion that there is a vast quantity of multidisciplinary group research. For example, comparing 18 related keyword strings (i.e., group decision making, decision success, face to face communication, computer mediated communication, distributed teaming, collaborative problem solving, group problem solving, electronic decision making, computer supported cooperative work, social cognition, group dynamics, group performance, computer supported collaboration, on line group, on line interaction, collaborative engineering, information fusion and humans, large group dynamics) to titles and abstracts back to 1991, Kevin Boyack[2] found 2586 related peer-reviewed articles. These did not include social sciences data from 2004-2005, so this is a conservative estimate that underscores the difficulty in understanding a unified empirical picture of group research.

In addition to the group literature's vastness, the area is further complicated by the necessity to anticipate complex interactions between potential group, individual, process, and contextual variables. These complexities can be appreciated in terms of the research examining effective group size, the benefits of groups, and the costs of groups.

How many people comprise an effective group? The answer is complex and context dependent. Moreland, Levine, and Wingert (1996) have concluded that the ideal group size is not well understood. It probably depends on many variables including the task being examined, the ambitiousness of the group's goal, and the research methodology that is instantiated. While anecdotal evidence suggests that work teams should consist of 4 to 12 members (Katzenbach & Smith, 1993; Scharf, 1989; Parker, 1994; Nasser, 1988), field observations indicate that people naturally tend to break up into 2 or 3 person groups for social interactions (Bakeman & Beck, 1974; Burgess, 1984; Desportes & Lemaine, 1988; James, 1951). When complaints are examined, small discussion groups containing five members were the ideal (Slater, 1958); yet, when people are asked to describe the ideal size of a group, they report that they prefer groups containing a dozen members (Carron, Widmeyer, & Brawler, 1989; Cini, Moreland, Levine, 1993; cf. Buys & Larson, 1979; McPherson, 1983).

[2] Personal communication concerning survey of the indicated abstracts using the Sandia National Laboratories literature mining tool, VxInsight, 2006.

Because there is no simple way to study groups, correlates of group size have also been examined. While larger groups enjoy advantages in their resources (including expertise, time and money; Dennis & Valacich, 1993; Grofman, Owen, & Feld, 1983; Haleblian & Finkelstein, 1993, Hill, 1982; Wegner, 1987), diversity (Bond & Keys, 1993; N. Miller & Davidson-Podgorny, 1987), and legitimacy (Singh & Lumsden, 1990), smaller groups may excel in terms of coordination (Diehl & Stroebe, 1987; Latane, Williams, & Harkins, 1979; McGrath & Rotchford, 1983; Stasser & Taylor, 1991), motivation (Albanese & Van Fleet, 1985; Karau & Williams, 1993; Shepperd, 1993), and cooperation advantages (Brewer & Kramer, 1986; Hamburger, Guyer, & Fox, 1975).

To anticipate how groups can best be utilized to solve wickedly difficult problems, one must also understand how group, individual, and contextual interactions relate to potential group benefits and costs. While groups satisfy important psychological and social needs, and also allow for achieving goals that are unattainable by individuals (e.g., groups provide insight that is often unavailable at the individual level; Paulus, 1989, as cited by Baron & Byrne), groups also relate to negative decision-making consequences. Understanding the variables that underlie these divergent outcomes is difficult.

Group decision-making assumes at least two forms of value including individual knowledge gains and improved decision quality. First, individual members may broaden their knowledge base by learning new information about the decision problem through the diverse knowledge and different perspectives shared through group discussion (Greitemeyer, Brodbeck, Schulz-Hardt, Frey, 2006). Consequently, each individual is assumed to acquire new information about the problem that regardless of the group's final decision, might later confer benefit. Second, groups have been assumed to improve decision quality (e.g., McGrath, 1984, as referenced by Greitemeyer et al., 2006), because the broader knowledge base that a group provides allows for better decisions than an individual's limited knowledge base (Hastie, 1986, as referenced by Greitemeyer et al., 2006).

Groups produce added value to decision-making when group members recognize the available expertise and use that knowledge to influence their decision process. As discussed by Bonner (2004), groups have outperformed the average individual (Hastie, 1986; Hill, 1982; Kelly & Thibaut, 1969), have performed at the level of an equivalent number of individuals, and have outperformed even the best comparison individuals (Laughlin et al., 2002, 2003).

Unfortunately, the knowledge gains and improved decision quality that are at the heart of the group decision-making value are rarely realized (for overviews, see Mojzisch & Schulz-Hardt, 2005, as well as Stasser & Birchmeier, 2003, as referenced by Greitemeyer et al., 2006). As explained below, potential pitfalls of group decision making have been related to the information sampling model, groupthink, and social loafing, and mitigations for each are not always reliable and well understood.

As discussed by Greitemeyer et al. (2006), the information sampling model suggests that groups will discuss and repeat shared information to a greater degree than unshared information (Larson, Christensen, Abbott, & Franz, 1996; Stasser, Stewart, & Wittenbaum, 1995; for summary, see Wittenbaum & Stasser, 1996), the effect of which directly counters knowledge gains among group members (see also Larson, Christensen, Franz, & Abbott, 1998; Lavery et al., 1999; Stasser & Stewart, 1992; Stasser & Titus, 1985). Such groups fail to find solutions (e.g., fail to solve "hidden profiles," the best alternative given all pieces of information available to the group), because they fail to share all the available information. When the best solution is thus "hidden" from the group, they predominantly choose the alternative that is implied by the shared information (Larson et al, 1998; Stasser & Stewart, 1992).

Winquist and Larson (1998, as cited by Greitemeyer et al., 2006) use their integrative dual-process model to point out two processes leading to the domination of shared information in group discussions. First, there is a probabilistic (quasi-automatic) sampling advantage of shared information. Thus, more shared than unshared information is discussed and this shared information becomes more likely than unshared information to affect the final decision (Larson et al., 1998; Winguist & Larson, 1998). This sampling advantage is reduced over time because to the extent that individuals wish to avoid redundancy, they will begin to sample from unshared information as the discussions temporally progress. However, the second process contributing to the dominance of shared information then becomes important. Group members frequently communicate and negotiate their individual preferences during group discussion rather than using the discussion as a tool for information exchange (Gigone & Hastie, 1993, 1997, as cited by Greitemeyer et al.) by predominantly including information that is consistent with their pre-discussion preferences (Dennis, 1996, as cited by Greitemyer et al.). Consequently, the increased probability that unshared information will be included and integrated into later temporal phases of the discussion is not typically realized, because group discussion and decision are largely based on shared information.

Group disagreement is expected to counteract the dominance of shared information because of the mediating mechanisms discussed above. Thus, there should be a reduced probability of premature consensus, and an increased likelihood of intensive information exchange, when there is conflict and controversy. In support of this hypothesis, Brodbeck, Kerschreiter, Mojzisch, Frey, and Schulz-Hardt (2002) have demonstrated that increases in pre-discussion dissent correspond to increases in the amount of information that is discussed. Groups have been shown to benefit from pre-discussion dissent (e.g., increased knowledge gains, more likely to solve the hidden profile, greater discussion intensity and less discussion bias in the dissenting groups) even when none of the group members initially favors the best solution (Schulz-Hardt, Brodbeck, Mojzisch, Kerschreiter, and Frey, 2005; see also Kerr & Tindale for other moderators of unshared information).

While the aforementioned data suggest that controversy about the solution facilitates both knowledge gains and improved decision quality, these benefits are not reliable.

For example, dialectical techniques that implement debate that is independent of the actual group members' preferences have been developed (e.g., devil's advocacy, Herbert & Estes, 1977; dialectical inquiry; Mason & Mitroff, 1981); however, they have demonstrated only partial success. Greitemeyer et al. (2006) found that while implementing a controversial debate independent of group members' true preferences resulted in decreased sampling bias and increased shared and unshared information, these positive effects were not sufficient to improve decision quality such that it facilitated the hidden solution.

In addition to information sampling, a second pitfall to group decision making involves groupthink, or "the tendency of highly cohesive groups to assume that their decisions can't be wrong: that all members must support the group's decision and ignore information contrary to it" (Baron & Byrne, 1997, p. 608). This phenomenon occurs when individuals are so committed to the group that they feel it is invulnerable, and members, concerned with maintaining consensus, stifle criticism (Pettijohn, 1995). Thus, groupthink occurs not only because of the individual's desire for conformity, but also because of group pressures. According to Janis (1982), group norms emerge that: a) prevent individuals from actively considering alternative course of action, b) support the idea that the group is incapable of error, and c) quickly silence group members with lingering doubts. Groupthink has also been related to the group's overly simplistic thinking (see Janis, 1982 for a discussion of Tetlock's systematic content analysis study).

Groupthink has been identified as one of the most important dangers in decision-making groups; one that leads to costly and potentially disastrous decisions (Hinsz, 1995). Janis has argued that a group displaying most of the groupthink symptoms previously described will also display defective decision-making symptoms[3]. These include inadequacies in: surveying alternatives and objectives, examining risks associated with the preferred choice, reappraising previously rejected alternatives, searching and processing information (e.g., exercising a selective bias), and contingency planning. The decision making deficiencies related to groupthink can be mitigated in three ways (Baron & Byrne, 1997). First, groupthink can be addressed by promoting skepticism and open inquiry (e.g., playing devil's advocate and intentionally finding faults with each option). Next, second-chance meetings, in which group members are asked to express their lingering doubts about a decision, can be useful. Finally, a second group, separate from the initial decision making group, can make a determination regarding whether the decision should be upheld.

In addition to information sampling and groupthink, a third group decision making pitfall is social loafing. Social loafing involves "reductions in motivation and effort when individuals work collectively in a group compared to when they work individually or as

[3] While groupthink concurrence-seeking is typically related to negative outcomes, Janis (1982) points out that it may occasionally contribute to the positive effects of morale maintenance. However, he cautions that these positive effects are generally outweighed by poor decision-making outcomes.

independent co-actors" (Baron & Byrne, 1997, p. 612), and applies to diverse work conditions (Brickner, Harkins, & Ostrom, 1986; Harkins, 1987). It occurs among males and females and across age ranges (Williams & Williams, 1981). Interestingly though, its influence is stronger among males (Karau & Williams, 1993, as cited by Kerr & Tindale, 2004) and in Western (as compared to Asian cultures; Yamaguchi, Okamoto, & Oka, 1985). It is stronger among individualists (Erez & Somech, 1996; Wagner, 1995, cited by Kerr & Tindale, 2004) and those who view themselves as better than others (Charbonnier et al., 1998; Huguet et al., 1999, as cited by Kerr & Tindale, 2004). Social loafing has been explained through both diffusion of responsibility as well as expectancy-valence theory. Social impact theory uses Latane's (1981) diffusion of responsibility to suggest that increases in group size negatively impact individual members' feelings of responsibility. This results in decreased individual effort. A similar idea by Harkins & Szymanski (1989) suggests that individual motivation is decreased because his/her contributions can't be evaluated on an individual basis. A more comprehensive explanation of social loafing is Karau and Williams's (1993) collective effort model (CEM). This model explains social loafing through an extension of expectancy-valence theory. Expectancy-valence theory suggests that an individual's work effort relates to expectancy, instrumentality and valence, where expectancy is a belief that working hard will lead to better performance, instrumentality is a belief that better performance will be rewarded and recognized, and valence relates to the available rewards' value and desirability.

Karau and Williams argue that an individual's perceived links between effort and outcome are weaker in group tasks than in individual tasks. Their meta-analysis examining dozens of social loafing studies offered support for each of the following of CEM's predictions. In fact social loafing is weakest in smaller groups, in tasks that are perceived by the individual as intrinsically interesting or important, when working with others whom they respect, when the individual perceives that his/her contribution to the group product is unique, when individuals expect their coworkers to perform poorly, and within cultures emphasizing individual outcome and effort (like the Western versus Asian culture difference previously described).

Social loafing can be reduced in several ways (Baron & Byrne, 1997). First, it is reduced when individual effort and/or output is readily identifiable (Williams, Harkins, & Latane, 1981), as well as when an individual views his/her contribution as unique (Weldon & Mustari, 1988). Social loafing is also reduced when individual commitment to the task's success is increased so that pressure to work diligently offsets social loafing tendencies (Brickner et al., 1986), and when the importance of the task is increased (Karau & Williams, 1993). Finally, strengthening group cohesiveness has also (preliminarily) been related to a reduction in social loafing. It is hypothesized that the more closely a person's role ties to the group's performance, the less likely that person is to engage in social loafing (Karau & Williams, 1993). For example, high-status people, like leaders, may perceive a closer link between their effort and the group's performance. However, there is not yet strong evidence of this last effect.

In addition to the pitfalls of information sampling, group think, and social loafing, group decision making may also be influenced by persuasion. While the dominant paradigm in recent group decision-making research has focused on information sharing, another paradigm, the influence of combining individual preferences, still receives some empirical and theoretical attention (see also Davis's Social Judgment Scheme model and Crott et al.'s median model; as discussed by Kerr & Tindale, 2004). Persuasion has been defined as "efforts to change our attitudes" (Baron & Byrne, 1997, p. 128). Traditionally, persuasion was described as addressing various aspects of "Who says what to whom and with what effect?" This approach (sometimes referred to as the Yale approach) focused on identifying the characteristics of communicators, communications, and audiences that influenced persuasion. While these findings have not always been robust, the generally accepted results include the following (Baron & Byrne, p. 129):

- Experts are more persuasive than non-experts (Hovland & Weiss, 1951).
- Messages that do not appear to be designed to change our attitudes are often more successful in this respect than ones that seem intended to reach this goal (Walster & Festinger, 1962).
- Attractive communicators are more effective in changing attitudes than unattractive ones (Kiesler & Kiesler, 1969).
- People are sometimes more susceptible to persuasion when they are distracted by some extraneous event than when they are paying full attention to what is being said (Allyn & Festinger, 1961).
- Individuals relatively low in self-esteem are often easier to persuade than those high in self-esteem (Janis, 1954).
- When an audience holds attitudes contrary to those of a would-be persuader, it is often more effective for the communicator to adopt a two-sided approach, in which both sides of the argument are presented, than a one-sided approach.
- People who speak rapidly are often more persuasive than persons who speak more slowly (Miller et al., 1976). Although this finding holds when speakers present views that are different from those of their audience (Smith & Shaffer, 1991), fast talkers may actually be less persuasive when they present views that are consistent with their audience.
- Persuasion can be enhanced by messages that arouse strong emotions (especially fear) in the audience, particularly when the communication provides specific recommendations about how a change in attitudes or behavior will prevent the negative consequences described in the fear-provoking message (Leventhal, Singer, & Jones, 1965).

Although the traditional approach has addressed much about the when and how of persuasion, it has not adequately captured the why of persuasion. More modern approaches have used a cognitive perspective on persuasion (Petty et al, 1994). For example, the cognitive response analysis focuses on what people think about during exposure to persuasive messages and how basic cognitive processes determine attitude change (Petty & Caccioppo, 1986; Petty, Unnava, & Strathman, 1991).

Understanding group decision-making is a daunting task that relates to understanding a complex set of processes and contexts. According to Kerr and Tindale (2004), a common criticism of small-group research has been that it oversimplifies these processes into linear, antecedent-consequence relationships, focusing on only one or a few variables, at the expense of all others. Thus, they conclude that the difficulty is "how can this complexity best be analyzed and understood?" Kerr and Tindale suggest that one "recent and promising way of addressing such questions" includes utilizing modern information technology to pose questions that might not arise in face-to-face groups (e.g., computerized brainstorming, electronic groups, using virtual reality to create and analyze group processes; Blascovich, 2001; see also McGrath & Berdahl, 1998). In addition to the complex processes inherent to group decision-making, its contexts are also complicated. For example, certain group processes that are ineffective in one context might be quite useful as heuristics in most other contexts. In fact, as Kerr and Tindale suggest, many group norms may have developed because they work well most of the time with little processing effort (e.g., tendency for discussing shared information: if all the members of a group know something, it probably does have more validity that is only known by one member).

Groups, ubiquitous in contemporary work environments as the way to "get things done," seem a good fit to solve the wickedly difficult problems core to the national security mission; however the current group research leaves unclear how this is best accomplished. From what is currently known, groups may offer the benefits of: 1) increasing a knowledge base and 2) improving decision quality, which seem to fit well with the incomplete, contradictory, and changing requirements of wicked problems, as well as with the identification of solutions that are often difficult to recognize. Importantly, though, for groups to fully harness their decision-making potential and produce value commensurate with the associated increases in employee time and effort, one must mitigate against their potential pitfalls (e.g., information sampling, groupthink, and social loafing along with the potential modulator of persuasion). The current literature leaves unclear the theoretical and empirical bounds of these potential pitfalls because of the complexities associated with studying groups, as well because of the current, non-unified, multi-disciplinary approach. Thus, future efforts geared toward a better understanding of group decision-making and its potential application to wickedly difficult problems must address the vastness of the current group literature, as well as the complex interactions between potential group, individual, process, and contextual variables.

Face-to-face vs. Computer-mediated groups

As computer networks attain omnipresence within work environments, electronic communication offers a new form of problem solving group, potentially interesting to solving wicked problems. Over the last 20 years, computer networks have been increasingly used to conduct business, because they convey decreased costs; increased information accessibility, and rapid document, database, and message exchange (Siegel, Dubrovsky, Kiesler, & McGuire, 1986, as referenced by Baltes et al., 2002). As

compared to face-to-face groups, electronic groups allow for more flexible (e.g., non-simultaneous and geographically distributed) forms of intragroup communication; however, they can also foster stronger group identification (Lea et al, 2001, as cited by Kerr & Tindale, 2004) and adherence to group norms (Spears et al, 1990; although see Douglas & McGarty, 2001, both as cited by Kerr & Tindale, 2004). Interestingly, this networking growth has not fully addressed questions about the decision quality arising from the computer-mediated communication (CMC) groups or interaction differences between online versus face-to face meetings. In fact, what empirical evidence is available "raises significant questions about the appropriateness of heavy reliance on computer-mediated communication for organizational group decision making" (Baltes et al., p. 175).

As described by Roch and Ayman (2005), the research into how technological innovations have affected team functioning hasn't kept pace with the advances. In discussing their meta-analysis, Baltes et al. (2002) concluded, "one of the most surprising findings in the present study was that, despite the wealth of writing and research on the topic of computer-mediated communication, there are relatively few studies that include the basic methodological rigor and statistical detail to be included in a meta-analysis" (p. 171). Furthermore, many of the studies focused on member satisfaction rather than effectiveness. In fact, their meta-analysis included only 22 published and 5 unpublished studies, and was the first to empirically consolidate and summarize research on computer mediated communications (e.g., narrative literature review: Bordia, 1997, as cited by Baltes et al.). A previous narrative review of the literature examining communication technology's affect on work teams (Hollingshead & McGrath, 1995, as discussed by Roch & Ayman) identified only 8 studies that compared face-to-face with computer mediated team performance in tasks with a correct answer ("intellective" tasks).

Both the Baltes et al. (2002) and the Hollingshead and McGrath (1995) studies found that computer mediated teams result in less successful group decisions than face to face teams on intellective tasks; however these effect sizes were not large and their reasons not well understood. Generally, Baltes et al. found that "computer-mediated decision-making groups are rarely if ever more effective than face-to-face groups, that CMC group members are rarely if ever more satisfied than member of face-to-face groups, and that CMC groups rarely if ever take less time than face-to-face groups. At best, CMC groups are not significantly worse than face-to-face groups, and even these results occur only in very unusual and uncommon organizational conditions" (p. 175) like when discussion contributions are anonymous and when groups have unlimited decision-making time.

One proposed advantage of CMC groups over face-to-face groups is that CMC groups might benefit from Communication Openness; however, this hypothesis has not been borne out by the existing data. Communication Openness, "which is encouraging, or at least permitting, the open expression of views divergent from one's own" (Baltes et al., 2002, p. 172) has been related to decision making quality (e.g., Buchanan, 1997, as referenced by Baltes et al.). Because CMC groups would seem to partially obscure status differences, it has been argued that these groups would benefit from increased participation across all group members (e.g., Dubrovsky et al., 1991; Hiltz et al., 1986;

McGuire et al., 1987; Siegel et al., 1986; Weisband, 1992; all as cited by Baltes et al.). In contrast to this suggestion, Baltes et al. found that CMC groups did not out-perform face-to-face groups. Instead, CMC groups for whom individual identity was anonymous did not significantly differ from face-to-face groups in performance. Interestingly, when individuals were not given anonymity, group performance was actually significantly worse than face-to-face performance. It has been argued that performance differences may be related to the lack of social cues inherent in computer mediated teams (Baltes et al., 2002); however, the lack of social cues might also be thought to increase performance in that this deficit may focus persuasion based on logic and facts rather than on nonverbal dominance (e.g., gender, race, age, etc.; Roch & Ayman, 2005).

Another proposed advantage of CMC groups over face-to-face groups has been related to the potential advantage of electronic communication in overcoming large group communication difficulties. However, the hypothesized advantage of CMC relative to face-to-face groups was not found, nor were negative CMC outcomes minimized in larger CMC groups (Baltes et al., 2002). In other words, group size did not impact any differences between face-to-face groups and CMC groups in terms of decision quality (although it is worth noting that groups were fairly small, with n = 3 for small groups and n = 4 or more for larger groups across the Baltes et al. meta-analysis).

CMC groups demonstrate less participation, or fewer verbal acts, than face-to-face groups (as discussed by Roch & Ayman, 2005, less total communication: Straus & McGrath, 1994; fewer remarks: Siegel, Dubrovsky, Kiesler, & McGuire, 1986; shared less information: Hedlund, Ilgen, & Hollenback, 1998; Hollingshead, 1996a, 1996b; Smith & Vanecek, 1988). "The computer does not simply reduce the participation of loquacious group members or simply increase the participation of quiet group members; it does not 'democratize' group discussion, as some researchers have implied. Rather, it reduces participation for all participants" (Hollingshead & McGrath, p. 74 as cited by Roch & Ayman, 2005). The finding that CMC groups communicate less and, therefore, share less information than FTF groups is a very robust finding" (Roch & Ayman, p. 17).

In fact, diminished individual participation (for the majority of participants) has also been noted as a problem within internet groups. Nielsen (2006) enumerates the many places on the web in which a very small minority of users account for a disproportionate amount of activity and content. This participation inequality, as he calls it, has been documented in Usenet newsgroups, Internet mailing lists, CompuServe bulletin boards, and large company internal discussion boards. Nielsen suggests that user participation generally follows a 90-9-1 rule in which 90% of users are lurkers (i.e., read or observing without contributing), 9 % of users contribute occasionally, and 1% of users account for most contributions. These inequities are even greater for weblogs where the rule is 95-5-.1. In other words, of 1.1 billion Internet users, only 55 million (5%) have weblogs, and only .1% of users post daily. Similarly, less than 1% of Amazon.com's customers contribute reviews and only .2% of Wikipedia's users are active contributors.

Although Nielsen notes that participation inequality can't be overcome, he suggests that it can be partially mitigated through the following:

- *Make it easier to contribute. The lower the overhead, the more people will jump through the hoop. For example, Netflix lets users rate movies by clicking a star rating, which is much easier than writing a natural-language review.*
- *Make participation a side effect. Even better, let users participate with zero effort by making their contributions a side effect of something else they're doing. For example, Amazon's "people who bought this book, bought these other books" recommendations are a side effect of people buying books. You don't have to do anything special to have your book preferences entered into the system. Will Hill coined the term* ***read wear*** *for this type of effect: the simple activity of reading (or using) something will "sear' it down and thus leave its marks – just like a cookbook will automatically fall open to the recipe you prepare the most.*
- *Edit, don't create. Let users build their contributions by modifying existing templates rather than creating complete entities from scratch. Editing a template is more enticing and has a gentler learning curve than facing the horror of a blank page. In avatar-based systems like Second Life, for example, most users modify standard-issue avatars rather than create their own.*
- *Reward – but don't over-reward – participants. Rewarding people for contributing will help motivate users who have lives outside the Internet, and thus will broaden your participant base. Although money is always good, you can also give contributors preferential treatment (such as discounts or advance notice of new stuff), or even just put gold stars on their profiles. But don't give too much to the most active participants, or you'll simply encourage them to dominate the system even more.*
- *Promote quality contributors. If you display all contributions equally, then people who post only when they have something important to say will be drowned out by the torrent of material from the hyperactive 1%. Instead, give extra prominence to good contributions and to contributions from people who've proven their value, as indicated by their reputation ranking.*

Kerr and Tindale (2004) suggest that a "striking exception to this generally disappointing picture (regarding electronic group performance) is the facilitative effect of computerized brainstorming" (p. 627). Group brainstorming is a method of idea generation in which groups are asked to: 1) generate as many ideas as possible, 2) avoid the criticism of ideas, and 3) combine and improve upon the ideas of others (Osborn, 1957, as cited by Kerr and Tindale, 2004). While these brainstorming groups have been touted as being superior to equal-sized sets of non-interacting individuals (i.e., "nominal groups"), several decades of research has demonstrated that the reverse is true: individuals usually outperform brainstorming groups (e.g., Mullen et al, 1991). According to Kerr and Tindale (2004), such process losses in brainstorming groups appear to derive from three areas. First, production blocking, or the inability for more than one group member to talk and think at a time, derails an ongoing train of thought (Nijstad, 2000). Second, evaluation apprehension leads to a hesitance in contributing ideas, and finally, social comparison leads to low performance standards for face-to-face groups (Camacho, 1995; Larey & Paulus, 1995; Paulus & Dzindolet, 1993; Paulus et al, 1996; all as cited by Kerr and Tindale, 2004). In response to these findings, several traditional group brainstorming improvements have been developed, the "most noteworthy" of which has been the

electronic brainstorming work. According to Kerr and Tindale (2004), electronic brainstorming decreases the group brainstorming process losses by isolating individuals so that they can provide their ideas without interruption (i.e., reducing production blocking; Gallupe et al., 1994), allowing for anonymity (i.e., reducing evaluation apprehension; Cooper et al, 1998), and still providing group members to see others' ideas at their convenience. In fact, electronic brainstorming has been demonstrated to perform as well as non-interacting individuals (e.g., Gallupe et al, 1991), and to even outperform them (n . 9: Dennis & Valacich, 1993, 1994; Valacich et al, 1994; all as cited by Kerr & Tindale). Rather than being attributed to the relatively higher probability of large groups tapping into rare ideas (Connolly et al, 1993), these findings are thought to relate to the stimulating effect of exposure to others' ideas (Leggett-Dugosh et al, 2000; Nijstad et al, 2003; Paulus & Yang, 2000; although also see Ziegler et al, 2000; all as cited by Kerr & Tindale) and the diversity and heterogeneity of those groups (Schruijer & Mostert, 1997; Stroebe & Diehl, 1994; both as cited by Kerr & Tindale).

In total, the current research into computer-mediated groups highlights several potential areas for future research. First, there are very few empirical studies addressing how computer mediated performance compares with face-to-face performance in terms of decision effectiveness. Moreover, the mechanisms circumscribing any existing differences have yet to be thoroughly delineated and explored[4]. For example, communication variables like openness, participation, and equality, that have theoretically supported CMC decision-making groups over face-to-face groups, have not been empirically supported; yet, some aspects of electronic brainstorming (possibly these same variables) appear to convey benefit within CMC groups. Alternative theoretical models predicting how computer-mediated groups may best be used have also yet to be thoroughly developed.

Furthermore, two of the trends that Baltes et al. (2002) found in their review of existing studies offer opportunity for empirical expansion. "First, the vast majority of studies utilized ad hoc groups of students engaging in hypothetical tasks as participants as opposed to organizational members role-playing realistic tasks for their work setting. Second…most existing studies (and thus the majority of studies included herein) examine synchronous, text-based conferencing systems (i.e., "chat")" (p. 159) rather than e-mail. Because email is asynchronous, with even fewer paraverbal cues, Baltes et al. argue that it may be an even *less* effective method for reaching group decision than chat. Thus, the Baltes et al. findings may actually be "underestimates of the decrement in effectiveness, increase in time required and changes in member satisfaction between face-to-face and computer-mediated communication" (Baltes et al., 2002, p. 174). To address these gaps, future efforts may be geared toward the use of real organization settings and

[4] Baltes et al. suggest that the functional perspective to group decision making (Cragan & Wright, 1990; Barge & Hirokawa, 1989; Gouran & Hirokawa, 1996; Hirokawa, 1985, 1988, 1994; Hirokawa, Gouran, & Martz, 1988; Hirokawa & Johnston, 1989), in which decision making effectiveness is seen as dependent on successfully understanding the problem, understanding requirements for an effective choice, and assessment of the alternatives, is an under-researched area in electronic communication that should be further examiend.

asynchronous communication methods, possibly including brainstorming and some aspects of Alternate Realty Games (Szulborski, 2005).

Conclusion

Group decision-making and electronic communication are integral to contemporary work organizations, and moreover, represent a ripe research context in which to solve wickedly difficult problems. According to Kozlowski & Ilgen (2006), organizations worldwide are at least 15 years into "shifting from individual jobs in functionalized structures to teams embedded in more complex workflow systems (Devine, Clayton, Phillips, Dunford, & Melner, 1999; Lawler, Mohrman, & Ledford, 1992, 1995; Mathieu, Marks, & Zaccaro, 2001). This shift is being driven by increased competition, consolidation, and innovation which increase needs for the skill diversity, expertise, rapid response, and adaptability that groups may enable (Kozlowski, Gully, Nason, & Smith, 1999, as cited by Kozlowski & Ilgen (2006). Add to this shift, the increased computer availability and broadband communication that enable groups to be distributed across time and space (Bell & Kozlowski, 2002b, as cited by Kozlowski & Ilgen, 2006), and an interesting and complex research area emerges. Kozlowski & Ilgen have argued that the confluence of such virtual groups with potentially worldwide membership is "inevitable and the source of new research challenges" including "how to harness the emerging technological capability to *enhance* and *evolve* team processes in virtual environments that cut across different cultures" (p. 114).

Although there has already been well over half a century of research regarding small groups and related topics, several broad challenges remain if computer-mediated groups are to be effectively used to solve wickedly difficult problems. First, much about group effectiveness remains unknown even within this substantial knowledge base. Second, identifying what is known amongst such vast and multi-disciplinary literatures remains challenging (Kozlowski & Ilgen, 2006). Add to these challenges, the research infancy of computer-mediated communications, and a great deal of empirical and theoretical work remains to be accomplished. Work that is especially valuable considering that group decision making requires greater time and effort among those involved in the process than does individual decision making (Greitemeyer, Brodbeck, Schulz-Hardt, Frey, 2006). Thus, it is important to be able to justify this increased investment and to be able to mitigate potential pitfalls.

Additionally, in order to solve wickedly difficult problems, the solution space must be extended beyond the laboratory environment of intellective tasks (e.g., tasks with a demonstrably correct answer) to tasks that because of their ambiguity are more difficult to empirically study. In real-world organizational contexts, groups are seldom aware of whether they have made the correct decision, regardless of whether they are face-to-face or computer-mediated. In fact, the correct answer is usually unavailable for teams outside the laboratory, because if the correct answer were available, there would be no reason to convene a team to make the decision (Roch & Ayman, 2005). Interestingly, little research has examined a group's judgment of its final decision (Roch & Ayman,

2005); however, “if a group cannot adequately evaluate the quality of a decision it has reached, it runs the risk of implementing a faulty decision” (Littlepage & Silbiger, 1992, p. 346, as referenced by Roch & Ayman).

Because of Sandia National Laboratories’ mission, “a variety of research and development programs to help secure a peaceful and free world through technology” (Sandia National Laboratories external homepage, 2007), Sandia’s success is integrally intertwined with solving wickedly difficult issues, especially through computer-mediated means. Achieving a better understanding of effective computer-mediated decision-making could allow us to mitigate the deleterious decision-making effects and bolster potential benefits.

References

Albanese, R. & Van Fleet, D. D. (1985). Rational behavior in groups: The free-riding tendency. Academy of Management Review, 10, 244-255.

Allison, M. A. (2006) personal communication of publisher's proposal for Running as fast as we can.

Baltes, B. B., Dickson, M. W., Sherman, M. P., Bauer, C. C.,, & LaGanke, J. S. (2002). Computer-mediated communication and group decision making: A meta-analysis. Organizational Behavior and Human Decision Processes, 87, 156-179.

Bakeman, R. & Beck, S. (1974). The size of informal groups in public. Environment and Behavior, 6, 378-388.

Baron, R. A., & Byrne, D. (1997). Social Psychology. Boston: Allyn and Bacon.

Blascovich, J. (2001). Immersive virtual environmental technology as a tool in psychological science. Psychological Science Agenda, 14, 8-9.

Bond, M. A. & Keys, C. B. (1993). Empowerment, diversity, and collaboration: Promoting synergy on community boards. American Journal of Community Psychology, 21, 37-57.

Bonner, B. L. (2004). Expertise in group problem solving: Recognition, social combination, and performance. Group Dynamics: Theory, Research, and Practice, 277-290.

Brewer, M. B. & Kramer, R. M. (1986). Choice behavior in social dilemmas: Effects of social identity, group size and decision framing. Journal of Personality and Social Psychology, 50, 543-547.

Brickner, M. A., Harkins, S. G. & Ostrom, T. M. (1986). Effects of personal involvement: Thought-provoking implications for social loafing. Journal of Personality and Social Psychology, 51, 763-770.

Brodbeck, F. C., Kerschreiter, R., Mojzisch, A., Frey, D. & Schulz-Hardt, S. (2002). The dissemination of critical unshared information in decision-making groups: The effects of pre-discussion dissent. European Journal of Social Psychology, 32, 35-56.

Burgess, J. W. (1984). Do human show a "species-typical" group size? Age sex, and environmental differences in the size and composition of naturally-occurring casual groups. Ethology and Sociobiology, 5, 51-57.

Buys, C. J. & Larson, K. L. (1979). Human sympathy groups. Psychological Reports, 45, 547-553.

Carron, A. V., Widmeyer, W. N. & Brawley, L. R. (1989). Perceptions of ideal group size in sport teams. Perceptual and Motor Skills, 69, 1368-1370.

Cini, M. A., Moreland, R. L. & Levine, L. M> (1993). Group staffing levels and responses to prospective and new group members. Journal of Personality and Social Psychology, 65, 723-734.

Cooper, W. H., Gallupe, R. B., Pollard, S. & Cadsby, J. (1998). Some liberating effects of anonymous electronic brainstorming. Small Group Research, 29(2), 147-178.

Conklin, J. (2005). Wicked problems and social complexity. http://cognexus.org.

Connolly, T., Routhieaux, R. L. & Schneider, S. K. (1993). On the effectiveness of group brainstorming: Test of one underlying cognitive mechanism. Small Group Research, 24(4), 490-503.

Desportes, J. P. & Lemaine, J. M. (1988). The sizes of human groups: An analysis of their distributions. In D. Canter, J. C. Jesuino, L. Soczka & G. M. Stephenson (Eds.), Environmental Social Psychology (pp. 57-65). Dordrecht, Netherlands: Kluwer Academic Press.

Davis, J. (1996). Small-group research and the Steiner Questions: The once and future thing. In E. H. Witte & J. H. Davis (Eds.), Understanding group behavior: Consensual action by small groups (pp. 3-12). Mahwah, NJ: Lawrence Erlbaum Associates.

Dennis, A. R. & Valacich, J. S. (1993). Computer brainstorms: More heads are better than one. Journal of Applied Psychology, 78, 531-537.

Devine, D. J., Clayton, L. D., Phillips, J. L., Dunford, B. B., & Melner, S. B. (1999). Teams in organizations: Prevalence, characteristics, and effectiveness. Small Group Research, 30, 678– 711.

Diehl, LM. & Stroebe, W. (1987). Productivity loss in brainstorming groups: Toward the solution of a riddle. Journal of Personality and Social Psychology, 53, 497-509.

Gallupe, R. B., Bastianutti, L. M. & Cooper, W. H. (1991). Unblocking brainstorms. Journal of Applied Psychology, 76(1), 137-142.

Gallupe, R. B., Cooper, W. H., Grise, M-L & Bastianutti, L. M. (1994). Blocking electronic brainstorms. Journal of Applied Psychology, 79(1), 77-86.

Greitemeyer, T., Schulz-Hardt, S., Brodbeck, F. C., & Frey, D. (2006). Information sampling and group decision making: The effects of an advocacy decision procedure and task experience. Journal of Experimental Psychology: Applied, 12, 31-42.

Grofman, B., Owen, G & Feld, S. L. (1983). Thirteen theorems in search of the truth. Theory and Decision, 15, 261-278.

Haleblian, J. & Finkelstein, S. (1993). Top management team size, CEO dominance and firm performance: The moderating roles of environmental turbulence and discretion. Academy of Management Journal, 36, 844-863.

Hamburger, H., Guyer, M. & Fox, J. (1975). Group size and cooperation. Journal of Conflict Resolution, 19, 503-531.

Harkins, S. G. (1987). Social loafing and social facilitation. Journal of Experimental Social Psychology, 23, 1-18.

Harkins, S. G. & Szymanski, K. (1989). Social loafing and group evaluation. Journal of Personality and Social Psychology, 56, 934-941.

Hedlund, J., Ilgen, D. R. & Hollenbeck, J. R. (1998). Decision accuracy in computer-mediated versus face to face decision-making teams. Organizational Behavior and Human Decision Processes, 76, 30-47.

Herbert, T. T. & Estes, R. W. (1977). Improving executive decisions by formalizing dissent: The corporate devil's advocate. Academy of Management Review, 2, 662-667.

Hill, G. W. (1982). Group versus individual performance: Are N + 1 heads better than one? Psychological Bulletin, 91, 517-539.

Hinsz, V. B. (1995). Goal setting by groups performing an additive task: A comparison with individual goal setting. Journal of Applied Social Psychology, 25, 965-990.
Hollingshead, A. B. (1996a). Information suppression and status persistence in group decision making: The effects of communication media. Human Communication Research, 23, 193-219.
Hollingshead, A. B. (1996b). The rank-order effect in group decision making. Organizational Behavior and Human Decision Making, 68, 181-193.
Hollingshead, A. B. & McGrath, J. E. (1995). Computer-assisted groups: A critical review of the empirical research. In R. A. Guzzo, E. Salas & Associates (Eds.) Team effectiveness and decision making in organizations (pp. 46-78). San Francisco: Jossey-Bass.
James, J. (1951). A preliminary study of the size determinant in small group interaction. American Sociological Review, 16, 474-477.
Janis, I. L. (1982). Victims of groupthink (2nd ed.). Boston: Houghton Mifflin.
Karau, S. J. & Williams, K. (1993). Social loafing: A meta-analytic review and theoretical integration. Journal of Personality and Social Psychology, 65(4), 681-706.
Katzenbach, J. R. & Smith, D. K. (1993). The Wisdom of Teams: Creating the High-Performance Organization. Boston: Harvard Business School Press.
Kerr, N. L., & Tindale, R. S. (2004). Group performance and decision making. Annual Review of Psychology, 55, 623-655.
Kozlowski, S. W. J., & Ilgen, D. R. (2006). Enhancing the effectiveness of work groups and teams. Psychological Science in the Public Interest, 7, 77-124.
Larson, J. R., Christensen, C., Abbott, A. S., & Franz, T. M. (1996). Diagnosing groups: Charting the flow of information in medical decision-making teams. Journal of Personality and Social Psychology, 71, 315-330.
Larson, J. R., Christensen, C., Franz, T. M. & Abbott, A. S. (1998). Diagnosing groups: The pooling, management, and impact of shared and unshared case information in team-based medical decision making. Journal of Personality and Social Psychology, 75, 93-108.
Latané, B. (1981). The psychology of social impacts. American Psychologist, 36, 343-356.
Latané, B., Williams, K. & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. Journal of Personality and Social Psychology, 37, 822-832.
Lavery, T. A., Franz, T. M., Winquist, J. R. & Larson, J. R. (1999). The role of information exchange in predicting group accuracy on a multiple judgment task. Basic and Applied Social Psychology, 21, 281-289.
Lawler, E. E., Mohrman, S. A., & Ledford, G. E. (1992). Employee involvement and total quality management: Practices and results in Fortune 1000 companies. San Francisco: Jossey-Bass.
Lawler, E. E., Mohrman, S. A., & Ledford, G. E. (1995). Creating high performance organizations: Practices and results of employee involvement and total quality management in Fortune 1000 companies. San Francisco: Jossey-Bass.
Marks, M. (2006). The science of team effectiveness. Psychological Science in the Public Interest, 7, i.

Mason, R. O. & Mitroff, I. I. (1981). Challenging Strategic Planning Assumptions. New York: Wiley-Interscience.

Mathieu, J. E., Marks, M. A., & Zaccaro, S. J. (2001). Multi-team systems. In N. Anderson, D. S. Ones, H. K. Sinangil & C. Viswesvaran (Eds.), Organizational psychology: Vol. 2. Handbook of Industrial, Work and Organizational Psychology (pp. 289–313). London: Sage.

McGrath, J. E. & Berdahl, J. L. (1998). Groups, technology and time: Use of computers for collaborative work. In R. S. Tindale & L. Heath (Eds.) Theory and Research on Small Groups: Social Psychological Applications to Social Issues, 4th ed. (pp 205-228). New York: Plenum.

McGrath, J. E. & Rotchford, N. (1983). Time and behavior in organizations. In L. L. Cummings & B. M. Staw (Eds.), Research in Organizational Behavior, Vol 5 (pp. 57-101. Greenwich, CT: JAI.

McPherson, J. M. (1983). The size of voluntary associations. Social Forces, 61, 1044-1064.

Miller, N. & Davidson-Podgorny, G. (1987). Theoretical models of intergroups relations and the use of cooperative teams as an intervention for desegregated settings. In C. Hendrick (Ed.), Group Processes and Inergroup Relations (pp. 41-67). Newbury Park, CA: Sage.

Moreland, R. L., Levine, J. M., & Winger, M. L. (1996). Creating the ideal group: Composition effects at work. In E. H. Witte & J. H. Davis (Eds.), Understanding group behavior (pp. 12-15). Mahwah, NJ: Lawrence Erlbaum Associates.

Mullen, B., Johnson, C. & Salas, E. (1991). Productivity loss in brainstorming groups: A meta-analytic integration. Basic Applied Social Psychology, 12, 3-23.

Nasser, D. L. (1988). How to run a focus group. Public Relations Journal, 44, 33-34.

Nielsen, J. (2006, October 9). Participation inequality: Encouraging more users to contribute. http://www.useit.com/alertbox/participation_inequality.html.

Nijstad, B. A. (2000). How the group affects the mind: Effects of communication in idea generating groups. Unpublished doctoral dissertation: Utrecht University.

Parker, G. M. (1994). Cross-functional Teams: Working with Allies, Enemies and Other Strangers. San Francisco: Jossey-Boss.

Petty, R. E. & Cacioppo, J. T. (1986). The elaboration likelihood model of persuasion. In L. Berkowitz (Ed.), Advances in Experimental Social Psychology, Vol 19 (pp. 123-205). New York: Academic Press.

Petty, R. E., Cacioppo, J. T., Strathman, A. J. & Priester, J. R. (1994). To think or not to think: Exploring two routes to persuasion. In S. Shavitt & T. C. Brock (Eds.), Persuasion (pp. 113-147). Boston: Allyn & Bacon.

Petty, R. E., Unnava, R. & Strathman, A. J. (1991). Theories of attitude change. In T. S. Robertson & H. H. Kassarjian (Eds.), Handbook of consumer behavior (pp. 241-280). Englewood Cliffs, NJ: Prentice Hall.

Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. Policy Sciences, 4, 155-169.

Roch, S. G. & Ayman, R. (2005). Group decision making and perceived decision success: The role of communication medium. Group Dynamics: Theory, Research, and Practice, 9, 15-31.

Sandia National Laboratories External Homepage (2007). Sandia National Laboratories: Mission Areas. http://www.sandia.gov/mission/index.html.

Scharf, A. (1989). How to change seven rowdy people. Industrial Management, 31, 20-22.

Schulz-Hardt, S., Brodbeck, F. C., Mojzisch, A., Kerschreiter, R. & Frey, D. (2006). Group decision making in hidden profile situations: Dissent as a facilitator for decision quality. Journal of Personality and Social Psychology, 91, 1080-1093.

Shepperd, J. A. (1993). Productivity loss in performance groups: A motivation analysis. Psychological Bulletin, 113, 67-81.

Siegel, J., Dubrovsky, V., Kiesler, S. & McGuire, T. W. (1986). Group processes in computer-mediated communication. Organizational Behavior and Human Decision Processes, 37, 157-187.

Singh, J. V. & Lumsden, C. J. (1990). Theory and research in organizational ecology. Annual Review of Sociology, 16, 161-195.

Slater, P. E. (1958). Contrasting correlates of group size. Sociometry, 21, 129-139.

Smith, J. & Vanecek, M. (1988). Computer conferencing and task-oriented decisions: Implications for group decision support. Information and Management, 14, 123-132.

Stasser, G. & Stewart, D. D. (1992). Discovery of hidden profiles by decision-making groups: Solving a problem versus making a judgment. Journal of Personality and Social Psychology, 63, 426-434.

Stasser, G., Stewart, 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. M. & Taylor, L. A. (1991). Speaking turns in face-to-face discussions. Journal of Personality and Social Psychology, 60, 675-684.

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, 1467-1478.

Steiner, I. D. (1974). Whatever happened to social psychology? Journal of Experimental Social Psychology, 10(1), 94-108.

Steiner, I. D. (1986). Paradigms and groups. In L. Berkowitz (Ed.), Advances in Experimental Social Psychology Vol 1 (pp. 251-292). New York: Academic Press.

Straus, S. G. & McGrath, J. E. (1994). Does medium matter? The interaction of task type and technology on group performance and member reactions. Journal of Applied Psychology, 79, 87-97.

Sunstein, C. R. (2006). Infotopia: How Many Minds Produce Knowledge. New York: Oxford University Press

Szulborski, D. (2005). This is not a game: A guide to Alternate Realty Gaming. www.new-fiction.com (no physical address provided): New-Fiction Publishing.

Wegner, D. M. (1987). 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.

Weldon, E., Mustari, E. L. (1988). Felt dispensability in groups of coactors: The effects of shared responsibility and explicit anonymity on cognitive effort. Organizational Behavior and Human Decision Processes, 41, 330-351.

Williams, K., Harkins, S. G. & Latane, B. (1981). Identifiability as a deterrent to social loafing: Two cheering experiments. Journal of Personality and Social Psychology, 40, 303-311.

Wittenbaum, G. M. & Stasser, G. (1996). Management of information in small groups. In J. L. Nye & A. M. Bower (Eds.), What's Social about Social Cognition: Research on Socially Shared Cognition in Small Groups (pp. 3-28). Thousand Oaks, CA: Sage.

Yamaguchi, S., Okamoto, K. & Oka, T. Effects of coactor's presence: Social loafing and social facilitation. Japanese Psychological Research, 27, 215-222.