# Collective Intelligence in Teams and Organizations

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In the 2014 Winter Olympic games in Sochi, the Russian men's ice hockey team seemed poised to sweep their competition. Comprised of star players from the National Hockey League in North America and the Kontinental Hockey League in Russia, and given home field advantage, fans thought they were sure to win gold. Even Russian President Vladimir V. Putin declared that the success of the games, costing an estimated $50 Billion, hinged on the success of the men's hockey team. Not long into the tournament, however, it became clear that the team might not live up to expectations. Players who were high scorers on professional teams failed to produce a single goal, and despite all of the resources and talent available to the team, and their strong drive to succeed, they were eliminated from contention before the medal rounds even began. To make matters worse, their final defeat was by the Finnish team, a collection of professional third- and fourth-liners. Everyone was dumbfounded; how could this team have failed?

By contrast, over 30 years earlier, another hockey team from a different country had the opposite experience. Dubbed the "Miracle on Ice," the 1980 US Men's Hockey team, made up of amateurs and collegiate players, rose above all expectations to win the Gold medal.

This distinction between talented individuals and talented teams is consistent with recent research documenting team collective intelligence as a much stronger predictor of team performance than individual member ability (Woolley, Chabris, Pentland, Hashmi & Malone, 2010). Collective intelligence captures a group's capability to collaborate and coordinate effectively across a range of tasks, which is predictive of a group's future performance. Smart or skilled people may be necessary, but not sufficient, for creating smart groups or organizations.

So what are the necessary ingredients for collective intelligence to develop? Here we review frameworks and findings from the team and organizational performance literatures that may be especially useful to collective intelligence researchers for thinking about this question. Guiding our review of the literature is the Star model proposed by Galbraith (1960) for analyzing organizations. The framework identifies the categories of design choices that can be made by managers or system designers to influence employee behavior. The first part of the framework focuses on *strategy*, or "What" the team or organization is trying to accomplish. The second is *structure*, which determines how units coordinate and who has decision making power. *Processes* have to do with the flow of information; they are the means of responding to information technologies. *Rewards* provide motivation and incentives for desired behavior. And finally, the selection and development of the *right people*, in alignment with the other elements of the system, allows the team or organization to perform at the highest level.

None of these categories of issues operate in isolation, and in some cases the boundaries between them are somewhat false or arbitrary, so our hope is to give the reader a tasting menu of sorts with a sense of how the areas relate to one another and information on where to look for additional information.

**Strategy: Group Tasks and Goals**

Two ways in which collectives can be set up to fail are by either (1) putting them to work on a task that isn't well suited for collective work, and/or (2) giving them vague or unclear goals. The first step in designing a collectively intelligent system, whether it is a team or an organization, is to make sure the tasks or goals toward which they are working are well-suited to being worked on by a collective. Tasks that benefit from a variety of inputs and combined efforts tend to benefit from group collaboration; simple tasks, and tasks that benefit from a high level of insight and coherence (such as many great works of art) are better done by solo individuals. Even when working on good group tasks, groups are often less than maximally effective because of *process loss* (Steiner, 1966). Steiner identified tasks as being *conjunctive* (operate at level of lowest performer, ex. running in a group), *disjunctive* (operate at level of highest performer, ex. answering math problems), *additive* (all contributions add to performance, ex. shoveling snow), or *compensatory* (performance of one offsets mistakes of other, ex. independent guesses to answer a question). Additive and compensatory tasks benefit most from groups working interdependently; disjunctive tasks benefit from contributions of non-interacting groups or "crowds," and highly skilled individuals will likely outperform teams on conjunctive tasks. Furthermore, a task can be classified as *unitary*, meaning that it cannot be divided into subtasks, such that the group must work on it all together (or one person does the work while others watch), or *divisible*, meaning that it can be efficiently or meaningfully divided into subtasks and assigned to group members (Steiner, 1972).

In addition, tasks can be characterized by the nature of the performance processes group members must engage in to carry them out effectively (Larson, 2009; McGrath, 1984). McGrath's task circumplex (1984) identifies four task categories that reflect different sets of team interaction processes: generate, choose, negotiate and execute. *Generate* tasks include creativity and planning tasks, that require idea generation; to succeed, group members should work in parallel to develop as many divergent ideas as possible. *Choose* tasks or decision making tasks require selecting among specified alternatives, either as in "intellective" tasks with an objectively correct answer, or as "judgment" tasks with hard to demonstrate correct answers (Laughlin 1980; Laughlin & Ellis, 1986). It is necessary for groups to engage in effective information sharing processes to identify the correct response (discussed further below in the section on Processes). *Negotiate* tasks involve resolving conflicts of interests or viewpoints. *Execute* tasks involve performance of psychomotor tasks that require a high level of coordination, physical movement, or dexterity, to produce a correct or optimal solution. The type of task a group is faced with has implications for many of the other facets of the group to be discussed, including group composition, incentives, structure and process, in order for collective intelligence to emerge.

Regardless of the type of work to be accomplished by the team or organization, another factor of great importance is the nature of and clarity of the goals being pursued. The positive effects of goal-setting on individual performance are probably among the most-replicated in all of organizational psychology (Locke & Latham, 2006). Goals serve the purpose of both energizing and directing behavior. Goal-directed people focus their attention on behaviors leading to goal attainment and ignore activities irrelevant to the goal. Goals also arouse energy in proportion to their difficulty (up to the level of the worker's ability). The effects of goals are moderated by commitment; the impact of goal difficulty on performance increases with

commitment to the goal. Goal specificity is also an important component; specific difficult goals produce better results than "do your best" or vague goals (Locke, Shaw, Saari & Latham, 1981).

The effects are similarly strong for goal-setting at the group level (O'Leary-Kelly et al., 1994; Weldon & Weingart, 1993), although the picture becomes somewhat more complex when one attempts to align individual goals with group goals. Whether group or individual goals are more salient, and aligned, determines the degree to which intragroup relations are characterized by cooperation or competition. Other features of the task also come into play, such as whether the task is complex (Weingart, 1993) and requires members to work interdependently (Weldon & Weingart, 1993). In addition, the nature of the goals assigned to groups have implications for the processes that develop. For instance, a team's strategic orientation, or whether their goals are more offensive or defensive in nature has implications for the kinds of information they will attend to within their group or in the environment (i.e., Woolley, 2011), as discussed further below (see.

**Group and Organizational Structure**

Coordination is one of the major problems a group or organization must face and solve in order to be effective (March & Simon, 1958; Georgopoulos, 1972). Coordination involves fitting together the activities of organization members, and the need for it arises from the interdependent nature of the activities that organization members perform (Argote, 1982). Okhuysen and Bechky (2009), in their review on organizational coordination, concluded that "at its core, coordination is about the integration of organizational work under conditions of task interdependence and uncertainty" (Faraj & Xiao, 2006). More specifically in teams, coordination refers to the process of synchronizing or aligning the activities of the team members with respect to their sequence and timing (Marks, Mathieu, & Zaccaro, 2001; Wittenbaum, Vaughan, & Strasser, 2002).

Furthermore, while groups and organizations can coordinate through the explicit development of plans and routines, dynamic situations call for planning that occurs in real time (Wittenbaum et al., 1998). For instance, when studying medical emergency units, Argote (1982) argued that non-programmed means of coordination, which involve on-the-spot sharing of information among organization members, are an effective way of dealing with the increased demands associated with increased uncertainty. While the ability to coordinate tacitly and dynamically may be an important contributor to collective intelligence, it may also be an outcome. In a study of tacit coordination in laboratory teams, Aggarwal et al. (in prep) found that collective intelligence was a significant predictor of teams' ability to coordinate their choices in a behavioral economics game, despite being unable to communicate, allowing some groups to earn significantly more money during the lab session.

Structure is a main vehicle through which groups and organizations coordinate. As groups grow in size, their structure can play an increasingly important role in determining their effectiveness [ref?]. At a very high level, organizational theorists and economists have made a distinction between organizing activities in *hierarchies* and in *markets* (Williamson, 1975). For instance, a given activity (say producing tires for a car) can, in principle, be performed inside the same hierarchical organization that manages other parts of the process (say General Motors making a car), or it can be performed by an external supplier (say Goodyear). In the former

case, the activity is coordinated by hierarchical management processes inside the firm (General Motors); in the latter, it is coordinated by negotiations in a market and contracts between a buyer (General Motors) and a seller (Goodyear). The choice of which arrangement is best depends crucially on the *transaction costs* of the different arrangements, and these costs, in turn, are affected by factors like opportunism, search costs, and the specificity of the assets exchanged (Williamson, 1975). Some authors have also talked about other kinds of organizational structures, such as *networks* in which rapidly shifting connections within a single organization or among different organizations are much more important than the stable hierarchies of traditional organizations (Powell, 1990).

The vast majority of research on organizational structure, however, has focused on ways of structuring hierarchical organizations. Several key lessons about collective intelligence, in general, emerge from this work:

(1) *Differentiation and integration*. As Lawrence & Lorsch (1967) point out, effective organizations usually need to *differentiate*, that is, to divide the overall goal of the organization into different kinds of tasks and to create different parts of the organization that are focused on these different kinds of work. For instance, this division of labor might involve creating different groups for marketing, manufacturing, and engineering, or for different products or customers. But then there also needs to be some way to *integrate* the different parts of the organization to achieve the organization's overall goals (Lawrence & Lorsch, 1967). For instance, organizations can coordinate the activities of different organizational parts using mechanisms such as *informal lateral communication* (such as casual conversations at lunch), *formal groups* (such as task forces), *integrating managers* (such as product managers or account managers), or *matrix managers* (Galbraith, 2002).

(2) *Integration can be viewed as managing interdependencies*. Thompson (1967) identified three types of interdependencies among activities: *pooled* (where, for instance, activities share a resource such as money or machine time), *sequential* (where resources from one activity flow to another one), and *reciprocal* (where resources flow back and forth between two or more activities). Thompson and later researchers (such as Van de Ven, Delbecq, & Koenig, 1976; Malone et al, 1999) showed how different kinds of coordination processes are appropriate for different kinds of interdependencies. For instance, pooled (or "shared resource") dependencies can be managed by coordination processes such as: "first come-first served", priority order, budgets, managerial decision, or market-like bidding (Malone et al, 1999).

(3) *There is no one best way to organize.* The widely accepted contingency theory of organization design (e.g., Lawrence and Lorsch, 1967; Thompson, 1967; Galbraith, 1973) holds that there is no one best way to organize. Instead, according to this view, the best organizational design for a given situation depends on many factors such as the organization's strategy, tasks, technology, customers, labor markets, and other aspects of its environment (e.g. Duncan, 1979; Daft, 2001). For instance, *functional structures* (with separate departments for functions like engineering, manufacturing, and sales) are well-suited to situations where maximizing depth of functional expertise and economies of scale are critical, but they are generally not well-suited to situations where rapid adaptation to changing environments is important. *Divisional structures* (with separate divisions for different products, customers, or geographical regions) are well-suited to environments where rapid adaptation to environmental changes is important or where success depends on customizing products or services for

specific types of customers or regions. But they are not well-suited to reducing costs by taking advantage of economies of scale. In *matrix structures,* there are both functional and divisional structures, and some employees report to two (or more) bosses. For instance, an engineering manager might report to both a vice-president of engineering and a vice-president for a specific product. The matrix structure has the potential to achieve the benefits of both functional and divisional structures (such as both economies of scale and rapid adaptation to change), but it involves significantly more managerial complexity and coordination costs.

While these principles of organizational design were articulated in the context of large, hierarchical, human organizations, we suspect that they can all be generalized in ways that could help understand collective intelligence in many other kinds of systems, such as computer networks, brains, and ant colonies.

In addition to analyzing traditional, hierarchical organizations, some organizational researchers have also begun to analyze the new kinds of organizational forms that are beginning to emerge as new information technologies make possible new ways of organizing human activity (e.g., Malone, Yates, Benjamin, 1987; Malone, 2004 [others?]). For example, more decentralized structures such as loose hierarchies, democracies, and markets may become more common as inexpensive communication technologies make them more feasible (Malone, 2004). More recently, Malone, Laubacher, and Dellarocas (2010) have identified a set of design patterns (or "genes") that arise repeatedly in many innovative new forms of collective intelligence such as Wikipedia, InnoCentive, and open source software communities such as Linux. Examples of these genes include contests, collaborations, prediction markets, and voting.

## Processes

While the literature on group process is vast, the facets of group process most germane to collective intelligence are those which characterize intelligent systems more generally, whether technological or biological--namely memory, attention and problem-solving. Analogous processes in each of these categories have been explored at the group level. This is consistent with the emerging view of groups as information processors (Hinsz, Tindale & Vollrath, 1997) in that many of the group processes most central to group functioning involve cognitive or meta-cognitive processes. In addition, we will review the findings on group learning, thought by many to be a key characteristic of intelligent systems and which builds on all of the processes discussed.

### Memory in Groups

Group memory has been studied mainly via work on transactive memory systems. A transactive memory system (TMS) refers to a shared system that individuals in groups develop to collectively encode, store, and retrieve information or knowledge in different domains (Argote & Ren, 2012; Hollingshead, 1998; Lewis & Herndon, 2011; Ren & Argote, 2011; Ren, Carley, & Argote, 2006; Wegner, 1986). Groups with a well-developed TMS can efficiently store and make use of a broader range of knowledge than groups without a TMS. According to TMS theory conceived by Wegner (1987), and first demonstrated in the context of small groups by Liang, Moreland, and Argote (1995), there are three behavioral indicators of TMS: specialization, credibility and coordination. Specialization in the team is reflected in how group members divide

the cognitive labor for their tasks, with members specializing in different domains. Credibility is reflected in members' reliance on one another to be responsible for specific expertise such that collectively they possess all of the information needed for their tasks. Coordination is reflected in smooth and efficient action (Argote & Ren, 2012; Lewis, 2003; Moreland, Argote, & Krishnan, 2002; Moreland & Myaskovsky, 2000; Ellis 2006). Through performing tasks and answering questions, a member establishes credibility and expertise status. Other members, being aware of the person's expertise, direct new knowledge in the domain to him or her, which reinforces the person's specialization and team members' trust in his or her expertise. Further, members know whom to count on for performing various tasks and whom to consult for information in particular domains, which improves coordination (Argote and Ren 2012). Dozens of studies have demonstrated the positive effects of TMS on group performance in both laboratory and field settings (Lewis & Herndon, 2011), though work continues to refine measures and conceptualization of the construct and its relationship to performance for different types of tasks (Lewis & Herndon, 2011).

### Attention in Groups

In individuals, teams, and organizations, attention is viewed as central to explaining the existence of a limited information processing capacity (Styles, 2006; Ocasio, 2011) and thus has a great deal of relevance to understanding and studying collective intelligence. Work on attention at the organizational level started with the work of Simon (1947) who examined the channeling, structuring, and allocation of attention as a central concept in studying administrative behavior. March and colleagues continued with the examination of attention allocation in the study of organizational decision making. Ocasio (1997) in his attention-based theory of the firm, focused on how attention in organizations shapes organizational adaptation. In a more recent review of the developing literature on attention in organizations, Ocasio (2011) identified three different theoretical lenses that are used in studying attention, including attentional perspective (i.e. the top-down cognitive structures that generate heightened awareness and focus over time to relevant stimuli and responses), attentional engagement (i.e., the process of intention, sustained allocation of cognitive resources to guide problem-solving, planning, sensemaking and decision making), and attentional selection (i.e. the emergent outcome of automatic or intentional attentional processes that result in focusing attention on selective stimuli or responses to the exclusion of others). Newer lines of work to examine the development of shared attention in groups fall under the "attentional selection" category identified by Ocasio (2011), and ask the question: what do teams make the center of their focus as they conduct their work? And what do they allow to fall by the wayside?

Teams exhibit regularities in the types of issues they attend to in the course of carrying out work, which has been described in research on team task focus. Some teams are process-focused, focusing on the specific steps necessary to carry out tasks and how those are arranged among members and over time (Woolley, 2009a, 2009b). By contrast, outcome-focused teams place more emphasis on the products of their work or the "big picture" and allow that to drive coordination and decision making. Teams that are high in outcome focus tend to produce more innovative or creative outcomes, and adapt more effectively to difficulties that arise in their work (Woolley, 2009a), while teams that are process-focused commit fewer errors (Aggarwal & Woolley, 2013). More recent work on offensive and defensive strategic orientation shows that a team's position in a competitive environment is an important contextual antecedent

of outcome or process focus and the balance of attention members pay to the internal workings of the group versus the environment (Woolley, 2011; Woolley, Bear, Chang, & DeCostanza, 2013).

Not only is the content of team focus important but also the agreement among members around it. In the literature, this agreement around strategic priorities has been termed strategic consensus at the team level (laboratory teams-Aggarwal & Woolley, 2013, as well as in Top management teams- Floyd & Wooldridge, 1992; Kellermanns et al., 2005 ) or strategic compatibility at the dyadic level (Bohns and Higgins, 2011). This agreement reflects whether group members are on the same page about the team's strategic priorities for the given task, which is likely to affect the clarity with which they will execute the task. Agreement around process focus, for example, has been shown to be extremely beneficial to reducing errors in production and execution tasks (Aggarwal & Woolley, 2013) while undermining the development of creative outcomes in teams (Aggarwal & Woolley, under review).

### Group Problem Solving and Decision Making

Comprehensive treatments of group problem solving encompass much of what we have discussed throughout this chapter, in thinking about group goals, task types, and social processes (i.e. Laughlin, 2011). Given the recent shift to a view of groups primarily as information processors (Hinsz, Tindale & Vollrath, 1997) central to group problem-solving is the processing of information and the making of decisions. The ability of groups to process information effectively--that is, share relevant details, weight information appropriately, and arrive at the best conclusion--is directly tied to team performance (Mesmer-Magnus & DeChurch, 2009). Groups frequently base their decisions on irrelevant information, and disregard relevant information (Larson 2010). Thus factors affecting the quality of group decision making have direct implications for collective intelligence.

The main problems experienced in group decision making are associated with surfacing the necessary and relevant information, and combining it appropriately. Surfacing the necessary information becomes complicated by many of the issues concerned with other aspects of the STAR model -- is there a sufficient diversity of members to have access to all of the necessary information? Are their goals and motivations aligned such that they are willing to share the information that is needed? Assuming these aspects have been suitably addressed, there are a range of cognitive, motivational, and affective factors that can influence the kinds of information groups attend to (or ignore) in decision making. In terms of cognitive factors, a long line of work on social decision schemes has investigated how predecision preferences combine into a joint decision (Davis, 1973). Groups are also more prone to the use of certain cognitive heuristics and biases compared to individual decision makers (Kerr, MacCoun & Kramer, 1996). In particular, groups are vulnerable to the initial distribution of information and the existence of "hidden profiles," in which members initially prefer different alternatives based on conflicting information they hold, necessitating the surfacing and sharing of all relevant information to reach the correct solution (Stasser & Titus, 1985)

Motivational approaches to group decision making focus on group members' motivation to overlook disconfirming evidence and to believe in the infallability of their own group, as examined in work on groupthink and in social comparison approaches to decision making (Isenberg, 1986; Janis & Mann, 1977; Sanders & Baron, 1977). Toma and Butera (2009) further demonstrated how motivation alters group cognition, demonstrating that within-group

competition leads group members to share less information, and to be less willing to disconfirm initial preferences, as a result of mistrusting their teammates. In combining social and motivational factors, DeDreu, Nijstad, & van Knippenberg (2008) proposed a theory of motivated information processing in groups, in which epistemic motivation determines how deep vs. shallow group members will be in seeking out information, while social motivation encompasses the mixed cooperation-competition motives that group members experience which determine the nature of the information that is shared and processed by the group. Epistemic and social motivations interact to shape the quality of group judgment and decision making.

Given the biases and difficulties documented with group decision making in some circumstances, some have moved to the use of collections of independent decision makers, or "crowds," to gain the advantage of multiple perspectives without the drawbacks of the social processes that bias decisions. First demonstrated by Galton (1907), it has since been repeatedly demonstrated in studies of guessing and problem-solving that the average of many individuals' estimates can be closer to the true value than all of the separate individual or even expert guesses. However, for any benefits to accrue from the use of a crowd, individuals must be completely independent of one another and the sample sufficiently large and unbiased to enable errors to be equally distributed (Surowiecki). Even subtle social influence revealing knowledge of others' estimates can create a cascade of effects that reduces the accuracy of crowds (Lorenz PNAS 2011).

While crowds can be useful for some types of decisions when the conditions for accuracy are in place, there are a range of other circumstances such as when the options are not well-defined, or there needs to be buy-in by the group for a decision to be implemented, when traditional interacting group decisions are preferred. In these circumstances, a number of interventions have been demonstrated to successfully improve group decision making. One type of intervention focuses on structuring group conversation so that the group identifies key goals or questions that need to be answered and how their information needs to be integrated to answer those questions (Woolley, Gerbasi, Chabris, Kosslyn & Hackman, 2008). This approach can also be operationalized in the form of decision support systems in online communication, in which the system structures members' inputs and facilitates the process of integration.

A second type of intervention into group decision making involves putting group members into different roles to adopt opposing points of view. These are known most generally as "devil's advocate" approaches, named after a similar process adopted during the 16th Century as part of the canonization process in the Roman Catholic Church, in which an appointed person would take a skeptical view of a candidate in opposition to God's advocate, who argued in favor.

A third approach involves encouraging a group to grant equal speaking time to all group members with the assumption that this will enable all relevant facts to be brought into the discussion. Equality in speaking time has been associated with higher collective intelligence in groups (Engel, Woolley, Chabris, Jing & Malone, under review; Woolley et al., 2010). Interventions involving real-time feedback on relative contributions to group conversation have been shown to improve group decision making performance (DiMicco, Hollenbach, Pandolfo & Bender, 2007).

### Group Learning

Some views of intelligence equate the concept with learning. For instance, in work in

individual psychology, the information processing viewpoint on intelligence sees learning as a core process of intelligence (Sternberg & Saltman, 1982). Similarly, research on organizational IQ operationalizes the measure as the ability of the organization to gain new knowledge from R&D investments (Knott, 2008). However, other work conceptualizes learning as one outcome of the core capability of collective intelligence (Aggarwal, Woolley, Chabris & Malone, in prep).

Whether learning is encompassed within intelligence or an outcome of it, a lot of evidence suggests that groups and organizations vary enormously in their capability to learn. With experience, the performance of some organizations improves dramatically while the performance of others fails to improve or even deteriorates (Argote, 1999). Group learning refers to change in a group—which can manifest itself in changes in cognitions, routines, or performance—that occurs as a function of experience (Argote, Gruenfeld, & Naquin, 2001; Argote & Miron-Spektor, 2011; Fiol & Lyles, 1985). For example, as groups gain experience, they may acquire information about which group members are good at which tasks, how to use a new piece of technology more effectively, or how to coordinate their activities better. This knowledge may in turn improve their performance (Argote, 1999). An organization's ability to learn—that is, to improve its outcomes through better knowledge and insight (Fiol & Lyles, 1985)—is dependent on the ability of its teams to learn (Edmondson, 2002; Senge, 1990; Roloff, Woolley & Edmondson, 2011). In fact, teams are the fundamental unit of learning in organizations (e.g., Edmondson, 2002; Fiol & Lyles, 1985). Much of the work on group learning uses the concept of learning curves originally developed in individual psychology (Ebbinghaus, 1885; Thorndike, 1898) to characterize the rate of improvement, and researchers have found considerable variation in this rate for different groups (Argote & Epple, 1990; Dutton & Thomas, 1984; Knott, 2008).

In groups, learning is associated with change in knowledge, which may be gauged from change in performance, but also change in group processes or repertoires, (Argote et al., 2001; Argote & Miron-Spektor, 2011; Edmondson, 2002; Fiol & Lyles, 1985; Wilson, Goodman, & Cronin, 2007). Similar to individuals, though, groups may learn without evidencing performance changes, and conversely performance may change, because of contextual reasons, without any corresponding change in the group's knowledge (Argote, 1999). Observing knowledge changes in groups is complex; sometimes knowledge may be *explicit* (easily codifiable and observable; i.e., Zander & Kogut, 1995), and sometimes *tacit* (unarticulated and difficult to communicate, i.e., Nonaka, 1994).

**Motivation and Incentives**

Assuming that the group is working on a well-defined task, is structured appropriately and using the effective processes for conducting work, it is also important to evaluate whether they are properly motivated or incentivized to do the work. As discussed previously, specific difficult goals can be motivating, but motivation can come from other sources as well. The literature has generally looked at two sources of motivation -- extrinsic motivation, often in the form of money or cash incentives, and intrinsic motivation, derived from the internal satisfaction associated with the work itself.

Monetary incentives are the core foundation to induce high levels of effort in traditional organizational settings (Prendergast, 1999, Lazear, 2000). At times they have been shown to

increase the quantity, but not the quality of work produced (Jenkins, Mitra, Gupta and Shaw, 1998). The use of monetary incentives in group work can be tricky, as group-based incentives are highly subject to free riding (Alchian & Demsetz, 1972, Lazear & Shaw, 2007). Creating reward interdependence in teams can enhance performance, but only if accompanied by highly cooperative work behavior as well (Wageman, 1995; Wageman & Baker, 1997). When it is difficult for an employer to identify and reward the exact contribution made by each employee to the team output, employees working in a team will typically lack incentives to provide the optimal level of effort and work less than if they were working alone. This has also been referred to as the 'moral hazard' problem – and suggests that collaboration, particularly by anonymous workers outside of an employment relationship, should produce moral hazard (Holmstrom, 1982) and social loafing (Latane, Williams, & Harkins, 1979). This moral hazard potential is exacerbated in the group work typical of online platforms, which could attract individuals of any number of characteristics and inclinations—including those having greater inclination to free riding (Kerr & Bruun, 1983). However, despite the risk of free riding, monetary incentives have been shown to be effective in settings where output measures are not the outcome of the inputs of a single individual but rather derive from the joint contribution of many individuals, particularly when compared to alternative mechanisms such as incentive schemes that are not tied to output measures at all (Prendergast, 1999).

Turning specifically to motivation and team creativity, the research relating incentives to creativity is a bit muddled, with some evidence demonstrating that team extrinsic or cash rewards promote creativity (e.g., Eisenberger and Rhoades, 2001), whereas other studies suggest that rewards inhibit creativity or produce other undesirable effects (e.g., Kruglanski, Friedman, and Zeevi, 1971, Manso, 2011). Cash incentives can at times crowd out non-cash based motivations (e.g., Frey & Jegen, 2001), which are especially important in the case of creative problem-solving work (e.g., Stephan, 1996). Amabile and colleagues have demonstrated that reduced intrinsic motivation and reduced creativity can be caused by each of several different extrinsic factors, including: expected external evaluation (Amabile, 1979; Amabile, Goldfarb, and Brackfield, 1990; Hennessey, 1989), surveillance (Amabile et al., 1990), contracted-for reward (Amabile, Hennessey, and Grossman, 1986; Hennessey, 1989; Kruglanski, Friedman, and Zeevi, 1971); competition with peers (Amabile, 1982, 1987); and constrained choice in how to do one's work (Amabile and Gitomer, 1984; Koestner, Ryan, Bernieri, and Holt, 1984). While competing with peers (peers with whom they might ideally be sharing information) seems to dampen creativity, competing with outside groups or organizations can stimulate it (see Amabile & Fisher, 2011, for a review).

There are circumstances under which certain forms of extrinsic motivation may support intrinsic motivation and creativity - or at least not undermine it (Amabile, 1993). This "motivational synergy" is most likely to occur when people feel that the reward confirms their competence and the value of their work, or enables them to do work that they were already interested in doing. This is consistent with earlier research demonstrating that "informational" and "enabling" rewards can have positive effects on intrinsic motivation (see Deci and Ryan, 1985).

The presence of monetary incentives does not preclude the presence of alternative motivations. The puzzle of motivations has been resolved by pointing to the many conspicuous non-monetary motivations experienced by those participating in collaborative peer production

contexts. This includes direct, intrinsic motivations and any direct benefits from the use of any innovations by the contributor, him or herself (Lakhani & Wolf, 2005). It also includes a range of what might be regarded as "socially-oriented" motivations, fed by the presence of other participants on the platform (Lakhani & Wolf, 2005). These motivations include such things as an interest in gaining affiliation with the larger team as a community, or of accruing status or signaling one's expertise to the community (Butler et al., 2005, Lakhani & Wolf, 2005, Lerner & Tirole, 2005). Further, evidence suggests that rather than necessarily attracting loafers, a collaborative context may simply attract those who prefer collaboration and will work relatively diligently in these contexts (Boudreau, Lacetera, & Lakhani, 2011). Online collaboration contexts, particularly those that provide immediate feedback about the quality of work, encompass the job characteristics most directly associated with internal motivation (i.e., variety of content, autonomy over how work is conducted, and knowledge of results; Hackman & Oldham, 1976) which are not dependent on the presence of cash incentives to elicit sustained effort.

**Selecting the Right People**

We now come to the last component of the Star Model, which involves the selection of the right individuals to carry out the work. Two categories of characteristics are important to consider when selecting members of a team or organization with an eye toward enhancing collective intelligence--those that contribute information or skills to the group (and thus must be considered in combination with other members) and those that facilitate the transfer of information (and can be evaluated individually).

A long line of research on group diversity has examined the types of differences that are helpful vs. harmful to group performance. The information processing perspective suggests that composing diverse teams is best, arguing that a broader range of task-relevant knowledge, skills, and abilities provides a team with a larger pool of resources for dealing with non-routine problems (van Knippenberg & Schippers, 2007; Williams & O'Reilly, 1998). In fact, one of the primary reasons organizations use teams, and not simply individuals to perform tasks, is to have access to an array of information, perspectives, and skills that is thought to be brought with diversity, making group composition one of the most commonly studied team variables (Reiter-Palmon, Wigert, & Vreede, 2012; Tesluk, Farr, & Klein, 1997; Guzzo & Dickson,1996; Hollenbeck, DeRue, & Guzzo, 2004). Despite its potential value, however, a number of studies and meta analyses have failed to show strong effects of diversity on team performance (Joshi & Roh, 2009). Scholars have, thereby, urged researchers to pay close attention to the type of diversity variable studied, examining the specific type of diversity that is most relevant to the outcomes being investigated, because not all effects of team diversity are equal (Harrison & Klein, 2007; Horwitz & Horwitz, 2007; Joshi & Roh, 2009; Milliken & Martins, 1996; Shin, Kim, Lee, & Bian, 2012).

With regard to group composition, groups performing tasks which benefit from a range of skills or expertise will underperform unless composed with the requisite cognitive diversity (Woolley et al., 2007; Woolley, Gerbasi, Chabris, Kosslyn & Hackman, 2008) even when compared to groups of higher general intelligence or ability (Hong & Page). Groups that are too homogenous will also be less creative than more cognitively diverse groups (Aggarwal & Woolley, under review) and exhibit lower levels of collective intelligence than moderately

cognitively diverse groups (Aggarwal, Woolley, Chabris & Malone, in prep). However, cognitively diverse groups do run the risk of making errors in execution tasks, particularly when the diversity leads them to not be on the same page about how to prioritize task elements (Aggarwal & Woolley, 2013). Thus many researchers focus on the moderating effects of group process, such as the development of transactive memory systems and strategic consensus, in examining the relationship between diversity and performance.

Another important set of characteristics to consider in group composition which significantly enhance a group's ability to collaborate are those related to social or emotional intelligence. Emotional intelligence is defined as the capacity to reason about emotions, and of emotions to enhance thinking. It includes the abilities to accurately perceive emotions, to access and generate emotions so as to assist thought, to understand emotions and emotional knowledge, and to reflectively regulate emotions so as to promote emotional and intellectual growth (Mayer, Salovey, and Caruso, 2004). There is a general consensus that emotional intelligence enhances group performance (druskat), at least in the short term (ashkanasy). A specific subset of these skills, related to the perception of emotions and mental states, has been studied under the term "theory of mind" (ToM) (Apperly, 2012; Baron-Cohen, Leslie, & Frith, 1985; Flavell, 1999; Premack & Woodruff, 1978; Saxe, 2009). Theory of mind ability encompasses the accurate representation and processing of information about the mental states of other people, also known as "mentalizing ability" (Baron-Cohen et al., 2001), which contribute to successful interaction with others. Therefore, theory of mind appears to be the component of emotional intelligence with the greatest relevance to studies of collective intelligence.

The ability to make simple inferences about the false beliefs of others has been explored by developmental psychologists as a milestone reached by preschool age children (Wimmer & Perner, 1983), and it is widely recognized that people with various clinical conditions such as autism have difficulties with theory of mind (Baron-Cohen, 1991). A common--though usually untested--assumption in much of this research is that people with greater theory of mind abilities will be more competent at various kinds of social interaction. But only a few studies have tested this in limited ways with children (Begeer, Malle, Nieuwland, & Keysar, 2010; Peterson, Slaughter, & Paynter, 2007; Watson, Nixon, Wilson, & Capage, 1999), and fewer still have tested it with adults (Bender, Walia, Kambhampaty, Nygard, & Nygard, 2012; Krych-Appelbaum, Law, Barnacz, Johnson, & Keenan, 2007; Woolley et al., 2010).

For instance, Woolley et al. (2010) found that groups whose members had higher average ToM scores (as measured by the "Reading the Mind in the Eyes" test) also had significantly higher collective intelligence. Indeed, average ToM scores remained the only significant predictor of collective intelligence even when controlling for individual intelligence or other group composition or process variables, such as proportion of women in the group or distribution of communication.

The degree to which ToM, as measured by RME or otherwise, can be altered by training or experience remains an open question. Recent studies (Kidd & Castano, 2013) suggest that theory of mind abilities as measured by RME can be, at least temporarily, improved by reading literary fiction, which implies a new and interesting avenue of research for improving group performance.

## Conclusion

In this chapter we have provided a brief and selective overview of a relatively vast literature on group and organizational performance, with a focus on variables that strike us as particularly germane for the design and study of collectively intelligent systems. In so doing we have used Galbraith's STAR model to guide our consideration of the various issues to be considered by effective organizations. Intriguing to further consider are the possibilities for creating human systems or human-computer systems in such a manner that makes these issues either irrelevant or trivial. For instance, could we design human-computer environments in such a way that group processes would be structured to be optimal for the type of task facing the group at a moment in time? So that developing transactive memory systems in groups would be either automatic or trivial? So that group members would be prompted to balance their contributions to the work at hand so that they matched perfectly with the distribution of knowledge or skills? So that subtle social cues would be amplified in a manner to allow the group as a whole to enjoy a high level of emotional intelligence? These are only a few of the possibilities that are suggested by coupling an understanding of the key factors for collective intelligence identified in the teams and organizations literature with those of other literatures discussed in this volume. We hope the research and ideas discussed here will enable readers to see ways to increase collective intelligence to levels never conceived of before.

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