Digging into Implicit/Explicit States and Processes:

The Case of Cognitive/Social Process Interaction in Scientific Groups

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Abstract

Research in the psychology of science has typically fallen into separate, isolated subfields within psychology. This chapter examines two models that tie together social and cognitive psychological variables important in the development of innovation in multidisciplinary science teams, separately considering convergent versus divergent creative processes. The models are theoretically examined from the perspective of explicit and implicit elements. The chapter then draws on a recent study examining the moment-by-moment interplay of conflict (a social variable) and analogy (a cognitive variable) in a real-world multidisciplinary science team to examine the empirical nature of connections between social and cognitive models. While both conflict and analogies can be implicit and explicit simultaneously, the significant connections between these two variables seem to be mainly implicit, drawing on underlying knowledge structures and differences.

Implicit and Explicit Processes in Cognitive/Social Psychology of Science

To what extent are key psychological processes of science implicit or explicit? This central question has large methodological implications for how these processes can be studied, which critically includes the extent to which practitioner self-reflection and autobiographies can be taken as serious data points. In general, the psychology of science sits within two broader fields, the cognitive science of science (Dunbar, 1995; Holyoak & Thagard, 1995; Nersessian, 2009) and social studies of science (Knorr-Cetina, 1999), both of which include history of science and philosophy of science. Each of these perspectives relies to some extent on self-reflection and self-report methodologies.

Within psychology, there is a long theoretical and empirical history regarding the implicit versus explicit nature of psychological processes. This line of research has not always been called implicit versus explicit, but can be identified under studies of tacit versus explicit and unconscious versus conscious processing. Within cognitive psychology, there is now considerable agreement that some cognitive content (e.g., knowledge, beliefs, goals) is explicit, which includes aspects that are verbalizable, accessible to consciousness, and open to cognitive control (Ericsson & Simon, 1993), whereas some cognitive content is implicit, being non-verbalizable, not accessible to consciousness, and not open to cognitive control (Reder & Schunn, 1996). Relative degrees of practice with tasks is thought to influence automaticity and use of working memory for manipulating intermediate products, which then will influence implicit/explicit status (Ericsson & Simon, 1993; Schunn, Lovett, & Reder, 2001). However, there are also some processes which in general are not open to access, such as priming (Schunn & Dunbar, 1996).

Within social psychology, there is a somewhat different view. In general, self-reports of processes and explanations for behaviors are held in great suspicion when individuals self-report content and attitudes (Nisbett & Wilson, 1977). The rise of the implicit association test (IAT) to measure stereotypes and attitudes hidden from conscious thought, as well as the distinction between implicit and explicit attitudes, has its philosophical roots in this suspicion, even as a moderate correlation exists between implicit (automatic) and explicit (controlled) attitudes (Nosek, 2005). At the same time, surveys are the most common form of data collected, and the study of the actual behavior is quite rare in social psychology (Baumeister, Vohs, & Funder, 2007). In this field, the content of constructs is typically conceived of as explicit (e.g., attitudes, beliefs, role classifications) and the processes are typically conceived of as implicit (e.g., social comparison, dissonance, priming, schema formation), although some content is implicit (e.g., implicit theories of creativity (Paletz & Peng, 2008) and the self) and some processes have overt behavioral components (e.g., the success of various persuasion techniques).

Why Psychology of Science Needs Cognitive and Social Psychology Integration

In response to the high-level question about whether key processes in science are explicit or implicit, a simple first cut would be to divide the processes into cognitive and social psychological processes, and then apply the relevant frameworks and methods from those literatures. But what about processes that sit on the boundary between cognitive and social psychology? Whose frameworks and methods should take priority in those cases?

We claim that science is inherently cognitive (i.e., a process by which information is transformed through complex problem solving and decision making component processes) *and* inherently social (i.e., a process that engages groups of individuals frequently working together collaboratively or in opposition, involving interaction and/or social perception). Further, we claim that the social/cognitive divide is a somewhat arbitrary sociological distinction of communities as found in graduate training programs, journals, and conferences, rather than a real ontological distinction with clear dividing lines based on underlying processes. For example, motivation and shared mental models are psychological constructs that are important to the psychology of science and are partially owned by both cognitive and social psychology literatures.

The potential interconnections between primarily social and cognitive processes further complicates the implicit/explicit issue in the psychology of science. Suppose, for example, that analogical reasoning, a process intellectually owned primarily by cognitive psychologists, had an influence on intragroup conflict, a process intellectually owned primarily by social and organizational psychologists. Would the influence process follow the frameworks of cognitive psychologists or that of social psychologists?

To come to a more complete understanding of the psychology of science, in order to address issues of explicit/implicit or indeed any larger questions, integration between social and cognitive psychology will become important. In any real-world situation, both kinds of processes will be in play, with many processes actually sitting at the boundary of cognitive and social. In addition, there can be interactions among cognitive and social variables. Thus, making performance predictions will require understanding both components and their interactions. The current chapter is an example of work in this integration space.

A Social/Cognitive Model of Scientific Collaborative Processes

We begin with the description of a particular model that integrates social and cognitive processes to produce a deeper understanding of the effects of disciplinary knowledge on science team success. These input and output variables have been studied by both cognitive and social psychologists but with very different intermediate process variables. The model includes a range of processes to illustrate a number of substantive ways in which cognitive and social variables can come together.

Our particular model (described in greater depth in Paletz & Schunn, 2010) goes from external team structures to social processes, which in turn influence cognitive processes, which in turn influence team innovative outcomes. Thus, we assume no direct links from team structures to cognitive processes or from team processes to team outcomes. Furthermore, we assume that cognitive processes do not influence social processes directly, though we note such relationships are possible.

In a later section in this chapter, we describe some empirical work that reexamines these assumptions of the model with the test case of one particular social/cognitive connection, specifically that of conflict and analogy. This particular case also acts as a test of the implicit versus explicit nature of the interconnections between social and cognitive processes in science.

Convergent and Divergent Thinking in Scientific Creativity

The most commonly studied aspect of creativity in general is divergent thinking. Divergent thinking includes, among other factors, fluency (the generation of many ideas), originality (ideas that are novel compared to prior solutions), and elaboration (the depth with which each idea is explored;Torrance, 1988). However, divergent thinking alone is an incomplete view of creativity (Amabile, 1996; Hocevar & Bachelor, 1989). Research on scientific creativity must take into account the quality of ideas (Cropley, 2006). We argued that divergent thinking results in new ideas, but that there must also be convergent thinking in which good ideas are selected, adapted, and refined from the generated set. Furthermore, we suggested in our model that different processes and relationships are important for divergent and convergent thinking. The connections we described in our models are the likely strongest relationships between the variables of interest, based on the available literature. These models did not preclude the possibility of other relationships, but simply focused on those most likely to both have an effect.

Our social/cognitive models addressed both divergent and convergent aspects, and showed both potential causal pathways. We did not seek to reduce social factors to cognitive factors, although cognitive variables may mediate the relationship between certain social factors and innovation; rather, we sought to understand whether cognitive factors previously associated with innovation were also influenced by team factors. In addition, by integrating social and cognitive explanations, we can understand why interventions aimed at the cognitive level in team settings may sometimes produce unexpected outcomes. In other words, this approach enables us to gain a deeper understanding of the interactive influence of social and cognitive factors in scientific creativity.

Cognitive Processes of Scientific Creativity

Many cognitive processes have been implicated in science creativity. Our model focused on three variables that have been most commonly implicated: information search, analogy, and information evaluation. Information search is a systematic search through possible solutions, often guided by simple heuristics (e.g., simplicity first, more available first). Analogy is the process of drawing abstract relational comparisons between the current problem and prior problem/solutions to generate solutions for the current problem. Analogy has been studied in depth in science (Dunbar, 1997; Gentner, et al., 1997). Information search and analogy are primarily associated with divergent thinking: They lead to novel ideas, a wider variety of ideas, and more ideas. They also help problem solvers overcome mental blocks or fixation on one particular solution (Christensen & Schunn, 2005). Information evaluation is a convergent thinking cognitive process by which problem solvers examine the value of and select among the various generated ideas to determine which ones best solve the task at hand. Along the explicit-implicit continuum, all three of these are explicit cognitive process, insofar as their results (e.g., the analogy, the query, the selection) can be perceived by the thinker by and by the audience. However, the causal cognitive processes behind these three processes are likely to be implicit, involving knowledge structure activation, association, and comparisons. Surprisingly, of these three simple cognitive processes commonly associated with creativity in the cognitive literature, only information search has been discussed in the social psychology creativity literature (Nemeth & Rogers, 1996). This gap is particularly surprising because commonly discussed social variables underlying scientific creativity are likely connected to analogy and evaluation cognitive processes as well.

Social Processes of Scientific Creativity

Team creativity literature has a rich and varied history (see Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Kozlowski & Ilgen, 2006 for reviews). Brainstorming is often the focus of team creativity researchers (Thompson & Choi, 2006), but it is a subset of what scientists do: They also expound, problem solve, criticize, test, debate, and get off-topic. Most conceptual models of teamwork highlight the broader organizational context, the task demands, team processes, and/or team outputs, generally in the input-process-output type of model (Kozlowski & Ilgen, 2006; McGrath, 1984). One weakness of input-process-output models is that they often do not examine individual cognitive processes. Our model took as illustrative examples two team structures and processes of likely importance to both creative outcomes in science and to creative cognitive processes: knowledge diversity and member roles (Saunders & Ahuja, 2006). Team processes in the model that were hypothesized to be influenced by these team structures included communication, task conflict, and shared mental models.

Diversity in teams, particularly knowledge diversity, has historically resulted in mixed effects on teamwork: It is often positively associated with divergent thinking but can also hinder convergent thinking via increasing unproductive conflict and making it difficult to achieve a shared vision (Gebert, Boerner, & Kearney, 2006; Kurtzberg & Amabile, 2000-2001; Mannix & Neale, 2005; van Knippenberg & Schippers, 2007). Background knowledge diversity may be implicit or explicit, depending on team meta-knowledge about members' expertise. Formal roles are a type of team structure encompassing the behavioral norms and scripts surrounding individuals' roles. In our model, we proposed that formal roles help guide team processes and manage the contradictory effects of knowledge diversity. The three team process variables were interrelated with each other and the structure variables. Groups where individuals do not share unique information have poorer decision making (Stasser & Titus, 1985), so broad participation and communication of information are necessary to harness knowledge diversity. Knowledge diversity is thought to lead to task conflict, which is commonly thought to lead to better team performance (Mannix & Neale, 2005), although see De Dreu and Weingart (2003). Task conflict, as opposed to relationship and process conflict, involves disagreements about the work being done by the group (Jehn & Chatman, 2000). Social and organizational psychologists have also discussed the importance of a shared vision in the convergent aspect of team innovation (West, 1990). Shared mental models are the similarity and overlap of schemas regarding tasks, teamwork, and norms held by group members. As with cognitive processes, social processes are explicit when they are obviously experienced (e.g., long-lasting task conflict), but not when they lie outside of conscious thought (e.g., many mental models and the degree to which they are shared).

Social/Cognitive Model—Divergent Path

On the surface, the relevant social factors for divergent and convergent elements seem to be in opposition. Multidisciplinary teams are particularly illustrative of this contradiction: They both hold the promise of broad solutions and a great deal of difficulty (Derry, Schunn, & Gernsbacher, 2005). Attempts to unpack and delineate the effects of diversity have served up weak or inconsistent results (Mannix & Neale, 2005; van Knippenberg, De Dreu, & Homan, 2004), suggesting that moderated and mediated models are necessary (van Knippenberg, et al., 2004; van Knippenberg & Schippers, 2007). Our model argued that formal roles are a key part of this moderation. Figure 1 presents the divergent path of our model. The rest of this section will explain the empirical and theoretical origins of each link in the divergent path; the next section justifies the convergent path (Figure 2).

Generally, diversity is theorized to be positively associated with team innovation via the team having access to a broader range of perspectives, information, and opinions (Mannix & Neale, 2005; van Knippenberg & Schippers, 2007), and thus is positively related to team performance when the team works on a task requires information processing and innovative solutions (van Knippenberg, et al., 2004). A diversity of opinions also increases perceived novelty and complex, integrative thinking (Antonio, et al., 2004). Furthermore, according to theory by Nijstad & Stroebe (2006), the more knowledge structures available and accessible to members of the group, the more ideas that group can generate. However, these different perspectives and knowledge structures must be communicated between members of the group. For a team to take advantage of knowledge diversity, all members must communicate relevant, unshared information. Therefore, broad participation is considered both a likely outcome of and a necessary condition for knowledge or disciplinary diversity to be innovative.

Informational diversity has been generally found to increase performance via disagreements about task-relevant ideas (Jehn, Northcraft, & Neale, 1999; Pelled, Eisenhardt, & Xin, 1999). Task conflict focuses on the work done by the group; process conflict relates to plans and delegation; and relationship conflict revolves around issues of interpersonal incompatibility and off-task social issues (Jehn & Chatman, 2000). We hypothesized that task conflict, but neither process or relationship conflict (Jehn, 1997), would be an important positive factor in the effect of functional diversity on team performance. Arguments of the positive effects of task conflict are supported by over two decades of studies showing systematic, positive effects of minority opinion dissent on others' cognitions (Hinsz, Tindale, & Vollrath, 1997). Dissent of any kind has been found to increase discussion intensity (Schulz-Hardt, Brodbeck, Mojzisch, Kerschreiter, & Frey, 2006). In particular, a minority dissenter promotes more original solutions (Nemeth & Kwan, 1985) via a more thorough search for information by other members of the group (Nemeth & Rogers, 1996).

A second task structure we hypothesized to be important is formal roles. Formal roles, if set up correctly with associated communication norms and added task structure, should influence the relationship between knowledge diversity and task conflict, heightening knowledge diversity's positive effect on task conflict and lessening the potential relationship conflict. In particular, formal roles make explicit the implicit differences in background knowledge between team members. Communication norms in this case are expectations and rules regarding communication behaviors stemming from formal roles, such as respecting expert opinion and tolerating expert-driven task conflict via formal communication structures (e.g., turn taking, asking for concurrence). Formal roles can make implicit communication norms explicit and privilege unique information. For example, minority dissent has a stronger positive impact if the source of the minority opinion can claim expertise (Hart, Stasson, & Karau, 1999). Formal roles that reify and manage domain expertise in cases of knowledge diversity may help promote productive task conflict without the associated disruptive relationship conflict. In addition, the related communication norms made salient by formal roles could encourage broader participation and information sharing: If the norm is that certain individuals in certain roles are both respected in those roles as experts and expected to share their expertise, both the individuals and the team would encourage sharing of unique information. When experts are assigned rather than assumed, the tendency in groups to not discuss unshared information can be significantly overcome (Stewart & Stasser, 1995).

We hypothesized that the cognitive process of analogies might be involved in the connection between task conflict and scientific discoveries via broader participation. In studies of group cognition, knowledge diversity has been associated with an improved ability to generate useful analogies. For example, Dunbar (1995, 1997) found that mixed background microbiology laboratories were much more successful than homogeneous microbiology labs: The mixed-background labs brought a broader set of analogies to bear, and were thus better able to solve problems. We hypothesized that task conflict would increase this benefit of diverse backgrounds by leading each individual to actively consider different perspectives, likely through the activation of a broader range of domains (Nijstad & Stroebe, 2006). In developing useful analogies, the most difficult step is often retrieving the right analogy from memory. Once the right case is retrieved, the analogical mapping and productive inference is relatively easy (Forbus, Gentner, & Law, 1995). Thus, thinking about different perspectives should prompt different knowledge within the individual. Furthermore, the previously discussed participation/information sharing might cue additional knowledge from memory across individuals. Therefore, conflict via information sharing could create opportunities to bring a broader set of useful analogies to bear.

In sum, we hypothesized that knowledge diversity under formal roles would lead to task rather than relationship conflict and increased breadth of participation, which would then lead to information search and analogies, which would increase the originality, quantity, and richness (elaboration) of solutions. Some of the underlying mechanisms behind this model involved making explicit what was implicit, such as conflicting knowledge and unique information.

Social/Cognitive Model—Convergent Path

Group members must also select the most effective of their creative ideas (De Dreu & West, 2001). There have been recent calls to examine shared mental models in diversity research (van Knippenberg & Schippers, 2007), because diverse groups may have more difficulty in creating shared mental models. Therefore, we hypothesized that knowledge diversity would have a negative impact on shared mental models, resulting in more representational gaps (Cronin & Weingart, 2007). Cropley (2006) described the importance of convergent thinking in effective creativity, discussing it as originating primarily via established knowledge, which defines, guides, and shapes what is considered creative. This established knowledge includes not only explicit knowledge, but also implicit knowledge such as heuristics and unspoken assumptions about a field. These are all, in fact, shared mental models. Knowledge diversity offers a broader base of information to be shared, but also offers conflicting and contradictory norms and assumptions regarding what might be considered optimal solutions.

In the model, we further hypothesized that shared mental models in turn positively influence evaluative cognitive processes, which are useful for idea quality. Shared mental models are “dynamic, simplified, cognitive representations of reality that team members use to describe, explain, and predict events” (Burke, Stagl, Salas, Peirce, & Kendall, 2006, p. 1199). Team members use shared mental models to integrate and interpret new information about the team, task, and the problem situation (Burke et al., 2006). Shared mental models help guide effective team functions such as plan execution (Burke, et al., 2006; Kozlowski & Ilgen, 2006) and are considered vital to timely problem solving (Jones, Stevens, & Fischer, 2000; Orasanu, 1995). Shared mental models shape how individuals perceive their environment and how they should react to it (Salas, Stagl, & Burke, 2004), and promoting shared mental models is often considered a key leverage point for increasing team effectiveness generally (Kozlowski & Ilgen, 2006), but not universally so (Edwards, Day, Arthur, & Bell, 2006). We hypothesized that shared mental models act upon team scientific discovery output via creating a high-level or broad-stroke common ground upon which fine-grained details could be effectively co-constructed across the team. On the one hand, this shared understanding can allow team members to accurately evaluate the various choices on the subtask they are working on by themselves as well as provide useful evaluative feedback to others regarding their subtasks. On the other hand, when shared mental models are implicit, it can be more difficult to tell what parts are genuinely shared versus dissimilar or non-overlapping. Such unshared elements, particularly with the details of perceptions of the team's problem, can cause difficulties for a team (Cronin & Weingart, 2007). On the other hand, if enough of a shared language exists to facilitate teamwork (via a "trading zone"), the team may yet succeed (Gorman, 2008).

Evaluation is defined here as reasoning about constraints and tradeoffs on the scientific discovery problem at hand (e.g., between parsimony and fit to data, or between ease of explanation and inclusion of underlying mechanisms). Original ideas, richly elaborated ideas, and many ideas all indirectly lead to better ideas, on average. Evaluation, however, is critical to select among the various generated ideas to choose the better ideas.

We hypothesized that formal roles would influence the effects of knowledge diversity on convergent thinking processes. For example, shared conceptions of team roles are key to coordinating activities, and thus key to performance (Kozlowski & Ilgen, 2006). In addition, assigning experts can help increase a group's tendency to share unique information (Stasser, Stewart, & Wittenbaum, 1995; Stasser & Titus, 1985), suggesting that formal roles, because of communication norms regarding those roles, may make mental models easier to share via broader participation and communication. In fact, we hypothesized that formal roles could serve to moderate the negative relationship between knowledge diversity and shared mental models such that when formal roles exist, the negative relationship would no longer be significant. In effect, the tendency for formal roles to make explicit team members' assumptions about others' knowledge and how to interact with them can help a team achieve more shared mental models.

In sum, in this model, we hypothesized that knowledge diversity would negatively impact shared mental models. However, formal roles would increase the commonality and accuracy of shared mental models via communication norms (i.e., regarding participation and listening) and would therefore mitigate the negative relationship between knowledge diversity and shared mental models. Shared mental models and broad participation would then increase the likelihood that the cognitive process of evaluation would be appropriate, leading to high-quality scientific discovery outputs.

Implicit vs. Explicit Social/Cognitive Connections

Within this larger model, we have hypothesized many different connections between social processes and cognitive processes. Each of these connections might have implicit or explicit elements. Scientists may explicitly choose a cognitive strategy in response to a social situation, or they may simply implicitly react with a cognitive behavior in response to a social situation without knowing why they are doing so. Here, explicit can refer to either the selection process, which is sometimes called metacognitive control of the choice, or simply to the triggering environment and selected action itself, which is sometimes called metacognitive awareness (Reder & Schunn, 1996).

In the empirical section that follows, we examine in depth just one of the social/cognitive connections in the larger model, that between conflict and analogy. We select these two because they are each particularly richly described processes within disparate subfields in the psychology of science. We examine whether there are empirical connections, whether the connections are discussed by the individuals (and hence more likely to be explicit processes), and whether they are simply statistical regularities of behavior (and hence more likely to be implicit processes).

An Observational Study of Scientist Teams In Action

Overview of Study

We summarize some results of an observational study of the interplay between conflict and analogy in one particular context (Paletz, Schunn, & Kim, 2011b). The study involved coding videos for conflict and analogy events as displayed in natural, informal, task-related conversations and then statistically examining lagged regressions for evidence of an influence of one variable on the other, followed by a qualitative examination of the relationship within statistically significant connections.

Context

The Mars Exploration Rover (MER) mission's goals were to land two rovers on opposite sides of Mars and use them to drive, dig, analyze, and photograph to determine whether Mars ever had liquid surface water. Water on Mars is a necessary precursor to life having developed or existed on Mars. Prior to the MER team's discoveries, the hypothesis that water historically existed on Mars was the minority view; after the first ninety days of their mission, it became a foregone conclusion. In addition to this major discovery, the mission produced large general improvements in scientific understanding of the geology, geochemistry, and atmospheric conditions on Mars. Overall, MER was considered one of the most successful scientific missions by NASA in the last several decades. This success was not just due to the robotics and logistical planning before the mission, but was in large part because of the continual, creative adaptation to challenges during those first 90 days and beyond. The greater MER science team had over 100 members and was inherently multidisciplinary. In the first 90 days, they operated in a co-located, real-time problem solving manner, often in a large room with workstations for each subteam.

Sampling and Coding Method

Video cameras were moved around the larger science room for a subset of the days and captured hundreds of hours of individual work and informal conversations involving groups of various sizes. From the larger video collection, a subset of informal but task-relevant conversations (totally over 11 hours) were selected for transcription and analysis based on the audibleness of conversations. The transcripts were segmented into thought statements, and then independently coded for presence of absence of both analogies and conflicts. Analogies were identified purely from the transcripts, whereas disagreements among coders regarding conflicts were verified from the video because tone and body gestures were very important to identifying real moments of disagreement. Conflict was identified not simply because the speaker took a controversial viewpoint, but because the speaker was disagreeing with something said previously (see Paletz, Schunn, & Kim, 2011a for the micro-conflict coding method). Then each analogy and conflict event was further coded for types of analogy and types of conflict to see whether the connections depended upon the subtypes (see Paletz, Schunn, & Kim, 2011a for details).

One key dimension of analogy was analogical distance: Within Domain (within the domain of exploration on Mars), Within Discipline (where the target and the source of the analogy was within the same discipline, such as geosciences or organizational processes), or Outside Discipline (from general knowledge). Dunbar (1997) argues that Outside Discipline analogies are not used for discoveries per se but rather simply serve an explanatory function.

One key dimension of conflict was whether it involved conflicts about the task (scientific data analysis or planning involving the rovers), human work processes, or relationships. Task conflict is often argued to be potentially useful whereas process and relationship conflict is generally thought to be harmful (Jehn, 1997).

Analysis Methods

The initial step was to look for statistical associations in the temporal relationships between conflict and analogy. This step was accomplished by dividing the larger transcripts into blocks of 25 lines, with the division done two different ways. First the blocks were created centered around analogy moments, with sequential blocks of 25 lines before and following each analogy and continuing throughout the video clip transcript. A given block could possibly be shorter than 25 lines if a transcript ended or another analogy began. Second, the blocks were created centered around conflict moments, with sequential blocks of 25 lines before and following each conflict. Then time-series logistic regressions of lag 1 were computed. For analogy to conflict, the regressions were done using the analogy-centered blocks, and tested whether the absence or presence of an analogy in block n predicted the absence or presence of a conflict in block n+1. For conflict to analogy, the regressions were conducted using the conflict-centered blocks, and tested whether the absence or presence of a conflict in block n predicted the absence or presence of an analogy in block n+1. These regressions were actually hierarchical logistic regressions (of bocks nested within conversational clips) in the case of the analogy-centered blocks because there was significant clip-level variance in the dependent variable. Simple logistic regression was used in the case of conflict-centered blocks because there was not significant clip-level variance in the dependent variable. In the case of significant overall effects, follow-up statistical analyses examined subtypes, and then qualitative analyses examined the cases captured by the statistically significant subtype connections.

Results

Main Variable Connections

Analogies overall were not a significant predictor of subsequent conflict overall. However, within-domain analogies led to a twofold increase in the occurrence of conflict in the subsequent block, whereas within-discipline and outside-discipline analogies did not have this effect. Furthermore, the effect was localized to particular kinds of conflict. In particular, within-domain analogies were associated with a twofold increase in scientific data analysis science conflicts and work process conflicts, but no change in scientific rover and experiment planning conflicts. Table 1 presents examples of within domain analogies followed closely by conflict.

Examining the reverse relationship, again the overall relationship of conflict to analogy was not statistically significant, but a more specific relationship was. In particular, process conflicts were associated with a more than twofold increase in the occurrence of subsequent within-discipline analogies. Note that here the relationship involves a different type of analogy; thus, we can rule out simple third variable context explanations in which a third variable C led to both more conflict and analogy because it was a different kind of analogy implicated in the two different directional effects. Table 2 presents examples of process conflict followed closely by within discipline analogies.

Data On Explicit Vs. Implicit Nature of Connections

In our study, we hypothesized that within-discipline analogies would result from more conflicts because they would play a direct role in resolving those conflicts; similarly, the within-domain analogies would spark the science (data analysis) and work process conflicts. Qualitative unpacking of the specific pairs revealed that these were not generally the case. The analogies were not aiding in the immediate resolution of preceding conflicts. We hypothesized that the within-discipline analogies following the process conflicts could have been due to more subtle types of social challenges and knowledge structure activation.

The analogy-to-conflict relationship was similarly complex. While the within-domain analogies were sparking 45% of the science and work process conflicts, 55% were only sparked indirectly or in some other way related to the conflicts. These results suggest that the main relationships between within-domain analogies and the science and work process conflicts were indirect and implicit rather than direct and explicit. The within-domain analogies preceding process and certain types of science conflicts could have been due to representational gaps in shared mental models regarding the domain of science on Mars. Given that the MER team was inherently multidisciplinary, the within-domain analogies may have been both assumed to be the most shared and, in fact, no more shared than within-discipline analogies. Both of these explanations appeal to underlying, hidden, implicit socio-cognitive processes, rather than explicit, direct socio-cognitive processes.

Discussion of Explicit Vs. Implicit Processes Question

Both our model and empirical study contained explicit and implicit elements. The content of shared mental models can be either implicit or explicit. Similarly, most of the social and cognitive processes in our model are explicit when they are experienced and noted, but are implicit when they are, essentially, underlying knowledge structures, representational gaps, norms, and differences in background knowledge. Most of our hypothesizing about the utility of formal roles was because of their power to reify and make explicit what would normally be implicit: communication norms, differences in unique knowledge between team members, and the need for broad participation.

Our empirical study extended our original model in that, instead of simply drawing a connection from social and cognitive processes, we examined possible links from a cognitive process (analogy) to a social one (conflict). Both conflict and analogy can be explicit: Our method relied on both conflict and analogy being represented in conversation and interaction. That said, the method had strengths and weaknesses. On the one hand, the results were based on an observational study, without experimental controls, that could be specific to that setting. In coding interaction, we lacked data on both self-reports (explicit, known content) and internal, implicit processes. On the other hand, by coding communication and interaction, we examined what people actually said and did, even if those actions were extremely brief and may have occurred without conscious thought or later memory. In fact, brief interactions can elude even the most perceptive participant (Gottman & Notarius, 2000), suggesting that coded interactions may be both or either implicit and explicit. Furthermore, these interactions were not staged, forced, or subject to demand characteristics outside of the real-world situation of mission planning and scientific analysis.

Conclusion

Within psychology, different constructs are often identified as implicit, explicit, or both. While the content of attitudes, beliefs, and knowledge is often considered explicit, they can also be implicit (e.g., a familiar face, Reder, et al., 2000), stereotypes, implicit theories of creativity). Similarly, processes are often considered automatic, but not all escape conscious awareness (e.g., the incrementally changing results of persuasion or power plays) and many require explicit goals to launch the process (Anderson, Bothell, Byrne, & LeBiere, 2004) or explicit goal structures to form new processes (Crowley, Shrager, & Siegler, 1997). In this chapter, we reviewed a pair of complex social-cognitive models of team innovation, drawing on both divergent and convergent thinking processes. In both pathways, most variables could be implicit or explicit. Because some of the variables sit between social and cognitive worlds, it will be important to negotiate a shared meaning of implicit/explicit across the cognitive and social psychology communities in conducting empirical work to establish the implicit/explicit status of each variable.

One particularly novel element of this work was to consider new connections between social and cognitive variables, and in this chapter we considered the nature of those connections. Overall, connections between variables may typically be implicit, either as part of processes in general or through implicit associations and priming in particular. However, some of the moderating variables (i.e., formal roles) were suggested to have an effect because of their power to increase meta-knowledge, that is, make explicit and known underlying, implicit factors. Overall, in examining the interaction between important variables from two such different subfields, we can better understand the nature of problem-solving conversations such as the implicit/explicit nature of thinking and, thus, creativity as it occurs in real time.

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Table 1

Examples of Within-Domain Analogies (in Italics) Leading to Conflict (Most Key Words Underlined)

Within-Domain Analogies Leading to Science Conflict
S2[a]: You don't see it there. That *looks like everything we've been seeing so far in transition*. S1: But it's different. It's been there for a long time in a windy spot.
S1: … Do an IDD <instrument reading> on it, get the Mössbauer <another instrument>. S2: Yeah, it's probably not going to look *like these little spheroids*, it's going to look different. And so, let's see what it looks like. … S2: inside the crater, then that would be a good place to do it Because we can work <missing words> S1: Now why do you think that that's the case? [said in a challenging manner] S2: Well, you're more likely to be able to tease out mineralogy <missing words> S1: But why do you think there are courser grains inside the crater? S2: Um, I'm just surmising, um S4: Well, you do see chunks— S2: The wind may have done this, this kind of the lag deposit inside here the sand is so coarse it's coarser than I would have expected.

S1: Well background sand is fine, fine sand, The particles are pretty <missing word> S3: But clearly larger particles are up on the slopes outside the crater, even some cobbles. S1: It may be that that's the background is the fine ground up basalt sand.
Within-Domain Analogies Leading to Process Conflict
S2: Okay, so you just do the… It's *almost like the context meeting presentation* in the downlink. S1: That's right, except I have abbreviated the context meeting because that ten minutes is all we have, we've got to move.
S2:…I think the name of it, don't you mean a "pancam," "pancam can" because panoramic is more of a generic term for looking across the surface… Well, I think it's pancam. S1: Yeah but we can't say that *Like we say navigation camera* or… S2: Oh I see, okay. Well, if you… Go ahead and say what you want. I would guess panorama or pan-cam, pan-camera, but I don't know. I, we were told to use pancam in everything we write.

[a] S2, S1, etc. are speaker numbers. The first speaker in the clip is S1, etc. S2 in one clip may not be S2 in another clip.

Table 2

Examples of Process Conflicts (Most Key Words Underlined) Leading to Within-Discipline Analogies (in Italics)

S5[a]: Put the little thumbnails on there

Cause I can look at them without opening the report…

S4: Yeah, that's true,

but, well, what I'm saying [missing words as loud laughter from offscreen drowns out S4]

I mean, if I just have, if it's a Word doc,

It just has a generic icon.

So you have to <missing words>

But if you see that it's over a couple hundred kilobytes

then you know there's <missing words>

like the SOWG documentarian <missing word> to yesterday that's 600 <missing words>

S5: Umm, I see.

S4: Yeah, but thank you for that

because I hadn't thought about it.

Somebody who was just reading the text wouldn't have a clue.

S5: See, <missing words>

S4: Nah, no, I mean I can say Rock, you know,

and I usually, I try to do that

because in the illustration it says "see attachment."

S5: Wow, I mean I, <missing words>

S4: [Laughs] Nah, I'm glad you told me that.

S5: <missing words>

…

S4: In fact, <missing words>

We made a picture of, we made a picture of the first soil targets.

But I guess that's gone now in this morning's report, probably

because it didn't have <missing words>

S5: <missing words>

S4: Yeah, if you'd have seen the, um, Pancam <missing words> higher resolution <missing words>

S5: Yeah…

S4: *See, it looked little, it looked like little SEM images*, you know? [Note: SEM images are scanning electron microscope images.]

S5: I saw them.

S1: But then—exactly, but the point is why then—

It sounded like you have a bias towards the RATting

versus getting [person's name] in a position where

he can really analyze some rocks with a Mini-Tes.

S3: Hey, let me make a suggestion--

S2: It's not my bias.

It's one that—it's one that you're hearing from several people.

S1: Well, it's just what [second person's name] said.

S2: Yeah, that's my point.

S1: But is that in general?

S2: And [third person] agrees with him.

S1: I don’t know that he does.

S2: Well, maybe he’s trying to be—

S3: We were poo-pooing [fourth person’s] super resolution,

But maybe that’s what you want to do to get a—something like the white rock.

S1: That’s exactly why I brought it up in SOWG yesterday,

because it seems to me that if we don’t go to this white rock,

which is the one I know [fifth person] was thinking about,

if we don’t ever go to that white rock

that’s the best we’ll do.

S3: That way it’s not a—it’s not just an experiment—

It’s an important experiment.

S2: Well, look, I’ve walked around in Nevada

And there’s hydrothermal systems out there that were active a million years ago <missing words>.

As a matter of fact, *gold prospectors walked over that terrain all through the 19th century and only when they realized that those things were sitting on top of gold deposits did they* <missing words>.

The point is: you walk out there,

you see low white rocks that are part of these quartz,

you know super <missing words> deposits,

And you can go another mile and not see another one.

S3: I thought of something,

The likelihood that we landed on one is pretty slim.

S2: Well, yeah, sure you can get into that discussion, but—

S5: Yes.

S1: But we have to get into that though,

because that's the sniper mentality.

Not applied to engineering, but applied to science.

[a] S2, S1, etc. are speaker numbers. The first speaker in the clip is S1, etc. S2 in one clip may not be S2 in another clip.

Figure 1: Hypothesized Social-Cognitive Pathways of Team Divergent Thinking

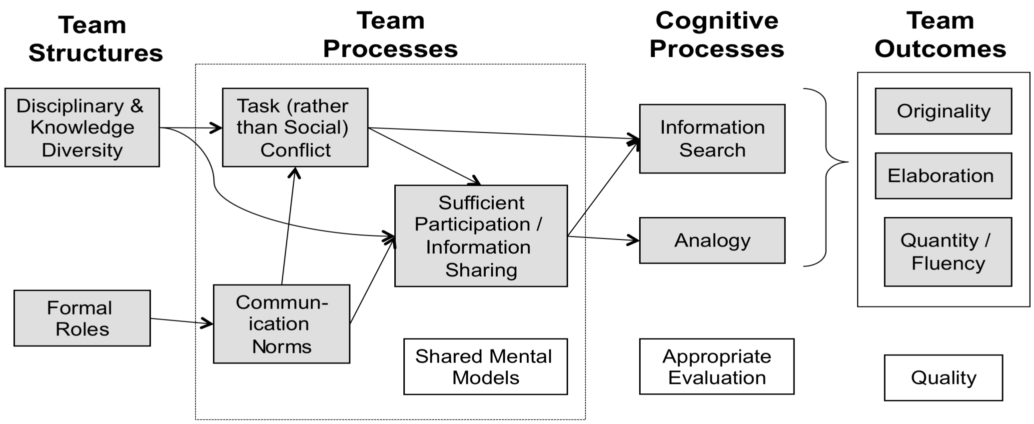

Figure 2: Hypothesized Social-Cognitive Pathways of Team Convergent Thinking