Cognition 126 (2013) 1–19

Contents lists available at SciVerse ScienceDirect

Cognition

journal homepage: www.elsevier.com/locate/COGNIT

The interplay of conflict and analogy in multidisciplinary teams

Susannah B.F. Paletz [a,*], Christian D. Schunn [b], Kevin H. Kim [c]

[a] Room 816, Learning Research and Development Center, University of Pittsburgh, 3939 O'Hara Street, Pittsburgh, PA 15260, USA
[b] Room 821, Learning Research and Development Center, University of Pittsburgh, 3939 O'Hara Street, Pittsburgh, PA 15260, USA
[c] School of Education, University of Pittsburgh, 5918 Wesley W. Posvar Hall, Pittsburgh, PA 15260, USA

ARTICLE INFO

Article history:
Received 5 January 2012
Revised 28 July 2012
Accepted 30 July 2012
Available online 12 September 2012

Keywords:
Analogy
Conflict
Field study
Teams
Creativity

ABSTRACT

Creative teamwork in multidisciplinary teams is a topic of interest to cognitive psychologists on the one hand, and to both social and organizational psychologists on the other. However, the interconnections between cognitive and social layers have been rarely explored. Drawing on mental models and dissonance theories, the current study takes a central variable studied by cognitive psychologists—analogy—and examines its relationship to a central variable examined by social psychologists—conflict. In an observational, field study, over 11 h of audio–video data from conversations of the Mars Exploration Rover scientists were coded for different types of analogy and micro-conflicts that reveal the character of underlying psychological mechanisms. Two different types of time-lagged logistic models applied to these data revealed asymmetric patterns of associations between analogy and conflict. Within-domain analogies, but not within-discipline or outside-discipline analogies, preceded science and work process conflicts, suggesting that in multidisciplinary teams, representational gaps in very close domains will be more likely to spark conflict. But analogies also occurred in reaction to conflict: Process and negative conflicts, but not task conflicts, preceded within-discipline analogies, but not to within-domain or outside-discipline analogies. This study demonstrates ways in which cognition can be bidirectionally tied to social processes and discourse.

1. Introduction

1.1. Background

Innovation and creativity increasingly occur in teams, particularly multidisciplinary teams (e.g., Squyres, 2005). Such teams create some of our most popular products and are essential for solving some of the world's most pressing problems. Team innovation and creativity have been increasingly studied by cognitive scientists (e.g., Ball & Christensen, 2009; Christensen & Schunn, 2007, 2009; Dunbar, 1995; Okada & Simon, 1997) while being a long-standing topic of social psychology (e.g., Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Levine & Moreland, 1998).[1] This disciplinary separation has resulted in theoretical and empirical gaps in our understanding of these constructs. The first gap is a segregation between organizational/social and cognitive perspectives. Some cognitive variables thought highly instrumental to team innovation are generally neglected in the social literature, and critical and contentious social variables are often ignored in the cognitive literature. Second, in the social literature, few studies unpack the 'black box' of mediating and moderating

* Corresponding author. Tel.: +1 412 624 2679; fax: +1 412 624 7439.
E-mail addresses: paletz@pitt.edu, sbfpaletz@gmail.com (S.B.F. Paletz), schunn@pitt.edu (C.D. Schunn), khkim@pitt.edu (K.H. Kim).

0010-0277/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cognition.2012.07.020

[1] While creativity involves the dimensions of both novelty and appropriateness (or usefulness), innovation additionally includes the elements of relative rather than absolute novelty, application/implementation, and the intentional benefit to others (West & Farr, 1990). For the purposes of this study, we are not distinguishing between innovation and creativity, as we are not examining outcomes directly.

variables to explain weak and inconsistent findings linking knowledge diversity to performance (van Knippenberg & Schippers, 2007). Third, there is a general shortage of field studies that examine real-world behavior, especially compared to the wealth of psychological research utilizing self-report and reaction times (Baumeister, Vohs, & Funder, 2007). Brief actions can elude perception, making self-report instruments a poor measure of fine-grained behaviors (Gottman & Notarius, 2000). Connections between cognitive and social variables are likely best unpacked through behavioral observation rather than self-report (Ericsson & Simon, 1993; Nisbett & Wilson, 1977).

This study addresses those three gaps via linking two key but little-connected variables together in real-time behavior. We focus on multidisciplinary teams: Research on disciplinary knowledge diversity has, on the cognitive side, implicated analogy as an important factor in problem solving team success (Dunbar, 1995, 1997). For example, mixed-background microbiology laboratories, compared to single-background labs, used a broader set of analogies and were better able to solve problems and be overall more successful. On the social/organizational side, knowledge diversity has, in certain circumstances, been found to increase performance via task conflict and disagreements about ideas (Jehn, Northcraft, & Neale, 1999; Pelled, Eisenhardt, & Xin, 1999). Analogy and conflict individually have been valuable in past research, and examining their interrelationship provides new theoretical avenues for accounting for mixed prior results. The purpose of this study is thus to explore the moment-by-moment interplay between analogy and conflict, here examined as micro-conflicts, in a real-world, multidisciplinary, long-term, large team, providing possible explanatory routes for why analogy and conflict on their own have complex relationships to success.

Using what is known about analogy and conflict separately, we will first break them down into the taxonomies used in their respective literatures (Table 1). Our aim is to explore whether there are connections between analogy and conflict based on their typical dimensions and to unpack likely explanations for any discovered relationships.

1.2. Analogy

Analogy is considered a fundamental cognitive process (e.g., Gentner, 1983; Holyoak & Thagard, 1997). An analogy involves drawing from and accessing past knowledge such as objects, attributes, or relationships (the source) to assist with the problem at hand (the target; Ball & Christensen, 2009). The process of applying information from the source to the target is referred to as mapping (Gentner, 1983). In a famous example, Christiaan Huygens suggested a wave theory of light, drawing from existing knowledge about sound traveling in waves (Sawyer, 2006). In this example, light was the *target*, sound was the *source*, and the shared properties that suggested traveling in waves was the *mapping*. Mapping and inferences that can be made from such mapping are different conceptually (e.g., Holyoak, Lee, & Lu, 2010), which is critical to the ways individuals may respond to an analogy posed by a team member.

Cognitive psychologists have examined analogy in naturalistic settings such as in science (Dunbar & Blanchette, 2001; Nersessian & Chandrasekharan, 2009), engineering (Ball & Christensen, 2009; Ball, Ormerod, & Morley, 2004; Christensen & Schunn, 2007), and politics (Blanchette & Dunbar, 2001). Analogies can help team problem solving (Dunbar, 1995), persuade others in political contexts (Whaley & Holloway, 1997), and teach concepts (Loewenstein, Thompson, & Gentner, 2003; Richland, Zur, & Holyoak, 2007; Young & Leinhardt, 1998). Our study focuses on scientific experts. Experts, compared to novices, are more likely to be able to correctly transfer elements, especially when the source has underlying similarities but surface dissimilarities (Novick, 1988). In other words, experts are better at seeing underneath superficial dissimilarities to recognize the utility of similar structural features.

Analogies can serve a variety of functional roles. Bearman, Ball, and Ormerod (2007) distinguished between analogies used to generate ideas for solving problems and those illustrating an existing idea. Illustrative analogies in the management decision-making domain "were designed not to facilitate directly the generation or development of a new solution idea, but instead for the purpose

Table 1
Different categories of analogies and micro-conflicts.

Analogy categories		Micro-conflict categories	
Distance	Within-domain Within-discipline Outside-discipline	Type	Science (task) Planning (task) Process Relationship
Mapping valence	Positive Negative Neutral Both positive and negative	Conflict sparked by	Simple correction Analogy Other
Problem-related vs. descriptive	Descriptive	Conflict resolved immediately/ quickly	No (unresolved)
	Problem-solving, explanatory, problem-finding		Yes (resolved)
Persuasive or not	Not used to persuade Persuasive	Conflict negativity presence	No negative affect Presence of negative affect
Depth	Superficial (1) to deep (5)	Conflict negativity intensity	None (0) to high (5)

of exemplifying an existing idea" (p. 287). Analogy researchers also distinguish between superficial mappings of only surface attributes versus deep analogies of underlying relationships and processes (Blanchette & Dunbar, 2001). Memory retrieval and problem representation factors can constrain the type of spontaneous analogical mappings that occur (Forbus, Gentner, & Law, 1995). However, in real world situations, it is often difficult to distinguish the superficial versus deep elements between the source and target, because these are dependent upon internal representations that are not usually explicitly stated.

The "distance" between the source and target is a feature connected to the deep versus surface distinction, easier to characterize in real world situations, and critically relevant to harnessing multidisciplinarity in teams (Dunbar, 1995). Within-domain analogies involve a target and source from the same domain, whereas between-domain analogies involve a target and source from different areas. For example, in design meetings from a medical plastics engineering team, within-domain analogies included sources related to medical plastics, whereas between-domain analogies involved sources such as the automobile industry or biology (Christensen & Schunn, 2007). Prior research suggests within-domain analogies might be more relevant to problem solving, but between-domain analogies might lead to more novel solutions. Dunbar (1995), in his study of biology lab groups, argued that between-domain analogies were primarily for illustration, but Christensen and Schunn (2007) found that engineers used both types in problem solving. Further, a lab study of engineering design found that encouraging access of multiple domains improved design originality, in part via the generation of distant analogies (Dahl & Moreau, 2002); another found benefits of providing engineers with more distant analogies (Chan et al., 2011). We break down distance to within-domain, within-discipline, and outside-discipline analogies. Within-domain analogies have the shortest distance between the target and the source, whereas outside-discipline analogies have the farthest.

Whether analogies include emotions is one possible type of connection between conflict and analogies. Thagard and Shelley (2001) theorized that analogies can be *about* emotions (e.g., happiness is like a butterfly), can transfer emotions from a source to the target (e.g., Quebec seceding is like a divorce, Blanchette & Dunbar, 2001), and can generate emotions (e.g., humor). In examining analogies used during the debate over whether Quebec should secede from Canada, outside-domain (outside-politics) analogies were more likely to be positive or negative than neutral (Blanchette & Dunbar, 2001), suggesting that the valence of mapping would be of interest. As these different distinctions between types of analogies have yielded a greater understanding of analogy, we will examine each of these distinctions in our study (Table 1).

1.3. Intra-group conflict

Theoretical models that link knowledge diversity to innovation via task-related conflict are common in the social and organizational psychological literature (e.g., West, 2002). We are interested in conflict as a possible means to raise different perspectives in support of team innovation in multidisciplinary teams. Intra-group conflict has been defined as "incompatibilities or discrepant views among the parties involved" (Jehn & Bendersky, 2003, p. 189). Individuals may have differences in background knowledge, roles, and goals, all of which may increase conflict. Many researchers focus on disagreement, with or without negative affect or obstructionist behavior, as the predominant dimension of conflict and the one most proximally connected to the functional role of conflict in problem solving (e.g., Amason, 1996; Barki & Hartwick, 2004 for a review; Jehn, 1995, 1997). We similarly focus on disagreements as conflict.

Jehn (1995, 1997) and Jehn and Chatman (2000) have argued that it is functionally important to distinguish between task, process, and relationship conflict. Task conflict revolves around the work itself; relationship conflict focuses on interpersonal incompatibility; and process conflict includes delegation and scheduling, among other human work processes. Under certain circumstances, task conflict is thought to improve team performance (Jehn & Mannix, 2001; Jehn et al., 1999; Pelled et al., 1999), whereas relationship and process conflict are thought to hurt performance (Jehn, 1997). Yet, a meta-analysis of team conflict and performance by De Dreu and Weingart (2003) found that both task and relationship conflict were negatively related to task performance and positively related to each other. This meta-analysis necessarily relied on self-reports, and may have missed lower-level, brief productive task conflicts that were not remembered later. In addition, the possible positive role of task conflict is supported by experimental research demonstrating that moderate disagreement, particularly by a minority opinion holder, can stimulate divergent thinking in listeners (e.g., De Dreu & West, 2001; Martin & Hewstone, 2008; Nemeth, 1986).

Two additional aspects of conflict are potentially important. First, the presence and intensity of negative affect makes the difference between possibly functional and likely dysfunctional conflict, with negative conflicts harmful (Amason, 1996; Barki & Hartwick, 2004; Jehn & Bendersky, 2003). Second, whether conflicts are resolved, particularly early in a team's lifecycle, has implications for later conflicts (Greer, Jehn, & Mannix, 2008). Specifically, early unresolved process conflicts may be associated with higher levels of all types of conflict later (Greer et al., 2008). These two variables will be examined in this study.

The operationalization of conflict itself is important to explain contradictory findings for conflict and performance (Barki & Hartwick, 2004; Mannes, 2008). For this study, we measured conflict not as global, retrospective assessments, but as utterance-by-utterance 'micro-conflicts'. Micro-conflicts are brief rather than long-lasting behaviors and measured via observation rather than self-report (Paletz, Schunn, & Kim, 2011). This measurement approach enables researchers to judge relationships involving affect, conflict, and other variables empirically. For example, we found that in a science setting, few micro-conflicts contained negative affect, but negative affect was associated with micro-conflicts not being resolved immediately (Paletz et al., 2011). Most importantly, micro-conflicts are at an appropriate, moment-by-moment conversational level for

examining the relationship between conflict and analogy. We use this method to examine micro-conflicts for affect, resolution, and type (e.g., task; see Table 1).

1.4. Possible links between analogy and conflict

Analogies in politics can be used as colorful and evocative arguments, suggesting that analogies and conflict may co-occur in that domain (Whaley & Holloway, 1997). What has not been examined is the conversational interplay between conflict and analogy in problem solving groups. Conflict and analogy may be unrelated, one may cause the other, they may co-occur, or both may be influenced by a third variable. To determine which relationships tend to occur, we measured both conflict and analogy as they arose in natural conversation, and then examined time-lagged correlations. Analogy may immediately precede conflict, conflict may precede analogy, or there may be no relationship. Such temporal relationships provide stronger clues to causation than simple co-occurrence correlations (Hume, 1739/1960). Although a third variable may still be affecting the co-occurrence of both variables, temporal relationships rule out some relationships between variables (e.g., it is unlikely that B causes A if A precedes B).

Although we have specific hypotheses based on a wide array of literature, the primary goal of this first study in this area is exploration, focusing on categories that commonly occur in healthy functioning teams. We use the main taxonomy for conflict that has been argued to be critical for functional vs. dysfunctional conflict (task, process, relationship) and one of the more important functional distinctions for analogy (analogical distance, i.e., within-domain, outside discipline). Secondary types of analogy and conflict are used to unpack possible relationships between these two primary types (Table 1).

1.4.1. Analogy to conflict

Analogy could precede conflict because comparing the current problem to another domain may reveal underlying differences or contradictions in perceptions of the target, source, and/or mapping. For example, US Presidential candidate John McCain and his running mate Sarah Palin compared Palin to President Ronald Reagan (Schwarz, 2010). The analogy attempted to make Palin seem more positive by mapping from Reagan a quality of Palin's, being "divisive" and polarizing (Schwarz, 2010). This analogy sparked disagreement about the mapping and inferences, with others noting differences in Reagan and Palin's leadership styles, character traits, and accomplishments (Rollins, 2010).

Literature on shared mental models informs our hypotheses regarding the analogy-to-conflict connection (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Mohammed, Ferzandi, & Hamilton, 2010). Teams diverse in terms of background knowledge and function are particularly likely to have representational gaps, or mental model dissimilarities, especially in problem representations (Cronin & Weingart, 2007; Weingart, Todorova, & Cronin, 2010). These gaps might result in different types of conflicts and difficulties with team information processing—conflicts that are likely harder to resolve than other types of conflict (Cronin & Weingart, 2007). Bearman, Paletz, Orasanu, and Thomas (2010) examined archival data of individuals with different functional roles in aviation and space missions, and found that many high-level breakdowns in coordinated decision making were caused by specific lower-level disconnects. The lower level disconnects could be operational (about actions and plans), informational (about facts), or evaluative (about appraisals of information). The evaluative and informational disconnects were theorized to be related to dissimilarities in the shared team mental model.

In multidisciplinary teams, when one group member raises an analogy that contradicts another's mental representation, either explicitly or through implication, the other team member might respond with disagreement. These conflicts could thereby be either indirectly or directly sparked by the analogy: Either the analogy is immediately contested, rather than accepted, or the analogy indirectly highlights differences in mental representations. Similarly, the analogy mapping could be rejected, or inferences based on the analogy could be rejected. With the Palin-Reagan example, the inferences about underlying qualifications rather than the explicit mapping of being polarizing were contested. Another possibility is that a third variable, such as a particularly difficult issue that a team is trying to resolve, influences both the analogy and its subsequent conflict. Based on the literature on shared mental models, we postulated that analogies that reveal or represent representational gaps in the source or target would be more likely to spark conflict. More distant analogies might actually be more shared (e.g., drawing on a source that is general common knowledge), whereas within-domain and within-discipline analogies may be more likely to draw on less overlapping mental representations in the context of a multidisciplinary team.

Hypothesis 1 (H1). Various kinds of conflict (e.g., task, process) will be more likely following analogies with a shorter distance (i.e., within-domain and within-discipline analogies).

Should H1 be supported, we also examine analogies according to the other dimensions listed above: descriptive versus problem related, persuasive or not, depth of the analogy, and mapping valence, which would help to provide insights into the nature of the connections between analogy and conflict (e.g., emotional vs. rational, confusion causing vs. simplistic).

1.4.2. Conflict to analogy

A different but not contradictory hypothesis is that more conflict, particularly task conflict, will lead to more analogies. Paletz and Schunn (2010) hypothesized that, as part of team divergent thinking, conflict caused by knowledge diversity would lead to analogy. There are at least two potential mechanisms: First, when faced with disagreement, one party might raise an analogy to explain their perspective, defend their opinions, or help resolve the conflict (e.g., Blanchette & Dunbar, 2001). The second mechanism

is more indirect via influences on memory retrievals in analogy. Theory and empirical evidence on minority opinion influence suggests that a determined minority opinion holder would force individuals to consider multiple perspectives, thus activating a broader range of mental structures and domains simultaneously (e.g., Nemeth, 1986; Nijstad & Stroebe, 2006; Peterson & Nemeth, 1996). It can be difficult to retrieve the right analogy from memory, but once the appropriate case is retrieved, analogical mapping and productive inference can be relatively easy (Forbus et al., 1995). A recent micro-level study supports this hypothesis: Compared to agreements, immediate disagreements yielded greater micro-creativity (Chiu, 2008). But, task conflict rather than process or relationship conflict is viewed as driving benefits for creativity and performance (e.g., Jehn, 1995). Further, activating a broader range of mental structures would enable retrieval from a greater array of potential analogical sources. Thus, we hypothesized that task conflicts will be more likely to activate the relatively farther distance (within-discipline and outside-discipline) analogies, rather than within-domain analogies.

Hypothesis 2 (H2). Within-discipline and outside-discipline analogies (vs. within-domain analogies) will be more likely following task conflict.

Within the context of a conflict, analogies may be used in the service of the debate (e.g., Blanchette & Dunbar, 2001). A well-placed analogy could be an attempt to persuade and explain, and thus help individuals with different opinions come to a shared understanding—or win over an opinion opponent. As noted earlier, whether a conflict is resolved may have long-term consequences for later team functioning. Thus, analogies may well be used in the service of resolving micro-conflicts.

Hypothesis 3 (H3). Conflicts followed by analogies are more likely to be quickly resolved.

According to prior theory, negative conflicts will be more likely than neutral conflicts to hurt team performance (Jehn & Bendersky, 2003). However, micro-conflicts may be less intense and negative than macro-conflicts (Paletz et al., 2011), and the literature on dissonance, disagreement and immediate memory retrieval may be more relevant. According to Matz and Wood (2005), group-based disagreement generates cognitive dissonance, and persuasion can reduce that dissonance. Furthermore, cognitive dissonance increases subjective negative affect and psychological discomfort (Elliot & Devine, 1994; Harmon-Jones, 2000). Thus, disagreement may lead to dissonance (Matz & Wood, 2005), which can be experienced as a motivational, negatively affective state (Elliot & Devine, 1994), which then encourages those involved in the disagreement to engage in dissonance-reduction strategies such as attitude change and persuasion (Matz & Wood, 2005). Given that analogies can be used to persuade, conflicts that involved negative affect may be more likely to precede analogies.

Hypothesis 4 (H4). Analogies will be more likely following negative micro-conflicts.

2. Methods

2.1. Research context: The MER science mission

The Mars Exploration Rover (MER) mission's goals were to land two rovers on Mars and to drive, dig, and photograph to determine whether Mars ever had liquid surface water. In the first 90 Martian days of the mission, the team discovered incontrovertible evidence for a history of water. This discovery was accomplished by numerous daily ideas and decisions, ranging from how to handle unexpected problems to interpreting complex, ambiguous information.

The team was organized into several science and engineering subteams (Squyres, 2005). The MER science team had over 100 members and was broken into two groups, one per rover. Each rover group consisted of a mix from atmospheric sciences, geology, geochemistry, and soil science; the interdisciplinary long term planning group; and engineers representing rover instruments. In the first 90 days, the scientists operated in a co-located, real-time problem-solving manner, often in a large room with workstations for each science subteam. Communication was primarily conducted via face-to-face structured and informal meetings within and between subteams, taking advantage of the open room.

2.2. Participants, clips and blocks

Four researchers each made four trips to visit the MER science operations and taped roughly 8 h a day for 3 days per trip, resulting in roughly 400 h of naturalistic video. Cameras were placed above large touchscreens (rotating across five different touchscreens in a room) prior to a workshift and left running for the whole shift. The cameras were quickly ignored by the scientists, resulting in natural conversations. This particular study involved 11 h and 25 min of informal conversation. Informal conversations were chosen rather than formal meetings, because the structured meetings involved a specific round-robin presentation style, were composed of a large number of mainly listening individuals, and unstructured back-and-forth was relatively rare. Conversely, the informal conversations were composed of fewer than 11 individuals and involved back-and-forth discussion between the participants. The specific informal conversations were broken up into separate audio–video clips ($n = 114$) based on when conversations naturally began/stopped and/or because the audibleness of the conversation started/stopped. Given the placement of the video cameras, clips could also end because the conversants left the room or moved too far from the camera to be heard. These particular hours were chosen based on being audible, broadly task-relevant conversations from early and late in the first 90 Martian days (versus times when no conversations were audible, individuals were quietly working or no one was present, etc.). The audio–video clips were transcribed into 12,336 utterances (thought statements or clauses, Chi, 1997).

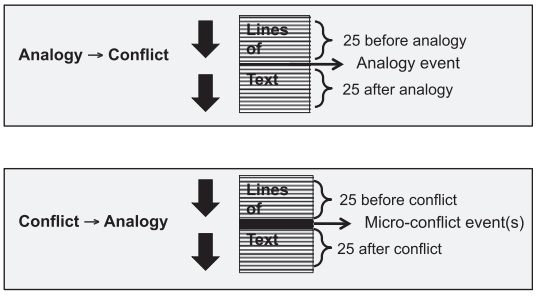

Fig. 1. Block segmentation strategy, with blocks centered around analogies (top) and blocks centered around conflict event(s) (bottom).

We coded whether each utterance was on-topic talk to exclude conversations irrelevant to MER (kappa = .96).[2] Task-relevant talk included anything regarding the mission (e.g., anything from the rovers to onsite parking). Off-topic talk included, for example, discussions about iPods and the scientists' families. The analyses were conducted on the remaining 11,856 utterances (11 h) of on-topic talk, 114 clips (or, roughly, conversations) that were 8–760 utterances long (M = 104, *Median* = 67, SD = 122). Only 26% of clips were a mix of males and females, and the rest were all males. Clips had a fluid numbers of discussants, ranging from 2 to 10 participants.

To find temporal patterns, we examined the data at the level of segmented blocks. Two types of segmentation strategies were used for examining, separately, the analogy-to-conflict and the conflict-to analogy relationships because the analogies and conflict events had different lengths. To support analogy-to-conflict analyses, blocks were segmented by first identifying the analogy utterance as its own block and then segmenting the 25 utterances before and after each analogy as two additional blocks (see Fig. 1, top). The rest of the clips were also broken up into successive blocks of 25 utterances, each ending at the 25th utterance, the end or beginning of the clip, or with the next analogy, resulting in 673 blocks. In the second segmentation strategy to support conflict-to-analogy analyses, the blocks were created by identifying the conflict event (or contiguous conflict events), segmenting the 25 utterances before and after each conflict event as two additional blocks, and then breaking up the rest of the clips into successive blocks of 25 utterances, each ending at the 25th utterance, the end or beginning of the clip, or with the next conflict, resulting in 688 blocks (see Fig. 1, bottom). Twenty-five utterances were chosen as the unit of the non-event blocks because it was roughly a minute in length, making it an appropriate amount of time to capture fleeting cognitive and social events. The number of utterances, however, rather than time, was the unit of analysis: The focus of the study was on information exchange and cognitive processes. The conflict events each ranged from 1 to 41 utterances long (see below), and multiple conflict events occurred in tandem, so blocks made up of conflict events were occasionally longer than 25 utterances. Blocks were also occasionally shorter than 25 utterances if events came faster than 25 utterances, or when clips began or ended in fewer than 25 utterances before or after the preceding/subsequent block.

By creating two segmentation strategies, we could test the bidirectional relationship between analogy and conflict in a manner that centered around each, optimizing the blocks to capture relevant proximal temporal relationships. The analogy-to-conflict relationship was tested using analogy-centered blocks, whereas the conflict-to-analogy relationship was tested using conflict-centered blocks. This strategy ensured that the predictor block would be relatively homogenous in its content and the dependent blocks would be standardized in length.

2.3. Measures

Each variable was assessed by two independent coders from a pool of six coders. Discrepancies were resolved through discussion. Conflict was coded independently of analogies. At least one coder for every code was blind to the hypotheses of this study.

2.3.1. Clip-level variables

There were two (mostly) separate groups of scientists, each focused on a rover. One rover had some early technical problems and because of where it landed, scientists discovered evidence for water later in the mission. The other rover discovered evidence for water early in the mission. In the analysis, we controlled for rover team and early/late in the first 90 days of the mission to account for possible differences in frustration and success.

2.3.2. Topic of the block

A third-variable potential confound to the temporal lag analyses was the topic discussed in each block, particularly because we are focusing on type of conflict, which may be correlated with general topic shifts (e.g., science conversations, planning conversations). Coders assessed the dominant conversational topic of each analogy-centered block. These topics were taken from the distinctions used for conflict type (see explanation in Section 2.3.4): science, rover planning, work process, relationships, and other (kappa = .72). The dominant topic of the blocks, for the analogy-centered blocks, was roughly evenly split between discussing science (34%), rover planning (35%), and work process (29%). These coders also assessed each analogy-centered block as to the percentage of the block that was from these different topics (intraclass correlations: science = .89, planning = .88, process = .87, relationship = .80). These percentages were used to generate the dominant topic of conflict-centered blocks. When examined using the conflict-centered block structure, rover planning was the most common dominant topic (41%), followed by process (32%) and then science (26%).

2.3.3. Analogy and analogy types

Analogies were identified at the utterance level (kappa = .60) using a previously established coding scheme for analogies in the wild (Christensen & Schunn, 2007). The literature distinguishes between mere appearance

[2] Kappas from 0.40 to 0.59 are considered moderate, 0.60–0.79 substantial, and 0.80 and above outstanding (Landis & Koch, 1977).

similarity and the deeper relational similarity assumed in analogies (Gentner & Markman, 1997). Although we did not include every instance of similarity or simple comparison as an instance of analogy, some of our coded analogies did involve the mapping of more superficial, surface features. We did not include as analogies simple categorical statements (e.g., "that is a basalt,"), clichés or changes in terminology that involved negligible cognitive work (e.g., 'we can't see the forest for the trees' or the use of 'blueberries' after the initial analogy as a term to describe certain mineral deposits), or statements that simply named attributes ("that rock is old"). However, because analogies are often not explicitly unpacked in expert conversations (Christensen & Schunn, 2007), strongly implied mapping of even superficial features was counted as naturalistic analogies. For example, when looking at tiny geological features, one scientist said, "Raspberries, strawberry..." and another qualified, "But they are sprinkles, 'cuz it's the size of them." In that case, while the mapping was relatively superficial (the color red, the size), the scientists were clearly making an outside-discipline analogy to highlight features in the data being examined.

Analogies were categorized on distance (kappa = .78; see Table 1). *Within-domain* analogies were those for which the source and the target come from the same narrow field, generally the MER mission; *within-discipline* analogies involved targets and sources across the broader discipline, such as between geological formations or processes seen on Mars versus Earth; and *outside-discipline* analogies identified sources far from the target. For example, Martian geologic formations were compared to cranberries, swords, and Oreo cookies. Note that in all three cases it was possible to map specific instances to one another or to map specific instances to more general cases, and thus could include analogies that are primarily similarity judgments as well as analogies involving inferences from categorical information.

Of particular relevance to conflict effects, the valence of the analogy's mapping (transfer of attributes from source to target) was coded as positive, negative, neutral, or both positive and negative (kappa = .64). Here, the focus was on only explicit mapping content because most sources have negative features and positive features that could be invoked. Most mappings were neutral, such as when the scientists compared a black and white striped pattern on a Martian rock to an Oreo. The positive (tasty) and negative (unhealthy) characteristics of Oreos were not being explicitly mapped, but the pattern of colors was. An example of a positive mapping is when a scientist compared their current conditions on Mars to the Viking Mars mission, with the mapping being that frost was found, implying a similarly beneficial science outcome for MER.

Coders also evaluated the analogies as to whether they were purely descriptive or fulfilled a more *problem-related* function (kappa = .78). Descriptive analogies illustrated simple commonalities and/or differences. Problem-related analogies were part of a larger attempt to solve, predict, or explain an issue, such as when a problem examining a past rock was seen as predictive of problems with a current rock.

Analogies were similarly assessed as to whether they were *persuasive* or not (kappa = .64). Persuasion was defined as when the speaker attempted to convince the listener of an opinion, interpretation and/or a necessary action, regardless of whether the listener already agreed. For example, the analogy of the rover instrument deployment strategy to chess was used to persuade that a set of instrument readings were possible if conducted in a specific order.

Finally, coders evaluated each of the analogies for *depth* on a five-point scale from 1 (very superficial mapping) to 5 (complex mapping; intraclass correlation = .83). Deeper analogies went beyond mapping a single attribute, such as color, to explicitly mapping multiple attributes, underlying processes, functions, and/or relationships between items.

2.3.4. Conflict and conflict types

Coders identified conflicts at the utterance level, often across several utterances, using a micro-conflict coding scheme (kappa = .62; Paletz et al., 2011). This conflict scheme follows Vuchinich's (1987) naturalistic study of family verbal conflicts over dinner. Coders were told to be conservative, such that "statements that were not clearly conflictual were not coded as conflict" (Vuchinich, 1987, p. 584). Conflict was identified not simply because the speaker took a controversial viewpoint, but because the speaker was disagreeing with something said previously in the same clip. Supporting arguments were also counted as part of the conflict. Although conflict was initially identified from the written transcripts, the coders referred to the audio–video recordings both when unsure of what to code and when discussing differences between coders' judgments. In particular, coders were directed to observe the participants' voices, body language, and (as possible) facial expressions. For example, some ambiguous questions (e.g., Table A1, "Why do you think that that's the case?") when listened to were clearly challenges, rather than innocent questions.

Coders assessed whether conflicts were *task*, (work) *process*, or *relationship* (Jehn, 1997; see Table 1). Task conflict was further divided into *science* and *rover planning* conflict (kappa = .48; Paletz et al., 2011) because they were possibly involving different use of prior knowledge/analogies. In the MER context, science conflict included arguments over interpretations of data and images. In contrast, rover planning focused on what the rovers should be doing and how/when to deploy instruments. These were considered task conflict because rover planning was one of the main mission tasks and the focus was on planning *science*, rather than people. For example, a particularly long conflict involved whether the team should direct a rover to a new area, or if additional instrument readings should be taken where the rover was currently stationed. Work process conflict, by contrast, focused on prioritization, scheduling, communication, and the coordination of *people* (Jehn & Bendersky, 2003). Relationship conflict involved personal relationships, dislike of people, and personal attacks (Jehn, 1997).

Conflict events were coded independently on three additional dimensions (see Table 1). Given our interest in

analogy, coders assessed each conflict event as to what sparked it: was the conflict a simple correction, was it started by an analogy, or something else (kappa = .68). Some conflicts were simply quick factual corrections, such as the number of meters a rover had driven. Second, conflicts were coded for whether they were resolved or not within 25 utterances (i.e., one block) after the conflict ended (kappa = .72). Longer-term resolution of these conflicts was not consistently codable because the resolution could have occurred days or months later.

Third, each conflict event was assessed for the expressed negative emotionality of the speakers. Positivity in conflict in this dataset was possible but rare (Paletz et al., 2011). Coders watched for and listened to the participants' body language, gestures, vocal tones, and the words they used in order to identify expressed negative emotionality and its intensity. First, coders assessed the conflict events for the *presence* of negative emotionality (kappa = .71), which could include irritation, anger, fear, disgust, sadness, fearful or angry surprise, contempt, regret, or negative sarcasm by anyone involved in the conflict (Watson, Clark, & Tellegen, 1988). Then the intensity of the expressed negativity was assessed from 0 (none, for those where negativity was coded as absent) to 5 (highest intensity; intraclass correlation = .81). Although coders were encouraged to use the whole scale, the general professional demeanor of the scientists meant that high scores were rare.

2.4. Analyses

When analyzing nested data (e.g., students within classroom), it may be necessary to statistically account for significant variance in dependent variables at the higher level. For example, students within a given classroom are not genuinely independent, requiring the use of hierarchical linear modeling statistics to accurately judge both student-level and classroom-level effects (Raudenbush & Bryk, 2002). Because our data were nested blocks within audio–video clips, we first tested statistically whether there was significant clip-level (Level 2) variance in our variables via running the base models in HLM 6 (Hierarchical Linear Modeling 6). A base HLM model is simply the dependent variable without any predictor variables, and it reveals using chi square estimation whether there are significant Level 2 components. Using this statistical cutoff, for conflict as the dependent variable in the analogy-centered blocks, the Level 2 variance was significant, Tau = .41, χ^2 (111) = 141.20, p = .028, but for analogy as the dependent variable for the conflict-centered blocks, the Level 2 variance was not significant, Tau = .36, χ^2 (111) = 109.36, p > .50. As a result, for our analogy-centered block analyses, a two-level hierarchical generalized linear model was performed, whereas a non-nested logistic regression was performed on the analyses for our conflict-centered blocks. All analyses controlled for the potential confounds of topic of block, rover, and mission time (early vs. late). All analyses were time-lagged, such that variables present in one block predicted other variables present in the subsequent block, essentially a time series analyses using only lag 1 (i.e., AR(1); see Fig. 1). Using only lag 1 focuses on immediate consequences that best fits the hypotheses under test, and exploring multiple lags raises the chance of finding spurious correlations.

Other than analogical depth and conflict negative intensity, the variables were dichotomized (e.g., did a block contain process conflict or not, a within-discipline analogy or not, a descriptive analogy or not). Topic was dummy coded as two variables with science used as the indicator reference group against rover planning and work process. The other two types, relationship and 'other', were very rare and so unanalyzed. For the hierarchical linear models, both fixed and random effects were estimated. Random effects were fixed at zero if the parameter estimates were not significant. Test statistics of parameter estimates using robust standard errors were used, which adjust for non-normality and heteroscedasticity (Raudenbush & Bryk, 2002). For the time-lagged logistic non-nested regressions, the assumption of no multicollinearity was met. Thus, analyses examining the possible relationships between analogy and the presence of conflict in subsequent blocks utilized time-lagged, logistic *hierarchical* regression, whereas the analyses of conflict on the presence of analogy in subsequent blocks utilized time-lagged logistical regression.[3] In addition, event-level analyses (e.g., analogy events, conflict events) were analyzed using chi square tests for associations between categorical data and Kruskal–Wallis one-way tests for examining associations between categorical data and non-normal continuous data, as appropriate.

3. Results

We first describe the frequency of various analogy and conflict types. We then present the analogy-to-conflict and conflict-to-analogy findings overall and then by subtype when there were sufficient numbers to permit such analyses.

3.1. Analogy frequency

Ninety-four analogies were identified, or about one every 7 min, similar to the analogy rate found in expert design team meetings (Christensen & Schunn, 2007). Of the 94 analogies, 32% were within-domain, 40% within-discipline, and 28% outside-discipline. The majority were problem related (70%) rather than descriptive, and 56% were used in persuasion. Sixty-nine percent were mapped neutral rather than having positive or negative (or both) implications. For the analogy-centered blocks, there were 94 single-analogy blocks (14% of the blocks). For the conflict-centered blocks, more than one analogy could occur within a block, such as when multiple analogies occurred

[3] To confirm the canonical order of our findings, we also tested (post hoc) the opposite time-lagged directions of our significant findings. We conducted these checks using both analogy-centered and conflict-centered blocks and simple logistic regressions, controlling for the rover, mission time (early/late), and topic of the independent variable/preceding block. We therefore tested for the effects of science and process conflicts on within-domain analogies, and on within-discipline analogies on subsequent process and negative conflicts. These predictors were not significant, lending credence to our orders and types as being the genuine findings.

in quick succession. Thus, only 11% of the conflict-centered blocks contained analogies.

3.2. Conflict frequency

There were 121 distinct conflict events (utterance length: *M* = 4.7, *Median* = 3.0, *SD* = 4.9, ranged 1–41 utterances). Conflict at the utterance level occurred in 20% of the analogy-centered blocks and 17% of the conflict-centered blocks, where continuous or overlapping conflict events were lumped into a single block. Science conflict occurred in 6% of the analogy-centered blocks and 4% of the conflict-centered blocks; rover planning conflict in 8% of the analogy-centered and 7% of the conflict-centered blocks; and process conflict in 8% of the analogy-centered and 7% of the conflict-centered blocks. Relationship conflict occurred during only 0.4% of each type of block and so was not analyzed further. Only 24% of the conflict events had any negative affect at all (intensity *M* = 0.49, *SD* = .99, range from 0 to 4) and almost half (49%) of the micro-conflicts were resolved within 25 utterances.

3.3. Analogy preceding conflict

First, we tested whether analogy was significantly followed by conflict using the analogy-centered block structure. We controlled for topic of the prior block at the block level, and success across rovers and early versus late in the first 90 days of the mission at the clip level.

3.3.1. Analogy to conflict

We hypothesized that specifically within-discipline and within-domain analogies would be likely to precede conflicts (H1). Overall presence of analogy did not significantly correlate with overall conflict in the subsequent block (Table 2). Rather, the influence of analogy on micro-conflicts did depend upon analogical distance: *Within-domain* analogies were twice as likely to precede conflict as when there were no within-domain analogies, whereas within-discipline and outside-discipline analogies did not significantly precede conflicts (Table 2, Fig. 2). The relationship also depended upon the type of conflict: within-domain analogies were over twice as likely to precede science and work process conflicts versus when those analogies were absent (Table 3; see Fig. 3), but this finding did not exist for rover planning conflicts. Thus, we see that only certain kinds analogies produce certain kinds of micro-conflicts; that is, a nuanced cognitive and social perspective is required to see the relationship. Table A1 (Appendix A) provides examples of within-domain analogies preceding science and process micro-conflicts. The examples reveal the micro-structure of scientific problem solving with simple analogies resulting in simple conflicts.

3.3.2. Unpacking the within-domain analogy to science and process conflict relationship

What was it about these within-domain analogies such that these particular micro-conflicts statistically followed them? And why, counter to our hypotheses, did within-discipline analogies not similarly precede conflict? Could within-domain analogies be more persuasive, valenced, and/or problem related? Clues about underlying mechanisms can be found in the relative predictiveness of other features of analogies. Because the number of units becomes smaller the more subtypes are added to analyses, individual associations may not be definitive. Nevertheless, the patterns provide useful information.

First, there were marginally significant findings for neutral valence of mapping such that neutral analogies were 82% more likely to be followed by conflict (Table 2) and non-significant results for positive and negative valence analogies predicting conflict. These findings were not statistically significant, but at the very least they suggest that the MER scientists were not stirred to conflict because of being offended by the negative or positive mapping of analogies.

Second, problem-related analogies and analogical depth were each statistically unrelated but marginally associated with overall conflict (Table 2). Compared to blocks without problem-solving analogies, problem-related analogies were 57% more likely to be followed by conflict and each higher point of analogical depth was 18% more likely to be followed by conflict. Again, these findings are not statistically significant, but the absence of even a trend in the reverse directions suggests that the analogy might begin a process that produces conflict, rather than cause direct confusion about what is being mapped due to it being particularly complex or simple, or problem-related or descriptive.

Could these marginal findings regarding individual features of analogies be due to correlations between specific features of analogies? Although problem-related and per-

Table 2
Analogy types followed by all micro-conflict (separate analyses for each independent variable[a]).

Independent variable[b]	*B*	SE	*t*	Odds ratio (95% confidence interval)	*df*	*p*
All analogies	0.36	0.26	1.38	1.43 (0.86, 2.39)	555	.17
Within-domain analogies	1.11	0.37	3.02	3.03 (1.47, 6.28)	98	.004
Within-discipline analogies	−0.38	0.50	−0.76	0.69 (0.26, 1.82)	493	.45
Outside-discipline analogies	0.13	0.69	0.18	1.14 (0.29, 4.50)	98	.86
Neutral analogies	0.60	0.32	1.88	1.82 (0.97, 3.40)	514	.06
Problem-solving analogies	0.45	0.26	1.74	1.57 (0.94, 2.62)	519	.082
Persuasion analogies	0.49	0.34	1.47	1.64 (0.84, 3.19)	98	.15
Analogy depth	0.16	0.09	1.85	1.18 (0.99, 1.40)	541	.064

[a] Controlling for covariates of MER mission, early/late, and topic of predictor block.
[b] Compared to no-analogy blocks in the first analysis, or blocks without that type of analogy for all the remaining analyses.

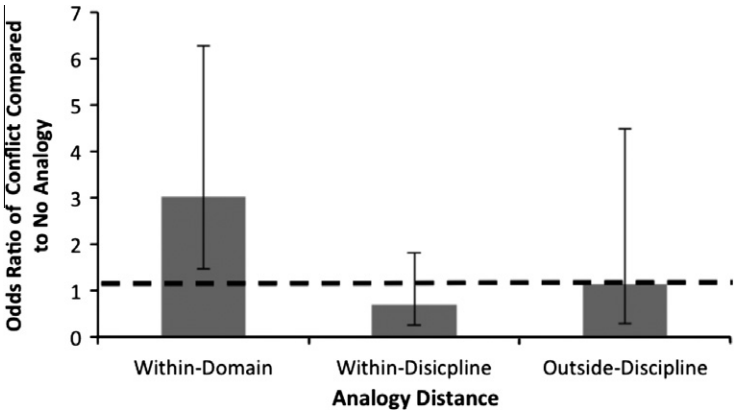

Fig. 2. Odds ratios of conflict occurring in subsequent blocks by analogy distance types.

Table 3
Significant analogy types followed by different types of micro-conflict (separate analyses for each independent and outcome variable[a]).

Independent variable[b]	*B*	SE	*t*	Odds ratio (95% confidence interval)	*df*	*p*
Outcome: Science micro-conflicts						
Within-domain analogies	1.19	0.43	2.79	3.28 (1.41, 7.62)	98	.007
Topic: rover planning[c]	−2.86	0.69	−4.17	0.06 (0.02, 0.22)	542	<.001
Topic: Work process	−2.54	0.76	−3.34	0.08 (0.02, 0.35)	542	.001
Outcome: Work process micro-conflicts						
Within-domain analogies	1.19	0.60	1.99	3.30 (1.02, 10.71)	485	.047
Neutral analogies	1.09	0.62	1.77	2.98 (0.89, 10.04)	514	.078
Analogy depth	0.24	0.13	1.91	1.28 (0.99, 1.64)	541	.056
Topic: Rover planning	1.33	0.67	2.00	3.80 (1.03, 14.05)	542	.046
Topic: Work process	1.36	0.67	2.02	3.89 (1.04, 14.61)	542	.044

[a] Controlling for covariates of MER mission, early/late, topic of predictor block. When that covariate is significant, it is presented above from its separate analysis.
[b] Compared to blocks without that type of analogy.
[c] Topic variables in this table are compared to blocks with science as the dominant topic.

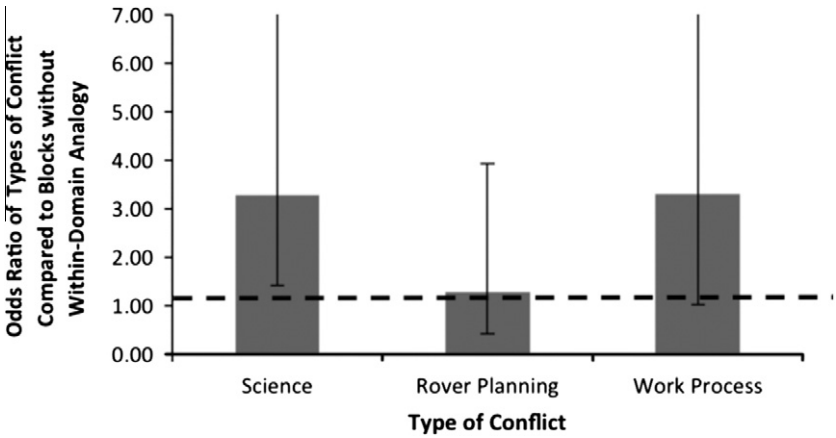

Fig. 3. Odds ratios of different types of conflicts in subsequent blocks for within-domain analogy compared to blocks without within-domain analogies.

suasive analogies were positively correlated, χ^2 $(1, N = 94) = 24.07$, $p < .001$, $\phi = .51$, persuasive analogies were not significantly followed by conflict (Table 2); thus it was not the attempt to persuade others of a different perspective *per se* within a problem-related analogy that produced the conflict. Depth was positively associated with problem relatedness (problem-related analogies mean rank of depth = 55, descriptive analogies mean rank = 30), Kruskal–Wallis χ^2 $(1, N = 94) = 16.75$, $p < .001$. Depth was also positively related to persuasion (persuasion mean rank of depth = 55, non-persuasive mean rank = 38), Kruskal–Wallis χ^2 $(1, N = 94) = 9.54$, $p = .002$.

These relationships suggest that it is sensible to discuss depth and problem-relatedness together.

More importantly, it is possible that analogical distance was associated with problem relatedness, persuasion, and/or depth, driving those trends (or vice versa). In fact, problem relatedness and analogy distance were associated such that within-domain (83%) and within-discipline (74%) analogies were more likely to be problem-related than outside-discipline analogies (50%), χ^2 $(2, N = 94) = 7.77$, $p = .021$, Cramer's $V = .29$. This finding was due to the significant difference between the combined within-domain and within-discipline analogies being more likely to be problem-related (78%) compared with the outside-discipline analogies (50%), χ^2 $(1, N = 94) = 7.02$, $p = .008$, Cramer's $V = .27$. There was no significant difference between the within-domain and within-discipline analogies on the descriptive versus problem-related function, χ^2 $(1, N = 68) = 0.91$, $p = .34$, Cramer's $V = .12$. Thus, the lack of conflict associated with outside-discipline analogies might be due to the lower rate of problem relatedness of outside-discipline analogies. Indeed, Dunbar (1995) found that outside-discipline analogies were rarely used for problem solving in the molecular biology labs he studied. However, half of the outside-discipline analogies and a majority of the within-discipline analogies were problem-related in nature: The lack of associated increases in conflict with those types cannot be entirely explained by those analogies not being used for problem solving.

Similarly, analogy distance was related to persuasion in that within-domain (67%) and within-discipline (61%) analogies (combined, 63%) were more likely to be persuasive than outside-discipline analogies (38%), χ^2 $(1, N = 94) = 4.69$, $p = .03$, $\phi = .22$ (non-significant difference between all three at once, χ^2 $(2, N = 94) = 4.95$, $p = .08$, Cramer's $V = .23$). Furthermore, analogy depth and distance were related, mainly in that outside-discipline analogies ($M = 2.2$, $SD = 1.1$, mean rank = 37) tended to have less depth than within-domain ($M = 2.7$, $SD = 0.8$, mean rank = 51) and within-discipline ($M = 2.8$, $SD = 1.3$, mean rank = 52) analogies (combined mean rank = 52), Kruskal–Wallis χ^2 $(1, N = 94) = 5.76$, $p = .016$ (non-significant difference between all three at once, Kruskal–Wallis χ^2 $(2, N = 94) = 5.83$, $p = .054$, and no significant difference on depth between within-discipline (mean rank = 33.5) and within-domain (mean rank = 35.5) analogies, Kruskal–Wallis χ^2 $(1, N = 68) = 0.24$, $p = .63$). Overall, this pattern of correlations between analogy distance and problem relatedness, depth, and persuasion suggests that outside-discipline analogies, compared to within-domain and within-discipline analogies, were more descriptive, less deep, and less persuasive, and thus perhaps less likely to precede (or lead to) conflict. But, our findings for analogical distance were specifically for within-domain analogies, not within-discipline analogies, suggesting that this pattern of differences is not entirely what is driving the finding for within-domain analogies.

Finally, we coded each of the micro-conflict events for what might have sparked it, and then focused on the 11 conflict events that followed within-domain analogies. Four (36%) of those conflicts had been coded as directly sparked by analogies (e.g., the first example in Table A1). For a fifth case, although the conflict was not *started* as a reaction to an analogy, the subsequent conflict was clearly a direct disagreement with that analogy (for a total of 5 conflicts, 45%, as direct reactions to the analogy). Of these, two were rejections of the entire analogy (e.g., "I was like you, I came to work late" "I didn't come late to work today"). One conflict was about the mapping (i.e., one speaker referred to a previous day's plan where they didn't end up learning anything new, and the second indicated they did find something new from that plan). The fourth was a rejection of the source. The fifth was raised in the context of an argument about appropriate MER terminology (Table A1, Appendix A, last example). While superficially the analogy was accepted ("Oh, I see, okay"), the listener continued his counter-arguments without addressing the analogy directly, implying the analogy was rejected in whole or part.

The majority (55%, or 6) of the analogy–conflict pairs appeared not to be disagreements started by the analogies. Of the remaining 6, two of the 11 (18%) entailed domino inferences: The analogy led to a trail of ideas that eventually led to a conflict. Three (27%) were analogies that in fact served to aid in the resolution of a conflict in some manner, even if that conflict continued past the analogy. Finally, one within-domain analogy–conflict pair was too vague to analyze due to the fact one of the speakers kept cutting off the other, who was clearly trying to disagree with him before and after the dominant speaker made the analogy.

3.3.3. Analogy to conflict summary

In sum, within-domain analogies, but not outside-discipline or within-discipline analogies, significantly preceded process and science conflicts. This finding represents partial support for H1, but still leaves the question as to why within-domain but not within-discipline analogies significantly preceded conflict. In the context of multidisciplinary teams, within-domain analogies may have more contestable representational gaps than either outside-discipline analogies (which rely on common knowledge without representational gaps) or within-discipline analogies, where experts may defer to each other (i.e., involve representational gaps but not contestable ones). Qualitatively unpacking the analogy–conflict pairs suggested that disagreements were often inspired by the preceding analogy; in some of those cases, the analogy was serving to resolve an ongoing conflict.

3.4. Conflict preceding analogy

Analyses of conflict preceding analogy were time-lagged by block, and we controlled for rover mission, time (early versus late) in the first 90 days, and topic of the preceding block. Unlike the analyses above, a simpler, non-nested time-lagged logistic regression was used.

3.4.1. Conflict to analogy

We hypothesized that conflicts would specifically precede within-discipline and outside-discipline analogies (H2). There was no statistical association between overall conflict and overall analogy. In addition, no type of conflict (science, planning, process) significantly preceded either

Table 4
Process micro-conflicts followed by within-discipline analogies (entire time-lagged logistic regression model).

Independent variable	*B*	*SE*	Wald χ^{2a}	Exp(*B*) (95% confidence interval)	*p*
Covariates					
Constant	−5.16	.73	49.71	.006	<.001
Early vs. late in mission	0.46	.48	0.93	1.58 (0.62, 4.03)	.33
Rover (A vs. B)	−0.13	.46	0.08	0.88 (0.35, 2.18)	.78
Topic: Rover planning[b]	1.41	.50	8.08	4.09 (1.55, 10.81)	.004
Topic: Work process	1.29	.56	5.38	3.63 (1.22, 10.83)	.02
Predictor variable					
Process conflict[c]	1.27	.62	4.18	3.55 (1.05, 11.92)	.04

[a] All degrees of freedom for the Wald χ^2 are equal to 1.
[b] Topic variables are for blocks preceding analogies.
[c] In prior block, compared to blocks without process conflict.

Table 5
Significant micro-conflict types followed by within-discipline analogies (separate analyses for each independent variable[a]).

Independent variable	*B*	*SE*	Wald χ^{2b}	Exp(*B*) (95% confidence interval)	*p*
Conflict resolved immediately[c]	0.46	.48	0.93	2.44 (0.86, 6.89)	.09
Presence of negative affect	1.83	.64	8.16	6.20 (1.77, 21.68)	.004
Intensity of negative affect	0.78	.26	8.92	2.78 (1.31, 3.63)	.003

[a] Controlling for covariates of MER mission, early/late, topic of predictor block. As with Table 4, the two topic variables dummy variables are significant.
[b] All degrees of freedom for the Wald χ^2 are equal to 1.
[c] Compared to blocks without resolved conflicts.

within-domain or outside-discipline analogies. However, process conflicts were 255% more likely to be followed by within-discipline analogies compared to those blocks with no process conflict (see Table 4). The logistic regression model was significant, χ^2 $(5, N = 688) = 14.89$, $p = .011$, Negelkerke $R^2 = .079$. The Hosmer–Lemeshow test was not significant, χ^2 $(7) = 4.45$, $p = .73$, indicating a model with adequate fit. This finding was contrary to our hypothesis that task conflicts would be related to within- or outside-discipline analogies (H2). Instead, we discovered a more specific process conflict to within-discipline analogy finding. Critically, this relationship is not simply the mirror image of the within-domain analogy to process and science conflict finding. Thus, these results rule out a general third variable explanation of conflict and analogy simply occurring in similar situations: The analogy to conflict to analogy relationship involved different types of analogy *and* conflict.

We then examined the analogy-to-conflict connection along additional dimensions. First, it is possible that the conflicts resolved within 25 utterances might include a within-discipline analogy in the resolution process—and in fact, the within-discipline analogy might be assisting in the conflict's resolution (H3). Controlling for the prior block's topic, rover mission, and early versus late (as above), conflicts that were resolved were not more likely to precede within-discipline analogies, failing to support Hypothesis 3 (see Table 5). The overall logistic regression model was significant, in large part because of controlling for significant effects of general topic of the preceding block, χ^2 $(5, N = 688) = 13.85$, $p = .017$, Negelkerke $R^2 = .074$, and the Hosmer–Lemeshow test was not significant, χ^2 $(7) = 3.95$, $p = .79$, indicating a model with adequate fit. However, the specific contrast of resolved versus unresolved micro-conflicts was not significant (see Table 5), although it did trend in the expected direction.

We also hypothesized based on dissonance theory that negative conflicts would be more likely to be followed by analogies (H4). This finding was supported whether negative affect was tested as a dichotomous variable (presence of negative affect or not) or as a continuous intensity variable (Table 5). Within-discipline analogies were over five times more likely to occur when preceded by a negative conflict than otherwise (i.e., preceded by neutral conflict or no conflicts). Both models were significant, χ^2 $(5, N = 688) = 17.81$, $p = .003$, Negelkerke $R^2 = .095$ and χ^2 $(5, N = 688) = 17.97$, $p = .003$, Negelkerke $R^2 = .096$, respectively, with non-significant Hosmer–Lemeshow tests as appropriate, χ^2 $(8) = 5.31$, $p = .72$ and χ^2 $(7) = 4.96$, $p = .67$, respectively.

3.4.2. Unpacking the conflict-to-within-discipline-analogy relationship

At the conflict event level, compared to task conflicts (41%), process micro-conflicts were more likely to be resolved immediately (64%), χ^2 $(1, N = 118) = 5.98$, $p = .015$, $\phi = .23$, but, as noted above, resolution was not significantly related to within-discipline analogies. Although process conflicts (26%) were slightly more likely to have negative affect than task conflicts (20%), this difference was not significant, χ^2 $(1, N = 118) = 0.56$, $p = .46$, $\phi = .07$ (nor for negative intensity, Kruskal–Wallis χ^2 $(2, N = 118) = 1.80$, $p = .40$). In fact, examining the different types of task conflicts more closely, process (26%) and rover planning (24%) conflicts were very similar in terms of whether negative affect was present, particularly in comparison to science conflicts (12%). Given that rover planning and science conflicts were examined separately and

neither significantly preceded any analogies, it is unlikely that negativity could be mediating the relationship between process and within-discipline analogies.

In order to judge whether resolution was a function of analogy, independent coders assessed the 43 conflicts that was resolved and followed by at least one analogy for whether the analogy played a part in the resolution (kappa = 1.0). Of these, only 6 (14%) were judged as the analogy actually playing a role in helping to resolve the conflict, suggesting that analogies were not playing a major role in immediate conflict resolution (at least not successfully).

We also examined in greater depth the conflict-to-within-discipline-analogy pairs (Table A2, Appendix A). There were four process conflict/within-discipline analogy pairs, four negative conflict/within-discipline analogy pairs, and five resolved conflict/within-discipline analogy pairs, with considerable overlap in these pair types. We qualitatively examined the six pairs where negative and/or process conflicts preceded within-discipline analogies. None of the three resolved negative or process conflicts that were followed by within-discipline analogies actually involved the analogy resolving the conflict. In all three cases, the analogies were related to the general topic under discussion, but occurred after the conflicts, which were particularly brief, were resolved.

In all three cases of *un*resolved conflicts preceding within-discipline analogies, although the analogies were related to the prior conflicts, they also did not seem to be deliberate attempts to resolve them. The two negative, *un*resolved process conflicts that preceded within-discipline analogies were part of either a broader conflict including individuals not present or a cluster of other micro-conflicts. In the unresolved negative science conflict preceding within-discipline analogy, two separate analogies occurred in the subsequent block and were both related to the general topic of the conflict (see Table A2).

3.4.3. Conflict to analogy summary

Process and negative conflicts were significantly more likely to precede within-discipline analogies, but no other pattern emerged. This relationship was not due to those analogies helping to resolve conflicts immediately. Not only was the overall rate of analogies used to resolve conflicts quite low, but qualitative examination of the particular pairs revealed that the analogies did not serve a resolution function for those conflicts. While these findings refute H3 (analogies will aid in the resolution of conflicts), there was support for H2 in that process conflicts significantly preceded within-discipline analogies, and H4, such that negative conflicts also significantly preceded within-discipline analogies.

4. Discussion

This study contributed to the literature on intra-team processes by unpacking the 'black box' of interdisciplinary team problem-solving conversations in real-world field data at a detailed level. Analogy and conflict, never before tested as interacting, are each central process variables within two disparate literatures that seek to understand and optimize team innovation. Focusing first on the analogy to conflict connection, we found that within-domain analogies significantly preceded science and work process conflicts. Because both within-domain and within-discipline analogies were more likely to be persuasive, deep, and problem-related compared to outside-discipline analogies, this finding cannot simply be due to these features of within-domain analogies. It is possible that there are more subtle differences between within-domain and within-discipline analogies, such as the degree to which the analogy embodied a shared, implicit explanation versus was easy to refute, or emphasized similarities in features vs. underlying processes that produced the features. The conflict–analogy finding was sometimes due to disagreements about the analogies themselves, but in the majority of the cases, the analogy indirectly led to the conflict. By voicing an analogy, a conflict in underlying assumptions was revealed. When individuals from different disciplines discuss their shared domain, they are approaching it from different perspectives.[4] This finding provides tentative support to our hypothesis that conflicts preceded by analogies, in the context of multidisciplinary teams, may be due to differences in underlying mental models in what should be a shared domain. Within-domain analogies are more likely to be within multiple team members' perceived area of expertise than within-discipline analogies, and thus perhaps more open to overt challenges.

Considering the reverse direction, work process conflicts and negative conflicts significantly preceded within-discipline analogies. We initially suggested that analogies with greater distance (within-discipline and outside-discipline rather than within-domain) would result from task micro-conflicts because of their power to encourage individuals to consider multiple perspectives. However, only process conflict was significantly predictive of analogies. In addition, it was within-discipline analogies rather than outside-discipline analogies that saw a post-conflict increase. The outside-discipline analogies tended to be less involved in problem solving/prediction and persuasion; Rather, outside-discipline analogies were often used in this sample for description (e.g., noting that certain microscopic geological features looked like cranberries), similar to Dunbar's (1997) finding. Process conflicts were not significantly more negative than task conflicts, particularly rover planning conflicts, yet both process and negative conflicts were predictive of increases in analogizing. These types of conflicts may have different mediating reasons for significantly preceded within-discipline analogies.

Why wasn't this effect on analogies present for task conflict? A possible explanation is that process conflicts may be more contentious than task conflicts, such that the desire to correct the other's assumptions is stronger (albeit not more negative), resulting in a greater desire for explanation. Perhaps process conflicts lead individuals to want to assert power, which can be done indirectly

[4] Because the majority of the conversations involved three or more individuals (57%) versus dyads (43%) and came from the genuinely multidisciplinary long term planning workstation area (93%), the use of analogies is unlikely to be due to disciplinary homogeneity versus heterogeneity of analogy sender/receiver pairs.

through displaying disciplinary knowledge, as in the case of within-discipline analogies. By contrast, task conflict may be more about knowledge and genuine differences in perceptions of the task than about jockeying for power, and relevant within-discipline analogies may not spring to mind or may not be perceived as persuasive regarding the knowledge given a lack of shared knowledge among discussants.

Dissonance theory would suggest that negative micro-conflicts would be likely to lead to attempts to resolve the conflict. The within-discipline analogies were certainly relevant to the topic at hand, albeit not direct attempts to resolve the specific negative micro-conflicts, suggesting that the negativity generated by group-based disagreement did motivate participants—but perhaps to engage multiple perspectives, as suggested by the minority influence research, rather than simply to resolve the disagreement immediately. Resolution is not the only dissonance-reduction strategy.

4.1. Theoretical implications

This study has implications for the development of theory regarding both analogy and conflict in team problem solving. Some analogy researchers have emphasized the importance of between-domain analogies in scientific discovery (Gentner et al., 1997), whereas others have argued that scientific discovery depends more on within-domain analogies (Dunbar, 1995). Our work suggests that outside-discipline analogies sometimes do participate in the reasoning of large discoveries, but not to the degree that within-domain and within-discipline analogies do. Separate analyses using this dataset found that analogy may also serve to reduce uncertainty (Chan, Paletz, & Schunn, 2012). Furthermore, within-domain analogies have a newly discovered consequence: They also precede and possibly lead to more process and science micro-conflicts, suggesting that there are meaningful differences between within-domain and within-discipline analogies, a distinction that has rarely been made in the literature. In our sample, both types of analogy were similarly likely to be persuasive, deep, and problem-related. But, within-domain was more likely to generate certain kinds of conflict in the context of multidisciplinary teams, whereas within-discipline was more likely to follow certain kinds of conflict.

These findings also suggest a micro-challenge to typical theorizing about intra-team conflict. Although prior theory on conflict predicts that negative macro-conflicts hurt performance, here negative micro-conflicts spurred analogies, and analogies are often associated with greater team problem solving. In this study, it was dissonance theory rather than conflict theory that was predictive, suggesting that different theoretical perspectives may apply at different levels and lengths of conflict. Also, different kinds of negative affect may have different effects: In Chiu's (2008) research, rude disagreements resulted in less micro-creativity, but if a wrong idea was raised, rude rather than polite disagreements raised teammate micro-creativity. In our study, negative affect was generally composed of irritation, mild anger, and cognitive dissonance, types of negative affect that are associated with approach motivational tendencies (Harmon-Jones, 2004). Activating and promotion-focused emotions are thought to lead to more creativity (Baas, De Dreu, & Nijstad, 2008).

That process micro-conflicts significantly preceded analogies, but task conflicts did not, suggests process micro-conflicts should be examined in more detail, and that task micro-conflicts may not be as powerful as on the macro level. Rather than simply examine relationship versus task conflict as is most commonly done (see De Dreu & Weingart, 2003), process conflict may be a rich topic of study at the micro-level (see Goncalo, Polman, & Maslach, 2010; Greer et al., 2008 for discussions of process conflict at the macro level). In addition, the typical conflict types should distinguish between work process and task planning, given that different relationships with analogies were found for these two types.

Finally, furthering theory on both analogy and conflict, the current work points to the value of jointly considering cognitive and social variables to understand their roles in creativity, discovery, and innovation. The literature on analogy in problem solving focuses on knowledge transfer (from one domain to another) as the causal function of analogy. This explanation, in essence, stays entirely within the cognitive realm. The current work, examining analogical reasoning in groups, suggests social elements may be involved in the consequences and precursors of analogical reasoning. Similarly, the current work suggests that analogy is relevant to understanding the effects of small conflicts. However, additional work is required to understand whether the effects of these evoked analogies are more cognitive in function (e.g., knowledge sharing, memory retrieval) or more social in function (e.g., persuasion).

4.2. Conclusion

The examination of real-world behavior is important for psychology (Baumeister et al., 2007). Surveying macro-level conflicts is insufficient for examining immediate consequences and antecedents with cognitive variables such as analogy. Similarly, a more nuanced view of analogy that explicitly studies the impact of social variables within naturalistic team conversations can be fruitful. In studying micro-behaviors of real teams having real, problem-solving discussions, we follow in the tradition of other areas of interpersonal research, such as facial expression and emotion (e.g., Ekman, 1993), negotiation (e.g., Weingart, Hyder, & Prietula, 1996), romantic relationships (e.g., Gottman & Levenson, 2000), and of course team cognition and problem solving (e.g., Chiu, 2008; Christensen & Schunn, 2007, 2009; Dunbar, 1995, 1997; Hutchins, 1995). Additional research on team creativity could also examine the ebb and flow of creativity in real teams. In terms of practical applications, analogy may be a useful tool for promoting innovation (Markman & Wood, 2009). But, if within-domain analogies precede conflict, encouraging analogy use may necessitate the teaching of conflict resolution and/or tolerance techniques.

This exploratory study suggests that analogy and conflict may co-occur in problem-solving conversations such that specific kinds of analogies in problem solving precede and perhaps lead to certain kinds of conflict, and vice versa. These nuanced results show the importance for future work to continue to understand detailed processes that occur in team innovation, linking social and cognitive literatures. By bridging sub-disciplines of psychology and using thorough behavioral methods, it becomes possible for researchers to unpack team processes in new ways.

Acknowledgements

Susannah Paletz and Christian Schunn are at the Learning Research and Development Center and Kevin Kim is in the School of Education at the University of Pittsburgh. This research was supported in part by National Science Foundation Grants #SBE-0830210 and #SBE-1064083 through the Science of Science and Innovation Policy Program. The authors are grateful to Alonso Vera, Irene Tollinger, Preston Tollinger, Mike McCurdy, Tyler Klein, Lauren Gunn, Julia Cocchia, Carl Fenderson, Justin Krill, Kerry Glassman, and Carmela Rizzo for assistance on this project. Findings from this study have been presented in part at the Annual Meetings of the Academy of Management in 2010 and 2011, as well as at the 5th Annual Conference of the Interdisciplinary Network for Group Research in 2010.

Appendix A

See Tables A1 and A2.

Table A1
Shortened examples of within-domain analogies (in italics) leading to micro-conflict (most key words underlined).

Within-domain analogies leading to science micro-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 micro-conflict (Note: naming schemes were important: The team of 100+ scientists needed to keep the terminology across reports, presentations, and scientific articles consistent.)
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 A2
Shortened examples of process conflicts and negative conflicts (most key words underlined) leading to within-discipline analogies (in italics).

Process conflict (neutral, resolved) leading to within-discipline analogy
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.
Negative conflict (science, not resolved) leading to within-discipline analogies
S2: We need to find what's underneath the rock. I mean, it won't… But the more of those we find that had nothing to do with water underneath this basalt, The more convinced we can make the case that this wasn't a lake. S1: But I still, I still don't think we have enough evidence Evidence that this isn't a flood plain or a <missing words>. It's just… <S2 missing words> No, no, no. Even a, even a… S2: Oh, like S1: A sedimentary, catastrophic large blocks of basalt. I mean <missing words>, if the water's fast, I mean. S2: We haven't seen, there's a lot of geomorphic science of catastrophic plate that we're not fully seeing. S1: Well, maybe catastrophic it's… S2: It'd have to be, to get in all of that muddy <missing word> Scattering these big chunks up close. S1: Hmph. Well, maybe the ripples are the stuff that's carrying everything So that you can get the fine grained Aeolians stuff being carried down And it's, you don't have enough water And it just kinda builds up in between. I mean, I wonder, I figure how much of it is trapped. S2: <missing words> S1: …But, but there are, there are specific experiments of <missing words> Looking at the details of the transport grain size is, I mean it's not sexy stuff. It's, it's tedious boring stuff. But that's where a lot of the things that we're going to learn in five or six years are going to come from. S2: …So far all that I see that's really convincing is that it's totally turned into rapid <missing word> very honestly, and it's not

and there's a big dark streak of material and the dark streak is <missing word> crescent
and what's in the crater.
Other than that it's pretty much the same to me.
I, I wouldn't be surprised
If the area that we're in was an impact garden before that crater
And so it's *just like impacting into a rubble pile*
And you just get more rubble, you know. . ..
S1: Alright.
S2: That's.
S1: I mean, to be honest with you all Mars is right now,
and I think the reasons that <missing words> has worked so much,
like they've done so much more erosion
because the materials that <missing word> are really incompetent.
Therefore you get the appearance of a lot greater erosion.
S2: That's true.
S1: And that's what they're seeing up at the eyeball area
Where they are forming these, *these delluvial features that look a lot like valley networks*[b] but with tiny amounts of water.
And you can get larger things moving just by carrying away the smaller stuff on their own and all down hill.

Negative, process micro-conflict leading to within-discipline analogy

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 [Science Operations Working Group Meeting] 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.
[b] This analogy is within-discipline because valley networks are features on Earth.

References

Amason, A. (1996). Distinguishing the effects of functional and dysfunctional conflict on strategic decision making: Resolving a paradox for top management teams. *Academy of Management Journal, 39*, 123–148.

Baas, M., De Dreu, C. K. W., & Nijstad, B. A. (2008). A meta-analysis of 25 years of mood-creativity research: Hedonic tone, activation, or regulatory focus? *Psychological Bulletin, 134*, 779–806.

Ball, L. J., & Christensen, B. T. (2009). Analogical reasoning and mental simulation in design: Two strategies linked to uncertainty reduction. *Design Studies, 20*, 169–186.

Ball, L. J., Ormerod, T. C., & Morley, N. J. (2004). Spontaneous analogising in engineering design: A comparative analysis of experts and novices. *Design Studies, 25*, 495–508.

Barki, H., & Hartwick, J. (2004). Conceptualizing the construct of interpersonal conflict. *International Journal of Conflict Management, 15*, 216–244.

Baumeister, R. F., Vohs, K. D., & Funder, D. C. (2007). Psychology as the science of self-reports and finger movements: What happened to actual behavior? *Perspectives on Psychological Science, 2*, 396–403.

Bearman, C. R., Ball, L. J., & Ormerod, T. C. (2007). The structure and function of spontaneous analogizing in domain-based problem solving. *Thinking & Reasoning, 13*, 273–294.

Bearman, C. R., Paletz, S. B. F., Orasanu, J., & Thomas, M. J. W. (2010). The breakdown of coordinated decision making in distributed systems. *Human Factors, 52*, 173–188.

Blanchette, I., & Dunbar, K. (2001). Analogy use in naturalistic settings: The influence of audience, emotion, and goals. *Memory & Cognition, 29*, 730–735.

Chan, J., Fu, K., Schunn, C. D., Cagan, J., Wood, K., & Kotovsky, K. (2011). On the benefits and pitfalls of analogies for innovative design: Ideation performance based on analogical distance, commonness, and modality of examples. *Journal of Mechanical Design, 133*, 081004-1–081004-11.

Chan, J., Paletz, S. B. F., & Schunn, C. D. (2012). Analogy as a strategy for supporting complex problem solving under uncertainty. *Memory & Cognition*. http://dx.doi.org/10.3758/s13421-012-0227-z (online first).

Chi, M. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *Journal of the Learning Sciences, 6*, 271–315.

Chiu, M. M. (2008). Effects of argumentation on group micro-creativity: Statistical discourse analysis of algebra students' collaborative problem solving. *Contemporary Educational Psychology, 33*, 382–402.

Christensen, B. T., & Schunn, C. D. (2007). The relationship of analogical distance to analogical function and preinventive structure: The case of engineering design. *Memory & Cognition, 35*, 29–38.

Christensen, B. T., & Schunn, C. D. (2009). The role and impact of mental simulation in design. *Applied Cognitive Psychology, 23*, 327–344.

Cronin, M. A., & Weingart, L. R. (2007). Representational gaps, information processing, and conflict in functionally diverse teams. *Academy of Management Review, 32*, 761–773.

Dahl, D. W., & Moreau, P. (2002). The influence and value of analogical thinking during new product ideation. *Journal of Marketing Research, 39*, 47–60.

De Dreu, C. K. W., & Weingart, L. R. (2003). Task versus relationship conflict, team performance, and team member satisfaction: A meta-analysis. *Journal of Applied Psychology, 88*, 741–749.

De Dreu, C. K. W., & West, M. A. (2001). Minority dissent and team innovation: The importance of participation in decision making. *Journal of Applied Psychology, 86*, 1191–1201.

Dunbar, K., & Blanchette, I. (2001). The *in vivo*/*in vitro* approach to cognition: The case of analogy. *Trends in Cognitive Sciences, 5*, 334–339.

Dunbar, K. (1995). How scientists really reason: Scientific reasoning in real-world laboratories. In R. J. Sternberg & J. E. Davidson (Eds.), *The nature of insight* (pp. 365–395). Cambridge, MA: The MIT Press.

Dunbar, K. (1997). How scientists think: On-line creativity and conceptual change in science. In T. B. Ward, S. M. Smith, & J. Vaid (Eds.), *Creative thought: An investigation of conceptual structures and processes* (pp. 461–493). Washington, DC: American Psychological Association.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48*, 384–392.

Elliot, A. J., & Devine, P. G. (1994). On the motivational nature of cognitive dissonance: Dissonance as psychological discomfort. *Journal of Personality and Social Psychology, 67*, 382–394.

Ericsson, K., & Simon, H. (1993). *Protocol analysis: Verbal reports as data* (2nd ed.). Boston: MIT Press.

Forbus, K. D., Gentner, D., & Law, K. (1995). MAC/FAC: A model of similarity-based retrieval. *Cognitive Science, 19*, 141–205.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*, 155–170.

Gentner, D., Brem, S., Ferguson, R. W., Markman, A. B., Levidow, B. B., Wolff, P., et al. (1997). Analogical reasoning and conceptual change: A case study of Johannes Kepler. *Journal of the Learning Sciences, 6*, 3–40.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52*, 45–56.

Goncalo, J. A., Polman, E., & Maslach, C. (2010). Can confidence come too soon? Collective efficacy, conflict and group performance over time. *Organizational Behavior and Human Decision Processes, 113*, 13–24.

Gottman, J. M., & Levenson, R. W. (2000). The timing of divorce: Predicting when a couple will divorce over a 14-year period. *Journal of Marriage and the Family, 62*, 927–947.

Gottman, J. M., & Notarius, C. I. (2000). Decade review: Observing marital interaction. *Journal of Marriage and the Family, 62*, 927–947.

Greer, L. L., Jehn, K. A., & Mannix, E. A. (2008). Conflict transformation: A longitudinal investigation of the relationships between different types of intragroup conflict and the moderating role of conflict resolution. *Small Group Research, 39*, 278–302.

Harmon-Jones, E. (2000). Cognitive dissonance and experienced negative affect: Evidence that dissonance increases experienced negative affect even in the absence of aversive consequences. *Personality and Social Psychological Bulletin, 26*, 1490–1501.

Harmon-Jones, E. (2004). Contributions from research on anger and cognitive dissonance to understanding the motivational functions of asymmetrical frontal brain activity. *Biological Psychology, 67*, 51–76.

Holyoak, K. J., Lee, H. S., & Lu, H. (2010). Analogical and category-based inference: A theoretical integration with Bayesian causal models. *Journal of Experimental Psychology: General, 139*, 702–727.

Holyoak, K. J., & Thagard, P. (1997). The analogical mind. *American Psychologist, 52*, 35–44.

Hume, D. (1960). *A treatise of human nature*. Oxford: Clarendon Press (original work published in 1739).

Hutchins, E. (1995). How a cockpit remembers its speeds. *Cognitive Science, 19*, 265–288.

Ilgen, D. R., Hollenbeck, J. R., Johnson, M., & Jundt, D. (2005). Teams in organizations: From input-process-output models to IMOI models. *Annual Review of Psychology, 56*, 517–543.

Jehn, K. A. (1995). A mulitmethod examination of the benefits and detriments of intragroup conflict. *Administrative Science Quarterly, 40*, 256–282.

Jehn, K. A. (1997). A qualitative analysis of conflict types and dimensions in organizational groups. *Administrative Science Quarterly, 42*, 530–557.

Jehn, K. A., & Bendersky, C. (2003). Intragroup conflict in organizations: A contingency perspective on the conflict-outcome relationship. *Research in Organizational Behavior, 25*, 187–242.

Jehn, K. A., & Chatman, J. A. (2000). The influence of proportional and perceptual conflict composition on team performance. *International Journal of Conflict Management, 11*, 56–73.

Jehn, K. A., & Mannix, E. A. (2001). The dynamic nature of conflict: A longitudinal study of intragroup conflict and group performance. *Academy of Management Journal, 44*, 238–251.

Jehn, K. A., Northcraft, G. B., & Neale, M. A. (1999). Why differences make a difference. A field study of diversity, conflict, and performance in workgroups. *Administrative Science Quarterly, 44*, 741–763.

Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics, 33*, 159–174.

Levine, J. M., & Moreland, R. L. (1998). Small groups. In D. T. Gilbert, S. T. Fiske, & G. Lindzey (Eds.), *The handbook of social psychology* (Vol. 2, 4th ed., pp. 415–469). Boston: McGraw-Hill.

Loewenstein, J., Thompson, L., & Gentner, D. (2003). Analogical learning in negotiation teams: Comparing cases promotes learning and transfer. *Academy of Management Learning and Education, 2*, 119–127.

Mannes, A. E. (2008). An integrative solution to the conflict over conflict. In George T. Solomon (Ed.), *Proceedings of the 2008 annual meeting of the academy of management (CD)*. ISSN: 1543-8643.

Markman, A. B., & Wood, K. L. (2009). *Tools for innovation*. New York: Oxford University Press.

Martin, R., & Hewstone, M. (2008). Majority versus minority influence, message processing and attitude change: The source-context-elaboration model. *Advances in Experimental Social Psychology, 40*, 237–326.

Mathieu, J. E., Heffner, T. S., Goodwin, G. F., Salas, E., & Cannon-Bowers, J. A. (2000). The influence of shared mental models on team process and performance. *Journal of Applied Psychology, 85*, 273–283.

Matz, D. C., & Wood, W. (2005). Cognitive dissonance in groups: The consequences of disagreement. *Journal of Personality and Social Psychology, 88*, 22–37.

Mohammed, S., Ferzandi, L., & Hamilton, K. (2010). Metaphor no more: A 15-year review of the team mental model construct. *Journal of Management, 36*, 876–910.

Nemeth, C. J. (1986). Differential contributions of majority and minority influence. *Psychological Review, 93*, 23–32.

Nersessian, N. J., & Chandrasekharan, S. (2009). Hybrid analogies in conceptual innovation in science. *Cognitive Systems Research, 10*, 178–188.

Nijstad, B. A., & Stroebe, W. (2006). How the group affects the mind: A cognitive model of idea generation in groups. *Personality and Social Psychology Review, 10*, 186–213.

Nisbett, R., & Wilson, T. (1977). Telling more than we can know: Verbal reports on mental processes. *Psychological Review, 84*, 231–259.

Novick, L. R. (1988). Analogical transfer, problem similarity, and expertise. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 510–520.

Okada, T., & Simon, H. A. (1997). Collaborative discovery in a scientific domain. *Cognitive Science, 21*, 109–146.

Paletz, S. B. F., & Schunn, C. D. (2010). A socio-cognitive framework of multidisciplinary team innovation. *Topics in Cognitive Science, 2*, 73–95.

Paletz, S. B. F., Schunn, C. D., & Kim, K. H. (2011). Conflict under the microscope: Micro-conflicts in naturalistic team discussions. *Negotiation and Conflict Management Research, 4*, 314–351.

Pelled, L. H., Eisenhardt, K. M., & Xin, K. R. (1999). Exploring the black box: An analysis of work group diversity, conflict, and performance. *Administrative Science Quarterly, 44*, 1–28.

Peterson, R. S., & Nemeth, C. J. (1996). Focus versus flexibility: Majority and minority influence can both improve performance. *Personality and Social Psychology Bulletin, 22*, 14–23.

Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical linear models: Applications and data analysis methods* (2nd ed.). Newbury Park, CA: Sage.

Richland, L. E., Zur, O., & Holyoak, K. (2007). Cognitive supports for analogies in the mathematics classroom. *Science, 316*, 1128–1129.

Rollins, E. (2010, December 1). Palin, I knew Reagan. You're no Reagan. In: *CNN opinion*. <http://www.cnn.com/2010/OPINION/12/01/rollins.palin/> Retrieved 21.12.10.

Sawyer, R. K. (2006). *Explaining creativity: The science of human innovation*. New York: Oxford University Press.

Schwarz, G. (2010, November 28). Political ticker: McCain compares Palin to Reagan. In: *CNN politics*. <http://politicalticker.blogs.cnn.com/2010/11/28/mccain-compares-palin-to-reagan/> Retrieved 21.12.10.

Squyres, S. (2005). *Roving Mars: Spirit, opportunity, and the exploration of the red planet*. New York: Hyperion.

Thagard, P., & Shelley, C. (2001). Emotional analogies and analogical inference. In D. Gentner, K. H. Holyoak, & B. K. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science* (pp. 335–362). Cambridge, MA: MIT Press.

van Knippenberg, D., & Schippers, M. C. (2007). Work group diversity. *Annual Review of Psychology, 58*, 515–541.

Vuchinich, S. (1987). Starting and stopping spontaneous family conflicts. *Journal of Marriage and the Family, 49*, 591–601.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*, 1063–1070.

Weingart, L., Hyder, E. B., & Prietula, M. J. (1996). Knowledge matters: The effect of tactical descriptions on negotiation behavior and outcome. *Journal of Personality and Social Psychology, 70*, 1205–1217.

Weingart, L. R., Todorova, G., & Cronin, M. A. (2010). Task conflict, problem-solving, and yielding: Effects on cognition and performance in functionally diverse innovation teams. *Negotiation and Conflict Management Research, 3*, 312–337.

West, M. A. (2002). Sparkling fountains or stagnant ponds: An integrative model of creativity and innovation implementation in work groups. *Applied Psychology: An International Review, 51*, 355–424.

West, M. A., & Farr, J. L. (1990). Innovation at work. In M. A. West & J. L. Farr (Eds.), *Innovation and creativity at work: Psychological and organizational strategies* (pp. 3–13). Chichester, England: John Wiley & Sons.

Whaley, B. B., & Holloway, R. L. (1997). Rebuttal analogy in political communication: Argument and attack in sound bite. *Political Communication, 14*, 293–305.

Young, K. M., & Leinhardt, G. (1998). Wildflowers, sheep, and democracy: The role of analogy in the teaching and learning of history. In J. G. Voss & M. Carretero (Eds.), *International review of history education. Learning and reasoning in history* (Vol. 2, pp. 154–196). London: Woburn Press.