Uncovering Uncertainty through Disagreement

Keywords: Teams, Disagreement, Uncertainty, Conflict, Team problem solving

Abstract

This study explored the association between different types of brief disagreements and subsequent levels of expressed psychological uncertainty, a fundamental cognitive aspect of complex problem solving. We examined eleven hours (11,861 utterances) of conversations in expert science teams, sampled across the first 90 days of the Mars Exploration Rover mission. Utterances were independently coded for micro-conflicts and expressed psychological uncertainty. Using time-lagged hierarchical linear modeling applied to blocks of 25 utterances, we found that micro-conflicts regarding rover planning were followed by greater uncertainty. Brief disagreements about science issues were followed by an increase in expressed uncertainty early in the mission. Examining the potential reverse temporal association, uncertainty actually predicted fewer subsequent disagreements, ruling out indirect, third variable associations of conflict and uncertainty. Overall, these findings suggest that some forms of disagreement may serve to uncover important areas of uncertainty in complex teamwork, perhaps via revealing differences in mental models.

Introduction

The most important scientific and technological advances are increasingly being produced by teams (Jones, 2009; Singh & Fleming, 2009; Wuchty, Jones, & Uzzi, 2007). Organizations are also looking to interdisciplinary teams to address especially difficult global problems (Beck, 2013; Derry, Schunn, & Gernsbacher, 2005). However, interdisciplinary teams have challenges: They must communicate across unshared norms and mental models, which may result in disagreement and gaps in understanding (Paletz & Schunn, 2010). Furthermore, real-world problems are notable for their high levels of uncertainty. Problem solving with complex, ill-defined problems often depends on significant effort devoted to the detection and resolution of uncertainty (Schunn & Trafton, 2012): Detection strategies are necessary to identify what is unknown (either because information is missing or because presented information is misleading), and resolution of the uncertainty is important for ultimately solving the complex problem.

This project studies how real-world science teams deal with uncertainty in problem solving. By taking a micro-process approach, this study examines how and whether brief intrateam disagreements can help teams detect uncertainty, and then compares the association between disagreements and subsequent uncertainty in conversations at two different time phases within a team's life. The past few decades have seen an increased interest in examining how teams' problem solving processes unfold over time (Cronin, Weingart, & Todorova, 2011; Kurtzberg & Mueller, 2005; McGrath, 1991; McGrath & Tschan, 2004). At the most micro-temporal level (at the time scale of seconds), brief speech acts, such as disagreement, may cumulate to have large effects on subsequent communication and cognition (e.g., Chiu, 2008a, 2008b; Paletz, Schunn, & Kim, 2013).

Uncertainty

Research in cognitive psychology has revealed that uncertainty is a central aspect of complex problem solving (for a review, see Schunn & Trafton, 2012). Psychological uncertainty is the recognition or feeling of missing, vague, or incomplete information (Schunn, 2010). Uncertainty is ubiquitous within and central to real-world problem solving, including science and engineering, management, medicine, and education (Kahneman & Tversky, 1982; Schunn, 2010). The research field of naturalistic decision making unpacks individual and team judgment in uncertain situations such as aviation (e.g., Bearman, Paletz, Orasanu, & Thomas, 2010; Klein, 1989). Indeed, one of the main differences between real-world and experimental tasks is the level of uncertainty, as well as uncertainty *about* uncertainty, in real-world tasks (Chinn & Malholtra, 2002; Kirschenbaum, Trafton, & Schunn, 2014; Schunn & Trafton, 2012).

Across real-world domains, problem-solving success depends on the effective detection, understanding, and resolution of uncertainty (Chan, Paletz, & Schunn, 2012; Downey & Slocum, 1975; Kahneman & Tversky, 1982; Schunn, 2010; Schunn & Trafton, 2012). For example, product development leaders have to deal with design uncertainties, while doctors have to deal with uncertainties regarding the true causes or diseases associated with a group of symptoms. People productively deal with task-related uncertainty in many ways (Jordan & Babrow, 2013; Lipshitz & Strauss, 1997; Schunn & Trafton, 2012), especially by taking it into account in decisions (e.g., avoiding irreversible action, explicitly noting confidence levels), communicating directly about uncertainty, or by reducing uncertainty through additional problem solving (e.g., collecting additional information, making analogies; Chan et al., 2012).

Although the importance of the resolution of uncertainty is obvious to problem solving, uncertainty *detection* is also important. Initial diagnostic certainty can be correct or incorrect. If incorrect, raising uncertainty about the initial idea will enable the re-examination of data and encourage information search. Indeed, past literature suggests that individuals are often bad at articulating their assumptions and identifying genuine uncertainties, especially in complex situations (Dunbar, 1997; Evans, 1989; Gorman, 1986). Uncertainty is also important in the earliest stages of problem solving. Problem *finding*, or how a problem is initially discovered and structured, is a vital precursor to problem solving (Mumford, Reiter-Palmon, & Redmond, 1994; Paletz & Peng, 2009), especially in ill-defined domains where uncertainty abounds (Runco, 1994; Runco & Nemiro, 1994). Put simply, teams and individuals need to know what they don't know in order to move forward and innovate.

Conflict

Researchers from different fields have examined conflict in many different forms, from violent acts perpetrated on behalf of nations to conflicts within oneself. We examine conflict as disagreements between individuals within teams, drawing from a tradition within social and organizational psychology (Barki & Hartwick, 2004). Teams are collections of individuals that perform interdependent tasks that affect others, are embedded in a larger social system, and perceive themselves, and are perceived by others, as a social entity (Guzzo & Dickson, 1996). Intrateam conflict can vary in its focus, length, and intensity, and these variations can change the effects of conflict on team processes (Paletz, Schunn, & Kim, 2011; Todorova, Bear, & Weingart, 2013; Weingart, Behfar, Bendersky, Todorova, & Jehn, 2014). Under certain conditions, conflict has the potential to increase creativity (e.g., Chiu, 2008a; Nemeth, 1986; Nemeth, Personnaz, Personnaz, & Goncalo, 2004; Paletz, Miron-Spektor, & Lin, 2014). However, it can also hinder creativity, including when the conflict is only observed by another (Miron-Spektor, Efrat-Treister, Rafaeli, & Schwartz-Cohen, 2011).

This study focuses on micro-conflicts, or brief, expressed disagreements, in order to unpack and illuminate team processes in detail. Prior research on micro-conflicts has examined complex interaction patterns and conflict management (e.g., Kuhn & Poole, 2000; Poole & Dobosh, 2010), affective conflict interactions within families or married couples (e.g., Gottman & Notarius, 2000; Vuchinich, 1987), and the immediate effects of brief disagreements on creativity, problem-solving, and analogy (e.g., Chiu, 2008a, 2008b; Paletz, Schunn, et al., 2013).

Intragroup conflict researchers distinguish between task conflict, or disagreements about the work being performed; process conflict, or *how* to go about doing the task (e.g., prioritization, scheduling); and relationship conflict, which is about personal issues (e.g., Barki & Hartwick, 2004; De Dreu & Weingart, 2003; Jehn, 1995; 1997). Relationship conflict is generally thought to be harmful (e.g., Amason, 1996; De Dreu & Weingart, 2003; He, Ding, & Yang, 2014; Jehn, 1997; de Wit et al., 2012; de Wit, Jehn, & Scheppers, 2013). Process conflict is also generally thought to be problematic (e.g., De Dreu & Weingart, 2003), but how destructive it is may depend on when it comes during the team's process (e.g., Goncalo, Polman, & Maslach, 2010). Task conflict is now thought to have a curvilinear effect on performance on intellectual tasks (creativity, Farh, Lee, & Farh, 2010; decision quality, Parayitam & Dooley, 2011). These studies suggest that moderate levels of task conflict are best for team outcomes.

In addition, the dynamics and implications of conflict may vary across a team's lifecycle. Conflict occurs throughout the life of a team, but it may be more common during early phases of a team's lifecycle (Paletz et al., 2011; Poole & Garner, 2006). Conflict earlier in the team's life may be functional, helping set up processes and tasks: Early process conflict may help forestall premature collective efficacy, leading to better team performance later (Goncalo, et al., 2010).

Most research on work teams examines conflict using retrospective self-report surveys (e.g., De Dreu & Weingart, 2003; Fahr et al., 2010; Greer, Jehn, & Mannix, 2008; Parayitam & Dooley, 2011; Shaw, Zhu, Duffy, Scott, Shih, & Susanto, 2011). However, self-report surveys or interviews fail to capture phenomena that require exact recall and are too fast or complex to be noticed by participants (Goh, Goodman, & Weingart, 2013; Gottman & Notarius, 2000; Weingart, 1997). Retrospection is often inaccurate, and confidence about memories may be unrelated to accuracy (e.g., Chua, Hannula, & Ranganath, 2012; Wong, Cramer, & Gallo, 2012). Further, surveys lose the fine-grained temporal structure of communication processes that occur during conversations. For example, micro-process research has found that polite disagreements are positively associated with micro-creativity (Chiu, 2008a) and subsequent correct contributions (Chiu, 2008b), whereas rude disagreements after a wrong idea can *increase* teammate creativity (Chiu, 2008a).

This current study follows this growing interest in examining the *immediate* consequences of disagreement, or micro-conflicts, on team processes (e.g., Chiu, 2008a, 2008b; Kauffeld & Lehmann-Willenbrock, 2012; Paletz, Schunn, et al., 2013). We examine individual utterances for the presence of disagreement, and then aggregate them into micro-conflict events.

Conflict and Subsequent Uncertainty

We embed our research questions within shared mental models theory to propose that expressed micro-conflicts, or brief disagreements (Paletz et al., 2011) may influence subsequent uncertainty, depending on the type of conflict and phase of the team's lifecycle. One aspect of teams as they develop is the creation of shared mental models (e.g., Burke, Stagl, Salas, Peirce, & Kendall, 2006; Johnson-Laird, 1980; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000). Shared mental models are the similarity in cognitive schemas regarding teamwork, norms, and tasks. They are important for effective plan execution and timely problem solving, among other team functions (e.g., Burke et al., 2006; Jones, Stevens, & Fischer, 2000).

Interdisciplinary work is often fraught with conflict, as individuals with different backgrounds, skills, and perspectives are brought together (Mannix & Neale, 2005; Paletz & Schunn, 2010). Conflict may be caused by underlying differences in shared mental models (Bearman, et al., 2010; Cronin & Weingart, 2007). Disagreement is generally expressed because an individual thinks or feels something contradictory to what was just said or implied. Indeed, disagreement can enable team members to hear previously unshared information from team members' different mental models.

On the one hand, additional information gained via conflict can decrease team uncertainty. Gathering additional information is, after all, an uncertainty reduction technique (Lipshitz & Strauss, 1997; Schunn & Trafton, 2012). Members of multidisciplinary teams may have information that resolves others' uncertainty. New information uncovered via conflict may enable team members to update their mental models and create new certainties.

On the other hand, the non-overlapping mental models that arise from interdisciplinary teams also may increase uncertainty. Individuals may not see ambiguity or errors in their own thinking that are then noticed by other scientists (Dama & Dunbar, 1996). Particularly in multidisciplinary contexts, a disagreement may raise and question underlying assumptions held by other members of the team, leaving previously (supposedly) known information to be suddenly up for debate. A period of uncertainty may then occur when mental models incorrectly thought to be shared are reassessed and re-formed.

Team context may affect whether disagreement decreases subsequent uncertainty or not. In this study, we focus on temporal context (early versus later time periods in a team's planned lifecycle), a contextual factor that seems especially likely to interact with team conflict and uncertainty. Teams often go through iterative cycles of sorting out their processes, self-evaluation, and focusing on the work (Gersick, 1988; Morgan, Salas, & Glickman, 1994; Tuckman, 1965; Tuckman & Jensen, 1977). Early in a team's lifecycle, there is more uncertainty and conflict, as processes are established and iterated (e.g., Poole & Garner, 2006; Paletz et al., 2011; Tuckman & Jensen, 1977). In other words, early on, the members are formulating their shared mental models of their tasks and processes. During this phase, disagreement may lead to *more* uncertainty. Later in a team's lifecycle, disagreements are less likely to reveal unknown, major underlying differences in assumptions and mental models. Thus, there may be different relations between conflict and uncertainty early on, when everything is in flux and being established, versus later in the team's lifecycle.

Finally, different types of conflict may have different effects on uncertainty, just as they have different impacts on team success (De Wit et al, 2012). Task conflict is most relevant to exposing gaps in mental models about the task, and thus most likely to be related to subsequent uncertainty. But process conflict may also reveal gaps, if perhaps more indirectly. For example, because mental models about the task support specific processes, arguments about processes may encourage others to share task information about these particular processes. It is unclear whether relationship conflicts should have an effect on uncertainty, and these will not be a focus of this study for practical reasons (see below).

Research Questions

This research is one of a small number of studies to examine fine-grained temporal processes of conflict (e.g., Chiu, 2008a, 2008b; Paletz, Schunn, et al., 2013; Poole & Dobosh, 2010) and the first to examine the association between conflict and subsequent uncertainty. The prior literature reviewed above suggests an association is plausible, but the exact form is difficult to predict, and it is likely dependent on both the time phase in the group's life cycle and the type of conflict. Our research questions are:

Research Question 1: What is the association between the different types of expressed micro-conflicts and immediate, subsequent levels of uncertainty in speech?

Research Question 2: How might these relations differ during an early phase of a team's life cycle versus a later phase?

In addition, to further probe the nature of observed associations, we also examine whether the relations between micro-conflicts and subsequent uncertainty is bidirectional or potentially caused by a third factor. We accomplish this by testing for an association between uncertainty and subsequent micro-conflicts.

Methods

Research Context and Data Collection

Research context. This study examined informal, task-relevant conversations occurring between scientists working on the multidisciplinary Mars Exploration Rover (MER) mission (Squyres, 2005). The MER mission aimed to, and succeeded in, discovering evidence for a history of liquid water on Mars via sending two rovers to separate sides of the planet. The mission was initially scheduled to last 90 Martian days, and so the scientists spent those days working at the Jet Propulsion Laboratory with workstations and screens enabling collaboration. Each rover had its own, roughly independent science team (MER A and B), which was further broken up into different science subteams. The discovery of the history of liquid water involved geological and atmospheric science, complex task planning, and general human work processes.

Data collection. Data were collected on 20 data collection trips over the 90 initial mission days. Researchers placed video cameras on top of large shared screens near different subgroups' workstation clusters. Each trip involved three days of about eight hours of data collection each day, resulting in roughly 400 hours of video. The scientists became habituated to the cameras, at times discussing personal matters.

Data sampling and transcription. We sampled 11 hours and 25 minutes of informal, task-relevant conversation clips from days early and later in the nominal mission (first 90 days). Reflecting the common realities of complex work unfolding over long time scales and distributed over multiple physical workspaces, much of the 400 hours of video ended up recording individuals working in silence, empty chairs, and/or such poor audio-video that it could not be transcribed. We excluded structured meetings from the sample because they were conducted in a formal round-robin presentation style, with most participants simply listening to people talking off-screen. During the normal workday, scientists sitting at their workstations would strike up task-relevant conversations, and these would end (as clips) when the conversation stopped or the speakers moved away together (e.g., to get food). Task-relevant talk was defined as anything relating to the mission at all, including process, relational, and organizational issues (e.g., organizational struggles between subgroups), whereas off-task talk was defined as exclusively personal matters such as family vacations. While the larger MER project consisted of over 100 scientists, "sub-teams" of two to ten MER scientists assembled organically throughout the project. These sub-teams were most often task-focused, engaged in interdependent tasks, and had a shared social identity (as MER scientists). Because the sub-teams tended to be task-focused and fluid in number, rather than centrally planned, configurations of individuals often overlapped imperfectly between sub-team conversations (Paletz & Schunn, 2011). This study examined conversations from these sub-teams, which occurred in video clips, representing natural within-team, interpersonal conflicts and uncertainty as they arose. The overwhelming majority of the conversations sampled (93%) were inherently multidisciplinary, as they came from video of the Long Term Planning area, the location of a cross-disciplinary group that was the hub for different groups' conversations regarding future science activities.

The video clips were transcribed into 12,336 utterances, which were then 100% double-coded as to whether they were related to the MER mission at all (on-task) or not (Cohen's kappa = .96). On-task talk was defined in the same way as in our clip sampling strategy. Trained transcribers broke (unitized) the conversations into utterances during the course of transcription. Utterances were operationalized as thought statements or clauses and are thus often briefer than turns of talk (Chi, 1997). Our analyses are conducted on the resulting 11,861 on-task utterances (roughly 11 hours), coming from 114 clips that ranged from 8 to 760 utterances long (*M* = 104.0, *Median* = 66.5, *SD* = 121.8). Twenty-six percent of the video clips had a mix of male and female scientists, whereas 74% of video clips were all male. The number of speakers in the clip ranged from two to ten. These data have been previously analyzed to examine the nature of micro-conflicts (Paletz et al., 2011), the temporal relations between micro-conflicts and analogy (Paletz, Schunn, et al., 2013), and the association between analogy and uncertainty (Chan et al., 2012).

Measures

The primary variables for this study were: micro-conflicts and their types, psychological uncertainty, and temporal context. To reduce noise from the difficult coding task, both uncertainty and micro-conflicts were double-coded (100% overlap in assessment by two independent coders) with mismatches resolved through discussion (Smith, 2000). To remove the influence of cross category coding cues, each variable was coded by a different pair of independent coders. All coders were blind to the results of the other coding and also to the goals and questions of this study.

Temporal context: early versus later in the first 90 days of the mission. The scientists were relative novices to real-time Mars operations initially, but gained expertise dramatically over the first 90 days (Paletz, Kim, Schunn, Tollinger, & Vera, 2013). The mission was initially planned to be 90 Martian days long. We chose 50 days as our cut-off point to divide clips into earlier versus later in the mission because the initial few days of each mission involved tests regarding rover health. Also, the scientists experienced a dramatic speed-up of their scheduled science planning over the course of these 90 days: 51 days was when one of the rover teams decreased their scheduled shift (and planning time) from 6 hours to 4.5 hours (Paletz, Kim, et al., 2013; Tollinger, Schunn, & Vera, 2006). Early in the mission, the scientists were more likely to grapple with the mission processes. Indeed, process micro-conflicts were less likely during the second half of the mission (Paletz et al., 2011). Further, by the second half of the mission, not only were the scientists more practiced at running a mission on Mars, but they had discovered strong evidence of liquid water and had granted a news conference on the topic. Sixty-five percent (74) of the conversation clips were from before day 50 (early phase), and 35% (40) were drawn from after or on day 50 (days 50-90, later phase). Finer-grained temporal analyses were not possible: The sampling was uneven due to mission events intermittently disrupting data collection.

Micro-conflicts. We coded for micro-conflicts, or brief disagreements using a coding scheme detailed elsewhere for this sample (Paletz et al., 2011). This scheme involved assessing each utterance for the presence (1) or absence (0) of conflict, as contrasted with other schemes that code 30 second to one minute segments in their entirety (e.g., Poole, 1989, used in Poole & Dobosh, 2010) and those that involve coding by sentence into one of several exclusive categories, collectively capturing all types of team interactions (e.g., act4teams, used in Lehmann-Willenbrock, Meyers, Kauffeld, Neininger, & Henschel, 2011). Each utterance was flagged as containing a micro-conflict whenever a speaker explicitly disagreed with something said earlier in the conversational video clip. Simply stating something controversial was not sufficient, but supporting arguments were counted as conflict. The coders read the transcript and referred to the audio-video recording to resolve differences and to clarify what occurred, paying close attention to participants' body language, tone, and, when possible, facial expressions (conflict event kappa = .62). For example, a group of scientists were discussing the probable geological nature of a small area on Mars. One noted that they would be able to find out more by looking at an outcrop closely. A second scientist disagreed, saying, "but I think you gonna see, I think if it's there, you're gonna see it remotely anyway" (via viewing by satellites). The original scientist tried to explain his position, "I think the, uh, I mean the scale of detail," and the second scientist continued his argument with "no, I think, because up close—up close you're gonna see the broken, you know, jumble." The first disagreed, "nah, I think it's worse than that," and the second continued his thought, "if you can get it." At that point a third scientist laughed and said, "you're, you're, I think you're both wrong. The problem is from looking at it from just sort of across, I don't think you can see close enough to see the lamination." This example is reflective of the natural micro-conflicts from this sample: overlapping ideas, low affect, and spontaneous. All disagreements between coders were resolved by discussion, with a consensus code assigned to each utterance. The coding scheme was developed iteratively on this dataset, with nuances noted in the coding scheme and past clips recoded as necessary (Paletz et al., 2011).

The micro-conflicts were also coded by utterance for type of conflict, using categories described widely in the social and organizational conflict literature (*task*, *process*, and *relationship* conflict, e.g., Jehn, 1997). Because the MER context clearly distinguished between the two major work task types of science (e.g., data interpretation) and rover planning (e.g., which instrument readings to do), the coders assessed each conflict utterance as to whether the conflict was about science (task), rover planning (task), work process, or relationship matters (see Table 1 for examples). To reduce noise from reliability issues, the data were exhaustively double-coded, and discrepancies were resolved through discussion (Smith, 2000). These utterances were clustered into conflict events (and blocks made up of continuous conflict events, see below) based on specific topic: For instance, a specific process micro-conflict could then lead to another process conflict, another type of conflict, or no conflict at all. Expressed relationship conflict was too rare in this sample to be included in the analyses (only 3 of the 688 total blocks had relationship conflict); leaving out relationship conflict, the conflict type coding had a reliability kappa of .67 at the utterance level (up from .48 with relationship conflict included, likely because the rarity of relationship conflict decreased the overall kappa; Bakeman, Quera, McArthur, & Robinson, 1997).

Uncertainty. Two coders used a preexisting coding scheme to assess each utterance for the presence of uncertainty, using "hedge words" (e.g., "I guess," "I think," "possibly," "maybe," "I believe", detailed in Trickett, Trafton, Saner, and Schunn, 2007) as cues to potential uncertainty. All coder disagreements were resolved by discussion, with a consensus code assigned. The uncertainty coding in this dataset is described in more detail elsewhere, in a paper that found that problem-related analogies may serve an uncertainty-reduction function (Cohen's kappa = .75; Chan, et al., 2012; see Table 2 for examples).

Schunn (2010) established the validity of this measurement approach using convergent and discriminant validity methods. For example, use of these hedge words corresponded also to the use of uncertainty gestures in team conversations at the utterance level, well above base rates in the local temporal context (Schunn, 2010). Further, uncertainty and imprecision (purposeful approximations like 'thirtysomething') could be reliably separated in speech and gestures, and they had different relations to other cognitive processes (Schunn, 2010; Schunn, Saner, Kirschenbaum, Trafton, & Littleton, 2007).[1]

Both conflict and uncertainty were analyzed at the block level (i.e., aggregated across utterances). We describe our block creation approach in the subsequent section.

Analyses

Blocks and video clips. To unpack temporal patterns, we broke the video clips (conversations) into segmented blocks made up of continuous, multiple utterances. Intuitively, segmenting video clips into blocks of utterances allows us to track the ebb and flow of uncertainty through conversations by examining how properties of one block relate to uncertainty in subsequent blocks. We created blocks by first identifying contiguous conflict utterances and events. These events would become the initial blocks. For example, the conflict described previously would become a single block made up of multiple utterances. We then identified the 25 utterances *before* and *after* each conflict event as two additional blocks (Figure 1). The rest of the clips were broken up into successive blocks of 25 utterances each, each ending at the 25th utterance, the beginning/end of a video clip, or with the next conflict event. Analyses

[1] To rule out the possibility that our uncertainty coding scheme merely reflected politeness norms, we tested differences by gender and status. Males in our dataset expressed uncertainty (proportion of uncertainty out of all utterances spoken by males, $M = 0.14$, $SE = 0.003$) at a slightly higher rate than females (proportion of uncertainty out of utterances spoken by females, $M = 0.11$, $SE = 0.01$), $z = 1.96$, $p = .05$. Faculty expressed uncertainty ($M = 0.14$, $SE = 0.003$) at a similar rate to graduate students ($M = 0.10$, $SE = 0.02$), $z = 1.44$, $p = .15$, and older and younger faculty ($M = 0.14$, $SE = 0.00$) used uncertainty at the same rate, $z = 0.07$, $p = .94$.

of temporal patterns in uncertainty in this and other complex problem-solving data (e.g., Chan, et al., 2012; Christensen & Schunn, 2009) suggest that uncertainty tends to show significant rises and declines in windows of 15-30 utterances. This approach to creating utterance blocks also enables the transcript and analyses to be relatively homogenous on the independent variable (conflict), and standardized in length on the dependent variable blocks (as with Paletz, Schunn, et al., 2013). This segmentation method resulted in 688 blocks nested within 114 video clips.

Block-level measures. As noted, we used aggregated measures of conflict subtype and uncertainty at the block level in our analyses. We flagged each conflict event block as to whether it contained at least one of each specific type of conflict (at the utterance level) to create three separate, dichotomous conflict type variables (science, planning, and process, 1 = present, 0 = absent). Uncertainty was defined as the number of utterances in given block coded as uncertain.

While the conflict subtype codes at the block level were theoretically not mutually exclusive (the same block could be marked as a 1, present, for multiple of the three conflict type variables), blocks were often relatively homogeneous with respect to conflict subtype. Using Chi square tests, lagged process conflicts were significantly negatively associated with both lagged planning conflicts, $X^2(1, 115) = 32.84$, $p < .001$, phi = -.53, and lagged science conflicts, $X^2(1, 115) = 21.30$, $p < .001$, phi = -.43, and planning and science lagged micro-conflicts were also negatively related to each other, $X^2(1, 115) = 17.97$, $p < .001$, phi = -.40. Indeed, 96% of the 118 conflict blocks had only one subtype. Thus, our data enable us to tease apart the associations between conflict, uncertainty, and temporal context by conflict subtype.

Statistical analyses. We addressed our main research questions using time-lagged, variable exposure overdispersed Poisson models. These models were tested with two-level hierarchical linear modeling (Raudenbush & Bryk, 2002) via the HLM7 (7.01) software, which uses penalized quasi-likelihood (PQL) estimation (Raudenbush, Bryk, Cheong, & Congdon, 2013). We report the unit-specific models with robust standard errors, as is appropriate for these analyses. Dependent variables that are count data (i.e., number of uncertainty utterances in the block) require Poisson models, and we used the overdispersed setting because the variance of uncertainty (5.0) was greater than the mean (2.3; σ^2 was 1.3 instead of 1). Because the blocks varied in their number of utterances due to the endings of clips, beginnings of new conflict events, and so on, we used variable exposure Poisson. As an offset variable, we used (1 + ln[number of utterances]) because the offset variable (i.e., ln[1]) cannot equal zero.

We utilized two-level hierarchical linear modeling of blocks (Level 1) within video clips (Level 2) to capture the dependence inherent in the data (greater similarity in, and non-independence of, conversational dynamics within clips) and manage unequal cell sizes. Supporting our assertion that uncertainty was influenced by conversation-level factors, a null model of the uncertainty dependent variable[2] showed that there was significant variance at Level 2 (video clip level), Tau = .096, X^2 (113) = 223.68, $p < .001$ (ICC = 6.8%).

Because our research questions centered on temporal associations, we used time-lagged analyses to test whether uncertainty in one block was predicted by the presence/absence of conflict, or a particular type of conflict, in the block (25 utterances) *before*. In creating the models to test our research questions, the time-lagged conflict-to-uncertainty tests were at Level 1 (blocks). Temporal context (early versus later in the mission) was at the conversational clip level (Level 2), and the moderation effect of early/later phase was a cross-level interaction between the clip and block level (interaction between Level 2 and Level 1 variables; Figure 1).

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[2] A null hierarchical linear model tests the dependent variable without any predictor variables using chi square estimation to determine whether there are significant higher-level components.

Before examining our independent variables, we tested for significant associations between uncertainty and several covariates. These covariates were plausibly connected to levels of uncertainty or conflict, and therefore represent possible confounds. First, the covariates at Level 1 (block level) were tested, then those that were significant at Level 2 (video clip), controlling for the significant ones at Level 1. These tested variables had to be significant to be retained in the final model. Three Level 1 variables passed these tests: the average number of words per utterance (across all the blocks, $M = 7.0$, $Median = 6.86$, $SD = 2.16$; $t(563) = 6.75$, $B = 0.11$, $SE = 0.02$, event ratio = 1.12 (1.08, 1.15), $p < .001$) and the two topic vector variables to account for the three topics of discussion (vector #1: $t(563) = -1.66$, $B = -0.14$, $SE = 0.09$, event ratio = 0.87 (0.73, 1.03), $p = .098$; vector #2, $t(563) = -2.21$, $B = -0.25$, $SE = 0.11$, event ratio = 0.78 (0.63, 0.97), $p = .027$). Although one of the topic vectors was not significant, we kept both vectors because together they represented all three topics of discussion (science, planning, and work process; see Paletz et al., 2013 for more detail on this covariate). The number of words per utterance was a control because the simple length of an utterance could inflate the likelihood of any feature, including uncertainty, in the block. The topic vectors were controlled for because topic alone could have been a third variable that could affect both uncertainty and conflict: Different topics may elicit or have more conflict or uncertainty regarding them.

We tested the following covariates, any of which could have reasonably been related to uncertainty or conflict, and found them not to be significant (ps > .05): at Level 1 (block), the average number of people present; and at Level 2 (video clip), the general age/status composition of the scientists present in the clip using two vector variables representing graduate students, young faculty, and older faculty; the average number of speakers in the clip; gender composition; type of science team (long term planning versus other types of science teams); number of utterances in the clip; the rover team (A vs. B); and whether the clip was from earlier or later in the initial 90 days. As appropriate to testing interaction effects, non-significant relevant main effects (i.e., temporal context) are included in models to control for main effects when testing interaction effects.

Results

Frequency of Uncertainty and Micro-Conflicts

At the block level, uncertainty occurred relatively frequently, with 75% (518) of the 688 blocks having at least one uncertain utterance (M = 2.3, *Median* = 2.0, SD = 2.2, range is 0 to 10). The frequency of the lagged versions of these different task and process conflict types are shown in Table 3 (see also Paletz et al., 2011; Paletz, Schunn, et al., 2013).

Associations between Types of Conflict, Team Factors, and Subsequent Uncertainty

Overall conflict. We first tested whether lagged conflict had a significant association with subsequent uncertainty and had a significant interaction with temporal context, as well as whether temporal context had a main effect. The interaction of overall conflict with temporal context was not significant, and the model removing it showed that overall lagged conflict was only a marginally significant predictor of uncertainty (see Table 4). We expected different forms of conflict to have different effects on uncertainty, so we then unpacked the effects by subtype.

Micro-conflict by subtype. Next, we conducted moderated tests of temporal context (early/later phase) for the three topic subtypes of lagged conflict: science conflict, planning conflict, and process conflict. Lagged *process conflicts* were unrelated to uncertainty either as a main effect, $t(462) = 1.18$, $B = 0.15$, $SE = 0.13$, event ratio = 1.17 (0.90, 1.51), $p = .239$, or in interaction with temporal context, $t(462) = -1.07$, $B = -0.35$, $SE = 0.33$, event ratio = 0.70 (0.37, 1.35), $p = .287$ (see Figure 2A). *Planning conflict* had a significant, positive main effect on subsequent uncertainty, but no significant interaction with temporal context, *t*(462) = -0.25, *B* = -0.05, *SE* = 0.21, event ratio = 0.95 (0.63, 1.43), *p* = .801 (see Table 5 for the final model without the interaction vector; Figure 2B). In contrast, lagged *science conflict* had a significant interaction with temporal context (early/later phase in the first 90 days of the mission). Early in the mission, lagged science conflict had a positive association with uncertainty (similar to planning conflict), whereas the association was not significant later in the mission (see Table 6, Figure 2C).

Two examples of conflict (planning micro-conflicts and early science micro-conflicts) leading to increased uncertainty are in Table 7. In the first example, two scientists are debating what a sensible plan of instrument readings for the rover would be. After the first speaker strongly explains his/her opinion and the second responds with disagreement, the first starts to express uncertainty about his/her proposed plan. In the second example, a scientist disagrees using uncertainty hedge words, but then after the disagreement, that scientist *and two others* express uncertainty about the nature of the geology they are observing. In both cases, the disagreements precede a significant increase in uncertainty rates.

In summary, micro-conflicts about rover planning and science conflicts (the aspects most central to work in the MER context) were predictive of increases in subsequent psychological uncertainty, but there was no relation between process conflicts and subsequent uncertainty. The association between science conflicts and subsequent uncertainty depended on whether the science micro-conflict came earlier or later in the mission, with only early science micro-conflicts increasing uncertainty.

Association between Uncertainty and Subsequent Conflict

Testing the predictiveness of conflict for subsequent uncertainty is only half the story in understanding the ebb and flow of conflict and uncertainty. It is theoretically possible that high levels of uncertainty before conflicts were related to high levels after the conflict and that the uncertainty was causing the conflict. Therefore, we analyzed our data using the same multilevel analysis approach (except with logistic regression to account for the binary nature of the dependent variable, the presence of conflict in blocks, and using R's multilevel modeling module *lme4*), and controlling for the same set of covariates (adding lagged within-domain analogies to predict process and science micro-conflicts because they were found in prior research to be significantly related to these micro-conflicts; Paletz, Schunn, et al., 2013). We found that uncertainty was, in general, significantly *negatively* related to subsequent and concurrent micro-conflicts. Indeed, we found that concurrent and previous uncertainty were significantly *negatively* related to rover planning: concurrent uncertainty, $t(462) = -2.54$, $B = -0.23$, $SE = 0.09$, odds ratio = 0.79 (0.66, 0.95), $p = .011$, and previous uncertainty, $t(462) = -3.02$, $B = -0.29$, $SE = 0.10$, odds ratio = 0.75 (0.62, 0.90), $p = .003$. Similarly, process conflicts were negatively predicted by concurrent uncertainty, $t(461) = -3.36$, $B = -0.40$, $SE = 0.12$, odds ratio = 0.67 (0.53, 0.84), $p < .001$, and previous uncertainty, $t(461) = -2.65$, $B = -0.27$, $SE = 0.10$, odds ratio = 0.76 (0.62, 0.93), $p = .008$. Previous uncertainty, but not concurrent uncertainty ($p > .20$), was negatively related to subsequent science conflict, $t(461) = -2.60$, $B = -0.34$, $SE = 0.13$, odds ratio = 0.71 (0.55, 0.92), $p = .010$. These findings suggest that conflict of any type is *less* likely to occur at the same time as or immediately following relatively high levels of uncertainty.

Discussion

Unpacking brief temporal relations between micro-processes is important for gaining a deeper understanding of team problem solving processes. This study analyzed conversations as a key medium for unpacking team problem solving, focusing on exploring the temporal association between expressed brief disagreements and subsequent uncertainty.

Summary and Interpretation of Findings

We discovered that two different types of preceding task conflict predicted subsequent increases in psychological uncertainty: Planning task conflict was associated with an increase in uncertainty without any interaction with temporal phase, and science conflict was associated with an increase in uncertainty, but only early in the mission. Process conflict was unrelated to subsequent uncertainty. Testing for a potential reverse association revealed that process, rover planning, and science conflict all *decreased* following uncertainty, suggesting that our findings for conflict predicting increases in expressed uncertainty could not be due to a general positive association between uncertainty and conflict through some alternate factor. Taken together, these findings suggest that individuals were more likely to disagree when they expressed more confidence and fewer hedge words, and that conflict exposed underlying team uncertainties.

Uncertainty is central to problem solving (Kahneman & Tversky, 1982; Schunn, 2010; Schunn & Trafton, 2012). Resolving uncertainty often entails sharing information previously unknown, whereas detecting uncertainty involves discovering what is unknown (Schunn & Trafton, 2012). Task conflict is commonly argued to be the least harmful to team success, at best (e.g., de Wit et al., 2012; Nemeth, 1986). Uncertainty is generally thought to be problematic, a relatively weak information state that needs to be improved. Does this finding imply that task conflict has yet another potentially unproductive function? Such a value judgment is unwarranted give the grain size of the current analysis. Micro-conflicts and expressed uncertainty are part of complex team dynamics that iterate many times and gradually unfold. In fact, the discovered dynamic may simply be a core characteristic of normal team functioning.

To interpret these findings, we examine the MER context more closely and draw on shared mental models theory (e.g., Burke et al., 2006; Mathieu et al., 2000), which describes the development of team cognition. We suggest that task conflict in this case may have uncovered disconnects between the multidisciplinary scientists' mental models, and the rise in uncertainty following task conflict may have reflected the identification of newly exposed problems. There was a great deal of uncertainty in conducting science on Mars in general. Although levels of uncertainty were not generally different between early and later in the first 90 days of the mission, disagreements about science were more likely to involve an increase in subsequent uncertainty early in the mission. The scientists during that phase were likely still developing their mental models (individually and jointly) of how and whether liquid water had existed on Mars—the high-level topic of the science conflicts. Roughly a third of the way through the original mission, the scientists felt confident that they had discovered evidence of historical liquid water on Mars. At this stage, mental models regarding the science may have become more shared across the scientists, affecting the interpretation of new findings. This turning point in scientific discovery may have constrained the types of new information that could arise from disagreement, such that disagreements after that point were no longer positively, significantly related to uncertainty.

However, issues of what instrument readings and activities to do with the rovers (i.e., planning activities) remained both contentious and uncertain throughout the mission. The different subgroups of scientists (e.g., soil science, atmospheres) each wanted to conduct their own instrument readings, and each rover team had to prioritize and plan what the rovers would do. For instance, the scientists would debate whether they should have a rover (i.e., Rover A, Spirit) stay in one location and conduct additional instrument readings or drive to another location. Thus, these kinds of arguments could be due to differences in explicit goals in addition to differences in perceptions of the utility of doing instrument readings in a particular location. Furthermore, there was still a great deal unknown about what the best course of action would be, either scientifically or logistically. The scientists did not know at the time that the rovers would last several years past their initial 90-day life. Thus, the underlying differences in goals, assumptions, and mental models of what the best courses of action would be may have continued throughout the first 90 days of the mission, unchanged by the discovery of historical liquid water. Disagreements would still lead to greater uncertainty, because they would point out the missing information inherent in trying to plan rover activities on Mars.

Uncertainty could, and did, lead to effective problem solving, even within the moment. Indeed, previous research we conducted on this dataset found a significant positive association between uncertainty and subsequent problem-related analogy, with a return to baseline uncertainty after the analogy was mentioned (Chan et al., 2012). This study also found that the most common topic of uncertainty was science problem solving, suggesting that much of the uncertainty was central to their primary problem solving. For example, one scientist expressed uncertainty about the cause of observed ventifacting (a geomorphic feature on rocks) and uncertainty about a potential mechanism for the ventifacting, desert varnish (Chan et al., 2012, p. 1361). That scientist and two others proceeded to discuss the problem. One of the scientists made an analogy to how desert varnish works on Earth and a later analogy to findings from a Viking mission. Between the three scientists, they identified several possible reasons for ventifacting and the known causes of desert varnish that could be occurring on Mars. This anecdote and the data supporting it illustrate how uncertainty in the MER context could, and did, precede problem solving (Chan et al., 2012). Thus, if task conflict is leading to uncertainty in this domain, that uncertainty then has the potential to lead to problem solving.

Previous findings suggest that self-reported assessments of task conflict have a curvilinear (inverse-U) association with team performance (e.g., Fahr et al., Parayiam & Dooley, 2011; Shaw et al., 2011). This study unpacks one possible function of task conflict at the process level: uncovering areas of uncertainty. Relating to the curvilinear pattern with success, it may be that low levels of task conflict leave critical misunderstandings or mental model gaps hidden, and that very high levels of task conflict unearth more uncertainty than can be resolved. Alternately, these very high levels of conflict inhibit the resolution of the uncertainty via limiting the team's ability to build shared mental models. These hypotheses should be investigated in future research.

Strengths and Limitations

A benefit of this study is that it studied real-world problem solving at the micro-temporal level. Too often, detailed process studies of actual behaviors are limited to the research lab with undergraduate participants completing artificial tasks over limited time periods, and self-report methods (survey or interviews) are used to study actual work contexts. Even the rare communication study of conflict as it arises from natural conversations do not ask the research questions posed here (e.g., Poole & Dobosh, 2010).

However, one limitation of the methods used in this study involves the lower reliabilities associated with coding micro-conflict types. There are multiple factors underlying lower measure reliability than that typically found with some other approaches. First, this coding scheme for this study follows traditional examinations of conflict types as distinct (i.e., task, process, relationship; Jehn, 1995), but these dimensions were developed on self-report measures, interviews, and larger grain sizes in observations of teams. It can be difficult for even trained coders to distinguish between these types at the utterance. To reduce the negative effects of lowered reliability on the statistical power of the analyses, the target behavior was 100% double-coded, with all disagreements resolved by discussion, giving us more confidence in our eventual resolutions (Smith, 2000). Further, the operationalization of micro-conflicts was at an aggregated level, not the utterance level, helping to reduce noise due to lower reliabilities.

Another benefit of the methods used in this study is the diversity of individuals and tasks. For example, it examined individuals across a range of professions (university scientist, government lab scientist, industry engineer) and along a range of skill levels (e.g., from famous full professors to early graduate students). The scientists also accomplished a large variety of tasks, including dealing with anomalies, planning, scheduling, data analysis, emailing, taking photographs, and so on. Thus, even though these conversations were taken from one larger context (i.e., the MER mission), the sample was quite diverse in many other ways.

At the same time, there were some unique features of the sample that may limit its generalizability. The scientists were overall an extremely successful team. They had complex processes and worked during the first 90 days on Mars time schedules, getting progressively out of sync with Earth day/night cycles. While some of these features may be generalizable (complex processes, expert team), some are unique (e.g., working on Mars time), which means the findings may not transfer to other settings. Furthermore, even given transcribing and coding over eleven hours of conversations, we acknowledge that these conversations were only a sample of what the scientists discussed, on and off camera. Future studies could examine data evenly across the life of a team, and so uncover with greater precision when the temporal moderation effects occur.

Implications and Future Directions

Scientific problem solving often attempts to resolve uncertainty, and uncertainty may drive scientific discovery (Schunn, 2010; Schunn & Trafton, 2012). Even before problem solving is used to resolve uncertainty, however, what is unknown needs to be identified. Problem finding is a necessary precursor to problem solving. This paper illuminates a possible, contingent association between brief disagreements and immediate, subsequent psychological uncertainty, joining with other studies that examine the immediate consequences of brief disagreements (e.g., Chiu, 2008a, 2008b; Kauffeld & Lehmann-Willenbrock, 2012; Paletz, Schunn, et al., 2013). Future research could continue to unpack potential contextual and other moderators of this micro-conflict/uncertainty connection. This study supports theorizing that different types of conflict may play different roles in team processes. For instance, process conflict early in a team's lifecycle may be positively related to eventual team performance, perhaps because it prevents premature closure (Goncalo et al., 2010). A fine-grained analysis, as conducted in this study, of multiple teams' process micro-conflicts in their early stages can shed light onto how they may influence uncertainty and closure on specific decisions.

This paper also has implications for the role of uncertainty in problem-solving conversations. Future directions might also include qualitative studies of different types of uncertainty (e.g., Lipshitz & Strauss, 1997) and how the uncertainty that arises after a conflict may serve a different role in problem-solving conversations compared to other types of uncertainty. For instance, how is decision-making impacted by whether or not a conflict-uncertainty pair is present? Additional studies could also examine whether the uncertainty that arises after a micro-conflict is related to problem finding and restructuring, exposing gaps in information, and/or freeing individuals to share their concerns.

This paper advances future theorizing about team processes by examining a new association at a micro-temporal level. Of all the potential functions of disagreement, uncertainty reduction or increase has been barely studied. Examining micro-conflicts serves to shift the lens of scientific examination from mostly static snapshots of broad team perceptions to examining the interplay of different types of quick conversational acts.

Practically, such research and theory could help guide the creation of team facilitation techniques and suggestions for how teams can better leverage their disagreements for specific problem-solving processes. Much of the literature on conflict focuses on reducing or mitigating it. This paper suggests that conflict resolution training could also be expanded to emphasize the useful cognitive functions of small disagreements, such as questioning underlying assumptions and restructuring problems. Once uncertainty is brought into the open, new problems can be explicitly addressed. Problem solving, particularly in multidisciplinary teams, is vital for scientific innovation, economic progress, and finding solutions to pressing societal problems. By unpacking problem-solving conversations as they occur in real-world successful expert teams, we discover more about their functioning.

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Table 1

Examples of Micro-Conflicts between MER Scientists (Key Words in Bold), Excerpts from Paletz, Schunn, & Kim, 2011

Coded as	Utterance
Example 1: Science Conflict	
No conflict	S2[a]: …I'm afraid that this very low angle interior wall reflects that
No conflict	there is no bedrock there.
Science conflict	S3: Well, Bereonies got a low slope also.
Science conflict	**It could be that the bedrock is just not very conical.**
Example 2: Rover Planning Conflict	
No conflict	S3: Then the issue becomes we all, we may not have enough time to do any mineralogy or this spectral stuff
No conflict	if we're going to have a long look at the salt.
No conflict	S2: You think of this
No conflict	as we've only been there for two weeks.
Rover planning conflict	**There's a time for everything now.**
Rover planning conflict	How do we spend it such that
Rover planning conflict	maybe your stuff, half the peoples' stuff doesn't get done on one sol,
Rover planning conflict	but the other half can really get something that's good.
Rover planning conflict	S3: Right, **but I need to do** the stuff I want to do, which is…
Example 3: Process Conflict (with "No")	
No conflict	S2: You showed me that already.
Process conflict	S3: **No, I showed you a single frame.**

Example 4: Relationship Conflict

Rover planning conflict	S1: Well, what I'm saying is common things occur commonly
Rover planning conflict	and rare things occur rarely
Rover planning conflict	and to say that we landed on the rare thing rather than the common thing
Relationship conflict	is a totally subjective decision that we make **that goes against logic**.
Relationship conflict	That's all I'm saying.
Rover planning conflict	S2: No, I agree with that, but—[is cut off]

Example 5: Conflict with No Conflict Embedded

Science Conflict	S6: **But to me** they look like each one of these things
No conflict	Even though they're really wide,
Science conflict	They do sort of look like single event types of features
Science conflict	Because the sides of each of them are sort of parallel to each other
Science conflict	**which you wouldn't get** if there was a swarm coming in from the same place.

Example 6: Use of "No" without Conflict

No conflict	S3: Is there any change in the plan here?
No conflict	S1: No.

Example 7: Use of "But" without Conflict (Additions Rather than Disagreement)

No conflict	S3: Let me ask.
No conflict	S2: Well, we need some,
No conflict	but I think we need to pick a number, you know,
No conflict	and I think we need to pick a number of rocks

No conflict	and there’s certainly at least two types that I can think of.
No conflict	But we need to have…

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

Table 2

Examples of Uncertainty from MER Scientists (Key Words in Bold) in Conversational Contexts, Excerpts from Chan, Paletz, &, Schunn, 2012

Speaker	Turn
Excerpt 1	
1	I would have thought that the ventifacting would have been very late and it would have destroyed the surface. Actually **maybe** that's why we don't see the black surface of the other two rocks, which also were ventifacts, right? Because **maybe** they just happened, we happened to hit faces where it had been scarred
2	And of course that, all that, would mean, if that is an injected block, all of that took place after; it did not take place at <missing words>
1	Yea, well I mean, I **don't think** that we can rule out that this isn't some kind of desert varnish, although I **don't understand** how desert varnish forms
Excerpt 2	
4	Can you do something with an acid fog? I know we got sulfate and sulfurs and chlorines; **is there some way** we can <missing words>
1	Certainly, yea, **maybe** that's a good explanation of it
4	**Maybe** it's a coating of some sort of sulfate chlorine, you know, crude
Excerpt 3	
1	Ok, so the idea is go, and then we're going to at the end of sol [Martian day] 90. At the end of the afternoon we deploy the Mössbauer to capture it.
2	Is this going to be the <missing words>
1	I **don't know, I think so**. And then we let it integrate all night. And then, or

maybe, we let it integrate, we let it integrate until some other pass at 3 o'clock in the morning **or something** and then

---

Table 3

Frequency of Presence of Lagged Science, Planning, Process, Quickly Resolved, Positive, and Negative Micro-Conflicts by Block

Micro-Conflict Type	Frequency % (n of 569 Lagged Blocks)
Any micro-conflict	20.2% (115)
Process micro-conflict	8.0% (46)
Rover planning (task) micro-conflict	8.2% (47)
Science (task) micro-conflict	4.4% (25)

Table 4

Any Lagged Micro-Conflict and Temporal Context on Uncertainty

Variable	*B*	*SE*	*t*	Event rate ratio (95% confidence ratio)	*df*	*p*
Intercept, γ_{000}	-1.20	0.15	-8.21	0.30 (0.23, 0.40)	97	< .001
Average Words per Utterance	0.11	0.02	6.23	1.11 (1.08, 1.15)	463	< .001
Topic Vector 1	-0.09	0.09	-1.01	0.91 (0.76, 1.09)	463	.315
Topic Vector 2	-0.22	0.12	-1.80	0.81 (0.64, 1.02)	463	.073
Early/Later Phase	0.14	0.08	1.76	1.15 (0.98, 1.35)	97	.082
Lagged Conflict	0.13	0.07	1.67	1.13 (0.98, 1.31)	463	.095

Table 5

Final Model of Lagged Planning Conflict and Covariate on Uncertainty

Variable	*B*	*SE*	*t*	Event rate ratio (95% confidence ratio)	*df*	*p*
Intercept, γ_{000}	-1.18	0.15	-8.00	0.31 (0.23, 0.41)	97	<0.001
Average Words per Utterance	0.11	0.02	6.27	1.11 (1.08, 1.15)	463	<0.001
Topic Vector 1	-0.12	0.09	-1.29	0.89 (0.74, 1.07)	463	.198
Topic Vector 2	-0.22	0.12	-1.85	0.80 (0.63, 1.01)	463	.065
Early/Later Phase	0.13	0.08	1.69	1.14 (0.98, 1.33)	97	.095
Lagged Planning Conflict	0.22	0.11	2.09	1.25 (1.01, 1.54)	463	.037

Table 6

Final Model of Lagged Science Conflict, Temporal Context, Their Interaction, and Covariates on Uncertainty

Variable	*B*	*SE*	*t*	Event rate ratio (95% confidence ratio)	*df*	*p*
Intercept, γ_{000}	-1.19	0.15	-7.97	0.31 (0.23, 0.41)	97	< .001
Average Words per Utterance	0.11	0.02	6.10	1.11 (1.08, 1.15)	462	< .001
Topic Vector 1	-0.08	0.09	-0.91	0.92 (0.77, 1.10)	462	.366
Topic Vector 2	-0.22	0.12	-1.82	0.81 (0.64, 1.02)	462	.069
Early/Later Phase	0.16	0.08	2.05	1.17 (1.01, 1.37)	97	.043
Lagged Science Conflict	0.30	0.18	1.64	1.35 (0.94, 1.93)	462	.102
Lagged Science Conflict X Early/Later Phase	-0.51	0.23	-2.23	0.60 (0.39, 0.94)	462	.027

Table 7

Examples of Micro-Conflicts Preceding Increases in Uncertainty

Coded Conflict	Coded Uncertainty[a]	Speaker Number	Utterance
Example 1: Planning Micro-Conflict Preceding More Uncertainty			
Planning	0	1	No, no, no, no
Planning	0	1	If you want to do the integration on the RAT [Rock Abrasion Tool],
Planning	0	1	you’re going to have to do some additional brushing
Planning	0	1	because you don’t want crap in the brushing in the gravel.
Planning	0	1	So you pretty much go through the standard sequence,
Planning	0	1	and the advantage of that is that you now have looked at all the different depths.
Planning	0	2	But what do you, what do you do with that??
Planning	0	2	So after you’ve done the integration,
Planning	0	2	then you do the final brush with backup.
None	0	1	Right, you can’t do any more, more brushing
None	0	1	You don’t want to contaminate the hole
None	1	1	So that could be one way you could get that Minitest [another instrument] observation,
None	0	1	and not a lot of <missing word> in one sol.
None	0	1	The only thing that’s scary about that is that you drive away not knowing what you got in the Minitest

			observation,
None	0	1	but it’s just a backup you know of 185.
None	0	1	I’ll show you what we’re talking about.
None	0	1	So that’s one option.
None	0	1	Then after you start to drive,
None	1	1	but I guess you’re on for what, two more sols, so pretty much.

Example 2: Science Micro-Conflict Early in Mission (Sol 16) Preceding More Uncertainty

None	0	3	So these aren’t exactly perfect.
None	0	3	These are actually old <missing words> weathered out.
Science	0	4	Well, but if you think about it,
Science	1	4	the history of this thing post-impact, you know, maybe, maybe these have, um, formed over time.
None	0	1	Well, do you think it could be impact generated?
None	1	4	No, not impact generated, ‘cause they maybe a certain, well I don’t know.
Science	0	1	Well, the problem is they look very specific, it’s not even penetrative <missing word>.
None	0	4	No, you’re right,
None	1	4	there would be if, there would have to be some fundamental difference in the hardness of those layers.
None	0	2	You know, one thing you can do on that is to say
None	1	2	that maybe these were, that there is a sulfate cement in

			there <missing words>,
None	1	2	but they don’t really look like <missing words>.
None	0	1	See, I love all this <missing words>
None	0	1	If you were on Earth you would just simply call that a nodular fabric
None	0	1	and go about your business
None	0	1	and then you’d speculate about whether it was nodular because of early cementation, pearling, or pressure solution
None	1	1	and probably here we can rule out the last two.

[a] Zero (0) is not coded as having uncertainty, 1 is coded as having uncertainty

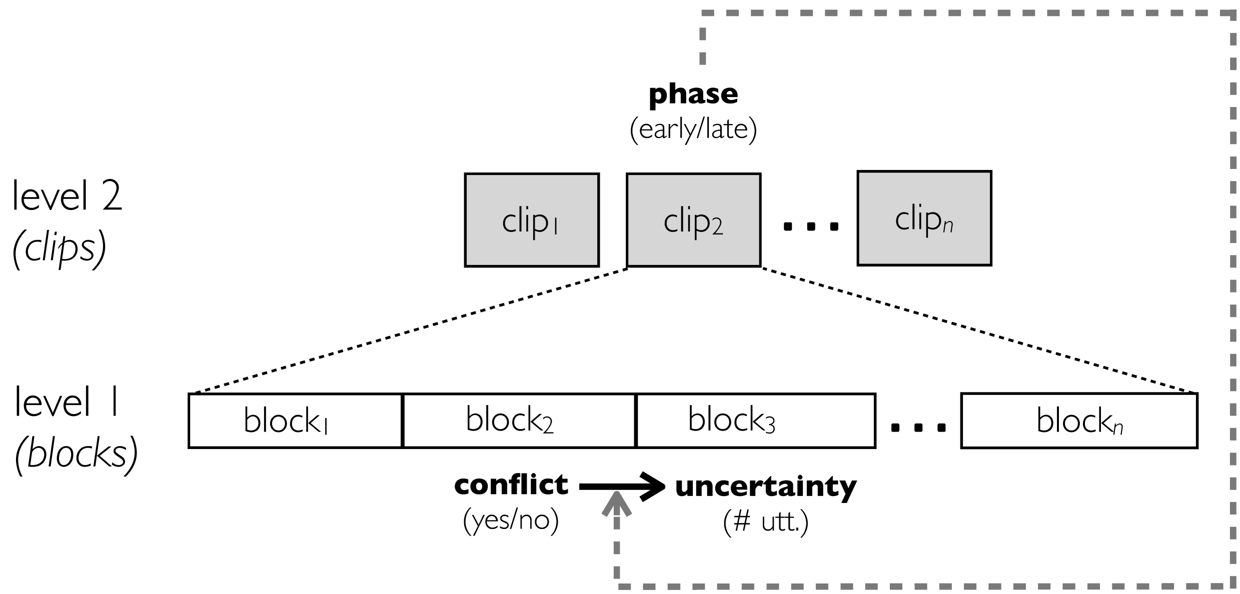

Figure 1. Data Structure: Blocks Nested within Clips, and Time-Lagged Analyses of Micro-Conflicts to Uncertainty Moderated by Temporal Context

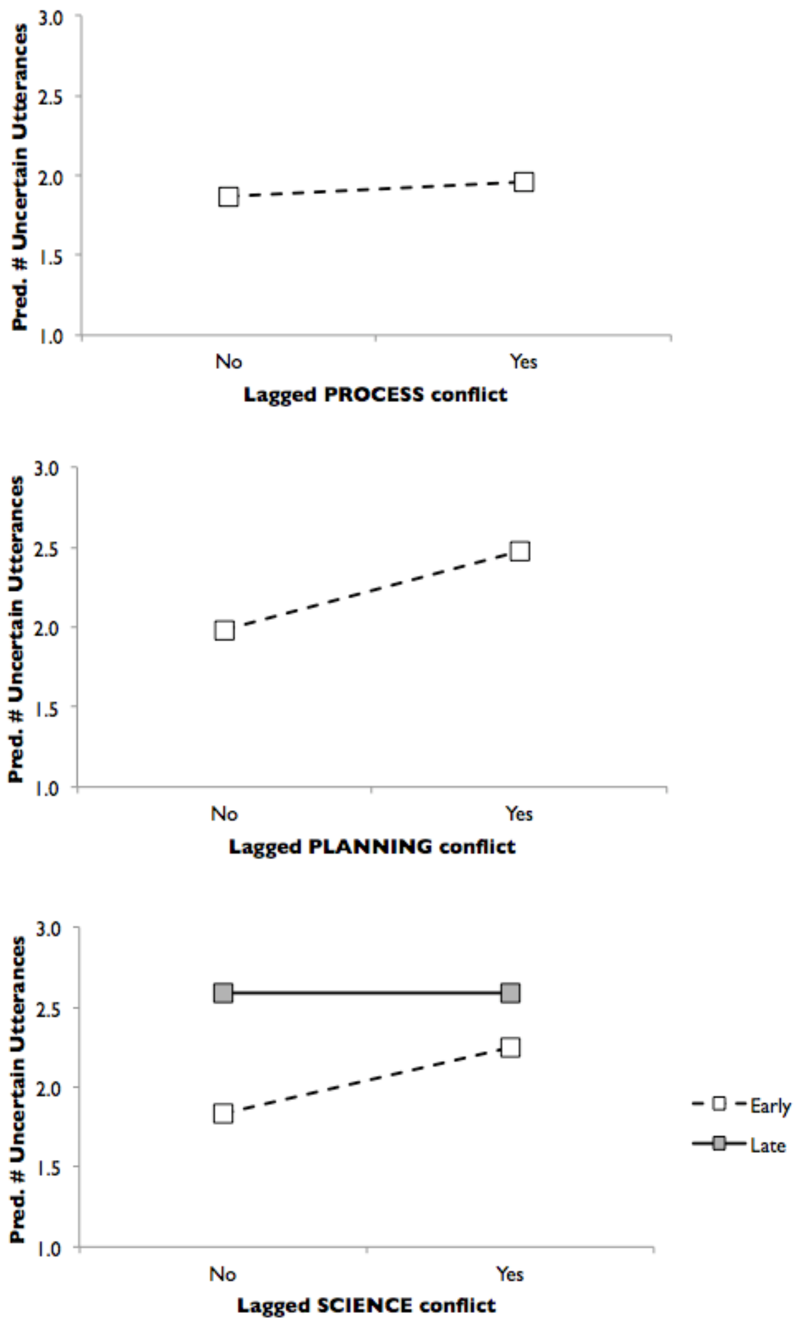

Figure 2. Predicted Number of Uncertain Utterances Controlling for Covariates by Time-Lagged (A) Process Micro-Conflicts, (B) Rover Planning Micro-Conflicts, and (C) Science Micro-Conflicts for Early and Later in the First 90 Days of the Mission