Understanding Rigor in Information Analysis

Daniel Zelik
The Ohio State University
Zelik.2@osu.edu

Emily S. Patterson
The Ohio State University
Patterson.150@osu.edu

David D. Woods
The Ohio State University
Woods.2@osu.edu

ABSTRACT

Across information analysis domains, it is often difficult to recognize when analysis is inadequate for a given context. A better understanding of rigor is an analytic broadening check to be leveraged against this uncertainty. The purpose of this research is to refine the understanding of rigor, exploring the concept within the domain of intelligence analysis. Nine professional intelligence analysts participated in a study of how analytic rigor is judged. The results suggest a revised definition of rigor, reframing it as an emergent multi-attribute measure of sufficiency rather than as a measure of process deviation. Based on this insight, a metric for assessing rigor was developed, identifying eight attributes of rigorous analysis. Finally, an alternative model of briefing interactions is proposed that integrates this framing of rigor into an applied context. This research, although specific in focus to intelligence analysis, shows the potential to generalize across forms of information analysis.

Keywords

Rigor, analytical rigor, information analysis, intelligence analysis.

INTRODUCTION

The proliferation of data availability and connectivity has exacerbated the risk of shallowness in information analysis. The risk of shallow analysis describes the possibility—inherent in all information analysis processes—that an analysis is of inadequate depth relative to situational demands. The risk, then, is of being insufficiently rigorous in analysis. Consequently, understanding the concept of analytical rigor emerges as an approach for coping with this fundamental uncertainty. The purpose of this research, based on a study of the professional analyst, is to refine the understanding of analytical rigor.

Defining Rigor

Formally defined, rigor is the quality of being strict and inflexible (McKean, 2005). When applied, rigor is often used to describe process. In information analysis, rigor—or analytical rigor—reflects an assessment of process quality, affording communication about the process, rather than the product, of analysis. One effort to identify a generic definition of analytical rigor describes it as the "application of precise and exacting standards... to better understand and draw conclusions... based on careful consideration or investigation" (Military Operations Research Society, 2006). In this view, to be rigorous in analysis requires only the meticulous adherence to standard process.

This colloquial perspective, however, mischaracterizes the understanding of analytical rigor. Despite the etymological implication that to be rigorous is to "be stiff" (McKean, 2005) expert information analysis processes often are not rigid in their application of a standard process, but rather, flexible and adaptive to highly dynamic environments. In information analysis, judgement of rigor reflects a relationship in the appropriateness of fit between analytic processes and contextual requirements. Thus, as supported by this and other research, rigor is more meaningfully viewed as an assessment of degree of sufficiency, rather than degree of adherence to an established analytic procedure.

This debate about what it means to be rigorous in analysis does not lessen the important role of understanding rigor. Rather, it shapes the perspective taken in exploring the concept of rigor.

A Brief History of Rigor

The research on rigor in information analysis began in engineering safety analysis, where significant and high-profile "failures" made salient the criticality of understanding analytic rigor. At NASA, following Columbia, accident investigation reports revealed that managers were unaware they were making decisions based on analyses that appeared thorough, but were in fact of very low rigor (Columbia Accident Investigation Board, 2003; Crippen, et al., 2005; Woods, 2005).

Prior to the foam strike event that ultimately fated the STS-107 mission, some NASA engineers and managers were concerned about the uncertain risk associated with the recognized problem of foam loss from the shuttle's External Tank. However, the understanding of this problem was not validated by rigorous engineering analyses, and past successes became the basis for justifying future flights. Moreover, as reports addressing the foam loss events progressed through the organization, decision makers increasingly failed to realize—in light of increasing pressures to remain on schedule—that the processes behind these analyses, and thus the bases for their decisions, were insufficiently rigorous relative to the safety-critical questions being asked and the potential consequences of the decisions being made.

It is in this context that a definition of rigor as "the scrupulous adherence to established standards for the conduct of work" again emerges (Crippen, et al., 2005). However, as noted earlier, this definition of rigor is also insufficient in much the same way that an error-as-deviation from standards definition of "human error" in safety analysis is inadequate: "defining error-as-deviation from a model of 'good' process... collides with the problem of multiple standards" (Woods & Cook, 2003). The "problem of multiple standards" describes the inherent difficulties in selecting which, among many viable candidates, is *the* standard process to which performance should be compared. In information analysis—intelligence analysis, especially—it is pragmatically even more challenging to define standard process.

Engineering safety analysis is not the only domain where understanding the role of judgments about the rigor of analyses is recognized as important. In the physical sciences, the significance of rigor is embodied in the canonical "scientific method" of experimentation. In the social sciences—although the definition of what constitutes rigor is a bit murkier—the appreciation of the importance of rigorous process remains.

In the design literature, Tufte (2003) is especially critical of the influence of slide-based presentations on the understanding of analytical process. At the root of his criticism is the observation, recognized in various manifestations, that poor representation hides and obscures the process being represented. Thus, rigor represents a mechanism for revealing the observability of an analysis process (Woods, Patterson, & Roth, 2002). This finding is extended through the acknowledgment that all forms of analytic products, to some extent, obscure the processes that produced them—a perspective that guides our exploration of rigor in information analysis.

Intelligence Analysis as Information Analysis

Information analysis—as a manifestation of abductive reasoning (Josephson & Josephson, 1994)—is defined loosely as a form of cognitive work that involves the collection and assessment of data with the goal of verifying or refuting hypotheses which explain that data. Information analysis is more than just explanation building and testing, however, as it is performed to support high-consequence decision-making in domains where explanations may not be testable in the same way as in classic experiments. Intelligence analysis—in particular strategic, rather than tactical or operational intelligence—provides a natural laboratory for refining the understanding of rigor in information analysis.

Intelligence analysis, also a form of abduction (Schum, 1987), is a special case of information analysis. While it shares the previously noted features with most other information analysis, it is confounded by the added challenges of necessary secrecy and adversarial intent. Similar to the above definition of information analysis, Johnson (2005) defines intelligence analysis as "the application of individual and collective cognitive methods to weigh data and test hypotheses within a secret socio-cultural context." This characterization partially overlaps with the model proposed by Elm, et al. (2005), which frames intelligence analysis as an interaction of the three primary functions of *Down Collect* of relevant data, construction of interpretations of the data through *Conflict and Corroboration*, and building explanations for those interpretations through *Hypothesis Exploration*.

Intelligence analysis is a particularly interesting domain for studying rigor because, in view of the consequences of failure, recent high-profile events have prompted many to question the present state of the U.S. intelligence community (National Commission on Terrorist Attacks, 2004; Duelfer, 2004; Johnson, 2005). In the ensuing debates, it has become apparent that changes in technology and in the international political landscape, among other influences, have transformed—and continue to transform—the role of professional analyst (Medina, 2002; Ward, 2002). In the face of significant production pressures (Johnson, 2005) and rapidly proliferating data availability (Patterson, Roth, & Woods, 2001)—and resulting data overload deluging the professional analyst—it is increasingly easy for analysts to be trapped by shallow, low-rigor analysis. Given similar pressures, it is also increasingly difficult for decision makers to recognize when an analysis is not of sufficient rigor for a given decision. Thus, it is increasingly clear that rigor is a relevant concept within the intelligence analysis community, contributing to its appropriateness as a context for studying the broader theme of rigor in information analysis.

FINDINGS

This exploration of rigor begins with a study of professional analysts—specifically, a scenario walkthrough study involving intelligence analysts. The *Supervisor's Dilemma* Study, embedded in the Liquified Natural Gas Scenario (LNG Scenario), investigated whether insight into the analysis process produces change in perceptions of rigor. While this study produced a number of valuable contributions, the most surprising finding challenged the conventional definition of rigor, leading to a

proposed re-conceptualization of rigor in information analysis around an understanding of sufficiency, rather than around process deviation. Based on this insight, the Rigor Metric was developed as a multi-attribute approach for assessing analytical rigor. Finally, based on this metric, we propose the Participatory Exchange Model as an approach for restructuring intelligence analysis briefings in order to reveal and support the assessment of rigor sufficiency.

LNG Scenario *Supervisor's Dilemma* Study

A study was performed that investigated how professional information analysts judge the rigor behind analysis products. The study examined the cues used by professional intelligence analysts to identify analytic rigor, implementing an innovative approach—based on a formal knowledge elicitation methodology—to tap into the domain expertise of professional analysts.

Study Description

The design of the study was based on the Elicitation by Critique (EBC) methodology (Miller, Patterson, & Woods, 2006). In this approach, participants share their expertise by critiquing the processes of other domain practitioners. Nine professional intelligence analysts participated in a study, embedded in a scenario walkthrough, in which they critiqued the analysis processes of two junior analysts—one representing a high-rigor analysis process [A(1)] and the other a low-rigor process [A(2)]. Participants were instructed to review both reports and "assess and compare the quality of the two written reports" and "comment on the 'rigor' of the processes that produced each of the reports."

In the study, participants assumed the role of analyst supervisor, deciding if the analyses of the junior analysts were of sufficient rigor to send to a decision maker—a fundamental judgment task characterized as the *Supervisor's Dilemma*. The *Supervisor's Dilemma* describes a generic situation wherein one must decide if the analysis product of an analyst is acceptably rigorous or if more resources must be invested to improve the analysis before sending it forward. This dilemma highlights the criticality of the interactions that occur at the interface between analysis and replanning components of information analysis. In intelligence analysis, it represents a point where a decision is made—whether by supervisors, decision makers, or the analysts themselves—as to whether or not an analysis product is ready to pass on to the next stage in the cycle. Simply, whether made implicitly of explicitly, the *Supervisor's Dilemma* addresses a basic question in information analysis—*When is analysis sufficient?*

This study design both validated and refined the EBC methodology, developing the Liquified Natural Gas Scenario—based on a case where security issues challenge previously established safety analyses—as a cognitive case for exploring themes in information analysis. The LNG Scenario reflects the debate in the United States energy sector as to whether the increasing importation of LNG is an appropriate approach for coping with increasing natural gas consumption, in light of the projected near-term depletion of the domestic natural gas supply. While there are many aspects of the LNG importation case that make it an interesting base scenario, there are four facets of the controversy—energy, siting, safety, and security—that interact to make it particularly valuable as a cognitive case.

Study Results

Three critical findings emerged from this study that relate directly to the understanding of rigor in analysis. First, the study revealed that providing insight into the analytic process changed assessments of rigor. In judging rigor, five of nine participants, after reviewing the process, altered their assessments of whether A(1) or A(2) was perceived as being more rigorous. Second, the study showed that participants used similar qualities of analytic products to make inferences about analytic processes, however there were substantial differences in how conclusions about rigor were drawn from these cues. While there was some agreement among participants as to which process documents were most useful, there were distinct differences in what those cues indicated to each participant. The data reveal that there were both positive and negative inferences made about process rigor, based on identical cues. Taken together, these findings highlight an important distinction between *perceived rigor*, based on cues inferred from an analytic product, and *effective rigor*, based on insight into the analytic process—indicating that they often may not be aligned.

Perhaps the most surprising finding from the study, however, was that—despite significant efforts in developing the scenario-based analyses and despite inputs from professional analysts in refining them as plausible analytic responses—very few of the participants thought either of the analysis reports was ready to send forward to a decision maker. The consequence of this finding was a re-conceptualization of the definition of analytic rigor that contrasts with the traditional perspective. Rather than focusing on deviation from a baseline process, study participants instead identified multiple attributes of process that comprise rigorous analysis. The common theme across these aspects of the analytic process was that rigor was consistently framed as a measure of sufficiency.

Rigor Metric

The Rigor Metric represents the revised definition of rigor that emerged from the study, which frames the concept of rigor as the composite of multiple process attributes. This multi-attribute metric characterizes these indicators as independent components of the analysis process which, when aggregated, reveal a composite assessment of analytic rigor. In addition to

the findings from the study, this framing of rigor was shaped by the traditional perspectives on rigor in intelligence analysis, the findings from other studies of professional intelligence analysts, feedback from a diverse group of professional analysts, and empirical insights that emerged from interactions with those analysts—all of which occurred during the study or as follow-ups to the study. Specifically, the findings led to the identification of eight critical attributes of analysis processes that contribute to assessments of rigor.

Attributes of the Rigor Metric

Hypothesis Exploration describes the extent to which multiple hypotheses were considered in explaining data. In a low-rigor process there is minimal weighing of alternatives. A high-rigor process, in contrast, involves broadening of the hypothesis set beyond an initial framing and incorporating multiple perspectives to identify the best, most probable explanations.

Information Search relates to the depth and breadth of the search process used in collecting data. A low-rigor analysis process does not go beyond routine and readily available data sources, whereas a high-rigor process attempts to exhaustively explore all data potentially available in the relevant sample space.

Information Validation details the level at which information sources are corroborated and cross-validated. In a low-rigor process little effort is made to use converging evidence to verify source accuracy, while a high-rigor process includes a systematic approach for verifying information and, when possible, ensures the use of sources closest to the areas of interest.

Stance Analysis is the evaluation of data with the goal of identifying the stance or perspective of the source and placing it into a broader context of understanding. At the low-rigor level an analyst may notice a clear bias in a source, while a high-rigor process involves research into source backgrounds with the intent of gaining a more subtle understanding of how their perspective might influence their stance toward analysis-relevant issues.

Sensitivity Analysis considers the extent to which the analyst considers and understands the assumptions and limitations of their analysis. In a low-rigor process, explanations seem appropriate and valid on a surface level. In a high-rigor process the analyst employs a strategy to consider the strength of explanations if individual supporting sources were to prove invalid.

Specialist Collaboration describes the degree to which an analyst incorporates the perspectives of domain experts into their assessments. In a low-rigor process little effort is made to seek out such expertise, while in a high-rigor process the analyst has talked to, or may be, a leading expert in the key content areas of the analysis.

Information Synthesis refers to how far beyond simply collecting and listing data an analyst went in their process. In the low-rigor process an analyst simply complies the relevant information in a unified form, whereas a high-rigor process has extracted and integrated information with a thorough consideration of diverse interpretations of relevant data.

Explanation Critique is a different form of collaboration that captures how many different perspectives were incorporated in examining the primary hypotheses. In a low-rigor process, there is little use of other analysts to give input on explanation quality. In a high-rigor process peers and experts have examined the chain of reasoning and explicitly identified which inferences stronger and which are weaker.

Visualizing the Rigor Metric

The rigor metric was also conceptualized to be conducive to representation in an intuitive visual form. In Figure 1, but one of many possible visualization, the three concentric circles identify high-, moderate-, and low- rigor—moving from the outside inward. The filled inner circle is malleable and allows for the consideration of analysis processes with respect to broader contextual factors, by defining the level of rigor demanded. The process being assessed is represented by a webbed overlay, which reflects how a process ranks on each of the relevant dimensions. Processes that score high on a dimension pull the form outward and those scoring low push inward—causing the size and shape of the web form to reveal a composite assessment of rigor.

Also included in Figure 1 are assessments of the analyses developed for the LNG Scenario—relative to the eight aspects of the metric—based on feedback generated by study participants. Interestingly, while A(1) and A(2) were originally designed to reflect high- and low-rigor processes respectively, within the revised framing of analytical rigor the two processes actually differed more in their patterns of rigor than in absolute levels of rigor. Despite collaborative design efforts, A(1), it turned out, did not contain high levels of rigor across all dimensions, but rather, showed generally moderate-rigor in most aspects of the process, while in fact even being low in one aspect. A(2) turned out to be low in many dimensions, as was intended, but also showed moderate- or high-rigor in some dimensions.

The general message of the figure, then, is that rigor in information analysis is not understood by assessing deviations of process, but rather, by assessing the contextual sufficiency of many different aspects of process. As revealed by the visualization of the metric applied to the LNG Scenario, this representation also allows for emergent assessments of rigor at a glance, as well as relative comparisons of process strengths and weaknesses.

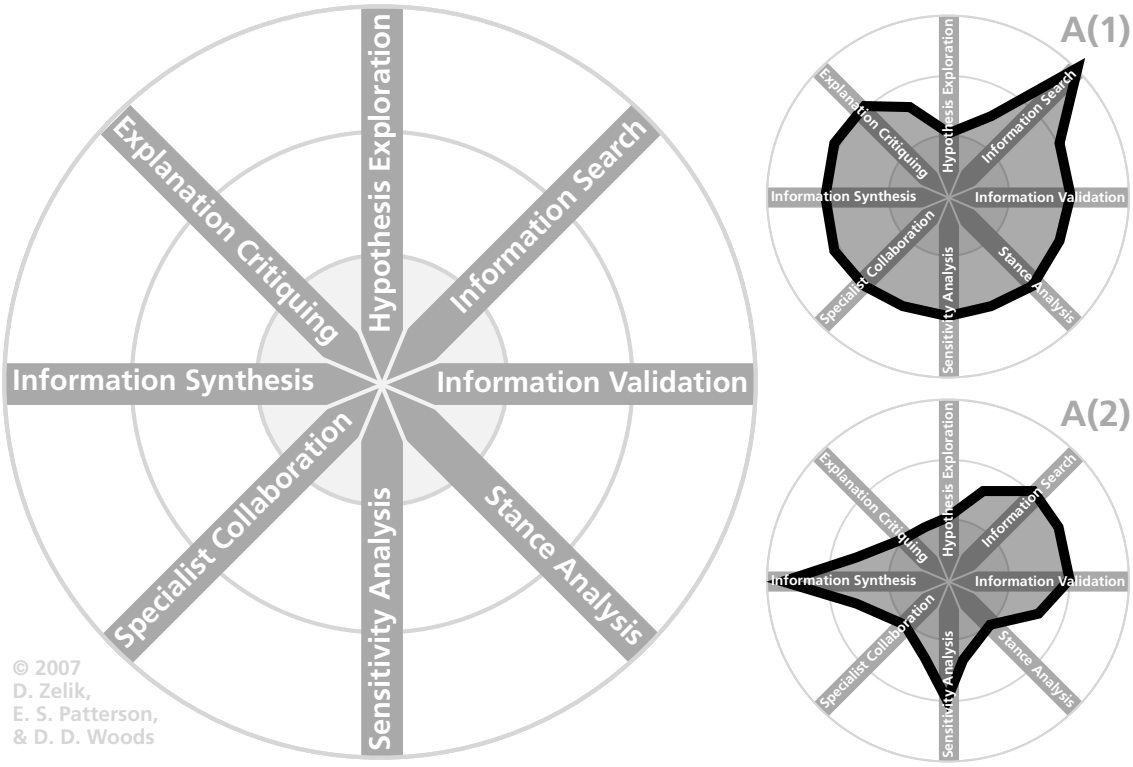

Figure 1. Visualization of Rigor Metric as Applied to LNG Scenario Analysis Process 1 [A(1)] & Process 2 [A(2)]

Participatory Exchange Model

The Rigor Metric provides a framework for understanding analytical rigor in information analysis, but there are many possible ways that it might be leveraged to lessen the risk of shallow analysis. One promising direction for using the metric to shape the envisioned future of information analysis focuses on applying it at transition points in the information analysis process. Thus, the Participatory Exchange Model is proposed as an approach for communicating about intelligence analysis outputs—an approach that shapes interactions around facilitating the ability of both analyst and decision maker to understand and discuss the rigor of an analysis process. This alternative approach to the traditional briefing interaction builds on the insights revealed by the study and through the Rigor Metric, emerging from a collaborative effort exploring data overload in intelligence analysis.

The Traditional Model of Briefing Interactions

The class of communications of particular relevance are those interpersonal interactions that occur with the primary intent of information transfer—a class of interactions referred to as briefing interactions. Briefing interactions include many events common to the intelligence community—from a senior analyst presenting critical intelligence findings to a decision maker, to a junior analyst sharing new information and insights with a group of peers—these briefings are unified in that the goal of the interactions, traditionally, is to transfer information about some product of an analysis process. In understanding the Participatory Exchange as a model, it is contrasted with the traditional model of briefing interactions.

The traditional model can be typified as a standard meeting presentation where the focus is on ensuring successful transfer of a central message. This model, however, largely ignores the significant role that feedback plays as an input to re-tasking, the counterpart of the analytical product. By framing briefing interactions as Participatory Exchanges, the criticality of this link is emphasized. While the traditional model frames interactions as being almost exclusively about information transfer, a participatory model reframes these interactions as collaborative and interactive exchanges of perspectives among participants.

Participatory Exchange Model of Briefing Interactions

In the Participatory Exchange, effective conversation is the model for success, rather than persuasion. A briefing interaction becomes "participatory" in the sense that both the briefer and the audience contribute to the development of the interaction. It

becomes an "exchange" through a two-way transfer of perspective understanding, rather than a one-way transfer of information. This perspective acknowledges that it is not only critical for the the audience to understand the perspective of the briefer, but it is also critical for the briefer to understand the perspective of the audience. Consequently, successful briefings are defined by the convergence of perspectives among stakeholders.

In the Participatory Exchange, depicted in Figure 2, stakeholders are conceptualized as Briefing Analysts and Audience Participants. The critical difference between the groups is their perspective on the cycle of intelligence analysis as a form cognitive work. In representing this cognitive work as the interaction between analysis and replanning, the briefing analyst characterizes stakeholders who have the process of analysis, which is in the foreground of their focus, occurring on a background of replanning. In contrast, audience participants—which might include decision makers as well as supervising, senior, or even peer analysts—represent stakeholders who have re-planning at the center of their focus. For them, analysis instead composes the secondary background on which primary replanning decisions are made.

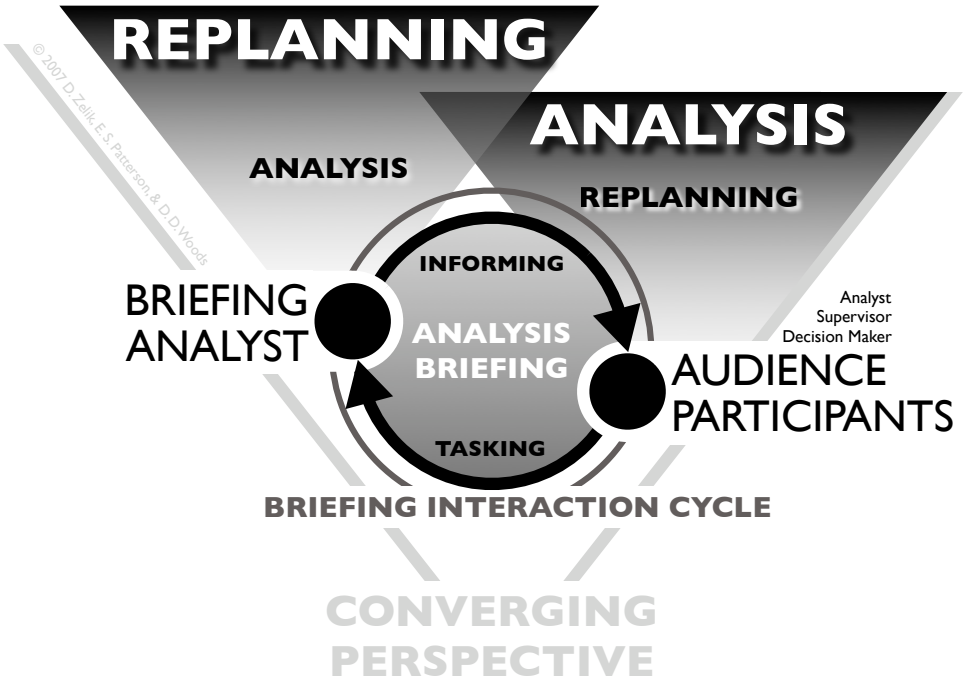

Figure 2. The Participatory Exchange Model of Briefing Interactions

There is both empirical and theoretical support for the Participatory Exchange as a promising model for briefing interactions. During the development of the study, a number of professional analysts commented that their best and most effective briefings were, in fact, more similar to conversational dialogs than to formal presentations. This observation parallels the feedback we received from study participants, as the majority of them preferred face-to-face interactions for developing an understanding of analytic process. Additionally, constructing briefing interactions as Participatory Exchanges is an approach aligned with the Laws of Cognitive Work—particularly those of Adaptation and Collaboration (Woods & Hollnagel, 2006).

Most critically, the Participatory Exchange Model, unlike the traditional model, supports the ability of both analyst and audience to visualize and understand the rigor of a process. Consequently, the interaction plays out more like a conversation —or *talking with* an audience—than a formal presentation, in which a speaker is *talking at* an audience.

The implication then, is that the audience does not end a presentation simply with a memory of a few main points, but rather they develop an understanding of the rigor of an analysis in relation to their own goals and interests. Concurrently, briefers develop a better understanding of how their analysis fits within a broader re-planning context. Thus, re-conceptualizing briefing interactions on the success model of the conversational dialog, rather than the traditional presentation, creates a flexible framework that provides a promising, innovative direction for the future of intelligence briefings.

DISCUSSION

While the research yielded a number of contributions, the most surprising aspect of the study was that none of the participants thought that either scenario-based analysis briefing was ready to send forward. This finding led to the development of the Rigor Metric, which identified eight critical indicators of rigorous analysis. In contrast with the perspective of rigor as strict adherence to process, the metric emphasizes the importance of understanding the sufficiency of rigor relative to situational factors. The Participatory Exchange Model of briefing interactions was then proposed as one way that rigor might be integrated in an applied information analysis setting. This model uses rigor as a mechanism for enhancing the connection between analyst and decision makers by re-envisioning the nature of their formal interactions.

Conclusions

Perhaps the most prominent issue still left unresolved is determining how well the findings of this intelligence-based research generalize to other areas of information analysis. For example, the Rigor Metric, though tailored for intelligence analysis, is well-suited to be refined and tested in other information analysis contexts. Similarly, the Participatory Exchange Model has not yet been the focus of a formal study, but also shows a significant potential to be applied in domains beyond intelligence analysis. While the extent to which these findings will generalize are yet unclear, this research has revealed promising directions for understanding how the concept of rigor plays a significant role within information analysis.

This collection of research builds on some of the initial insights into rigor revealed through the study of engineering safety analyses. Taken as a whole, the findings serve to further the understanding of rigor in intelligence analysis—and by extension the understanding of rigor in information analysis more generally—which is critical to confronting the risk of shallow analysis. As noted previously, across information analysis domains it is a persistent challenge for real decision makers and analysts to recognize when shallow, low-rigor analyses are insufficient, given an uncertain and dynamic world. A better understanding of rigor provides an analytic broadening check to be leveraged against this constant risk.

ACKNOWLEDGMENTS

This research was supported by the Department of Defense (BAA-001-04). The views expressed in this article are those of the authors and do not represent those of the Department of Defense. We thank our sponsor contacts for their assistance in coordinating this research effort, as well as the professional analysts who participated in the study. We also thank the analysts and domain specialists who assisted in the development of the study design and in the refinement of the Rigor Metric. Finally, we would like to thank those who participated in the 2006 CPoD Institute for Collaborative Innovation—in particular, Dan Kidwell, Robert Stephens, Richard Teynor, and Eric Aagard—that contributed to the development of the Participatory Exchange Model and the Rigor Metric visualization.

REFERENCES

Columbia Accident Investigation Board. (2003). *Columbia Accident Investigation Board report*. Washington, DC: U.S. Government Printing Office.

Crippen, D. L., Daniel, C. C., Donahue, A. K., Helms, S. J., Livingstone, S. M., O'Leary, R., & Wegner, W. (2005) Annex A. 2: Observations by Dr. Dan L. Crippen, Dr. Charles C. Daniel, Dr. Amy K. Donahue, Col. Susan J. Helms, Ms. Susan Morrisey Livingstone, Dr. Rosemary O'Leary, and Mr. William Wegner. In Return to Flight Task Group (Eds.), *Return to Flight Task Group final report* (pp. 188–207). Washington, DC: U.S. Government Printing Office.

Duelfer, Charles. (2004). *Comprehensive report of the Special Advisor to the DCI on Iraq's WMD*. Washington, DC: U.S. Government Printing Office.

Elm, W., Potter, S., Tittle, J., Woods, D. D., Grossman, J., Patterson, E. S. (2005). Finding decision support requirements for effective intelligence analysis tools. In Proceedings of the *Human Factors and Ergonomics Society 49th Annual Meeting*. Santa Monica, CA: Human Factors and Ergonomics Society.

Johnson, Rob. (2005). *Analytic culture in the US Intelligence Community: An ethnographic study*. Washington, DC: U.S. Government Printing Office.

Josephson, J. & Josephson, S. (1994). *Abductive inference*. New York: Cambridge University Press.

McKean, Erin (Ed.). (2005). *The new Oxford American dictionary* (2nd ed.). Oxford: Oxford University Press.

Medina, Carmen A. (2002). The coming revolution in intelligence analysis: What to do when traditional models fail. *Studies in Intelligence: Journal of the American Intelligence Professional*, *46*, Article 03. Retrieved February 10, 2007, from https://www.cia.gov/csi/studies/vol46no3/article03.html

Military Operations Research Society. (2006, July 19). Terms of reference. In *Bringing Analytical Rigor to Joint Warfighting Experimentation*. Retrieved February 27, 2006, from http://www.mors.org/meetings/bar/tor.htm

Miller, J. E., Patterson, E. S., & Woods, D. D. (2006). Elicitation by critiquing as a cognitive task analysis methodology. *Cognition, Technology and Work*, *8*, 90–102.

National Commission on Terrorist Attacks. (2004). *The 9/11 commission report: final report of the National Commission on Terrorist Attacks upon the United States*. Washington, DC: U.S. Government Printing Office.

Patterson, E. S., Roth, E. M., & Woods, D. D. (2001). Predicting vulnerabilities in computer-supported inferential analysis under data overload. *Cognition, Technology and Work*, *3*, 224–237.

Schum, David A. (1987). *Evidence and inference for the intelligence analyst* (Vol. 1). Lanham, MD: University Press of America.

Tufte, Edward R. (2003). *The cognitive style of PowerPoint*. Cheshire, CT: Graphics Press LLC.

Ward, Steven. (2002). Counterpoint to "The coming revolution in intelligence analysis": Evolution beats revolution in analysis. *Studies in Intelligence: Journal of the American Intelligence Professional*, *46*, Article 04. Retrieved February 10, 2007, from https://www.cia.gov/csi/studies/vol46no3/article04.html

Woods, D. D. (2005). *Creating Foresight: Lessons for resilience from Columbia*. In W. H. Starbuck and M. Farjoun (Eds.), Organizing at the limit: NASA and the Columbia disaster. Malden, MA: Blackwell.

Woods, D. D. & Cook, R. I. (2003). Mistaking Error. In M. J. Hatlie & B. J. Youngberg (Eds.), *Patient safety handbook* (pp. 95–108). Boston: Jones & Bartlett.

Woods, D. D. & Hollnagel, E. (2006). *Joint cognitive systems: Patterns in cognitive systems engineering*. New York: Taylor & Francis.

Woods, D. D., Patterson, E. S., & Roth, E. M. (2002). Can we ever escape from data overload? A cognitive systems diagnosis. *Cognition, Technology and Work*, *4*, 22-36.