A Collaboration Evaluation Framework

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Keywords: Multi-INT/fusion, Information Sharing and Collaboration, Usability/Habitability

Abstract

This paper presents a conceptual framework and an associated evaluation methodology and metrics for evaluating the effectiveness of collaborative environments, which include physical, organizational, and behavioral as well as technological elements. The framework provides: 1) descriptive dimensions for characterizing the nature of a collaborative process, 2) evaluative metrics regarding how technology fits a collaborative process, and 3) prescriptive guidance on how new technology can be integrated with changes to organizational characteristics to improve the performance to cost ratio. The framework is being applied to research evaluating multi-intelligence collaborative environments.

1. Introduction

Geographically-distributed teams are becoming an increasing part of how intelligence analysts work. Various tools are being developed to help these teams of analysts collaboratively accomplish their tasks. Some generic tools, such as InfoWorkSpace, Groove and Sametime are intended to support collaboration but not intelligence analysis specifically. Other analysis specific tools, such as Structured Evidential Argumentation System (SEAS) and Critical Intent Model (CIM), are being used collaboratively. This paper presents a conceptual framework for evaluating the collaboration-effectiveness of both of these classes of tools.

Consider a simple collaborative multiple-intelligence analysis (MIA) task for example. An ad hoc team of analysts at different locations, each expert in a particular form of intelligence (e.g., IMINT, COMINT, and HUMINT), must work together to develop a description of a target. Their basic joint task is to translate raw intelligence from their individual domains into a joint description of the target's location and vulnerabilities. To do this the analyses of images, communications and espionage may need to be compared and combined to validate the description.

Key to evaluating the impact of technology on such a joint task is understanding that there are actually three points of impact. In any task, technology can facilitate the task process itself, such as automating the screening of communications for information of interest. In a joint task, technology can also support collaborative behaviors that facilitate jointly doing the task process, such as notification of others when one participant has a significant piece of information to add to the description. Also in a joint task, technology can support task transmissions among the joint task participants, such as rationalizations or justifications for analysts' findings, which are needed to facilitate complete understanding. It is the combination of all three impacts that ultimately determines task performance and task cost.

Our conceptual framework shows how the characteristics of the joint task process are related to the collaborative behaviors and task transmissions of the participants. This allows us to evaluate a technology's impact in all three areas. Most importantly, it allows us to assess the potential for technology to change the collaborative characteristics of the joint task, resulting in less costly forms of collaboration and improved performance.

The rest of this paper presents our conceptual framework. The framework presentation is organized in terms of the mutually constraining task dimensions that define the joint task process. We rely heavily on Thompson's

(1967) seminal work describing the types of task environments in which organizations function, and the dimensions of coordination, task processes, and interdependence found in organizational processes. Applying ideas from Clark (1996) we further decompose the classes of coordination into collaborative behaviors. We extend this framework further by integrating concepts of joint situation awareness. Task transmissions are defined by the objective of the task; for brevity we will not discuss these in detail.

2. Types of Coordination

Thompson (1967) defines three types of coordination: *standardized*, *planned*, and *mutual adjustment*.

Under *standardization*, there are established rules or routines for how people should coordinate their activity. As with traffic rules, standardization improves performance per unit cost, by reducing coordination costs in both financial and cognitive terms because rules remove many uncertainties about how people should coordinate their behaviors. Standardization functions best in stable task environments.

In some task environments (e.g., when an MIA team must produce various kinds of reports), team members must *plan* their coordination processes based on the task at hand. They will establish task-dependent schedules, work assignments and milestones.

When the task environment doesn't lend itself to standardization or even planning, team members have to coordinate through continuous *mutual adjustment* to each others' activities. This requires constant communication to make sure that coordination requirements (and expectations) are clear and that activities are performed with minimal confusion and maximum benefit. As a result, mutual adjustment is the most costly form of coordination. This can happen, for example, when the task environment is very dynamic and unpredictable.

3. Collaborative Behaviors

Clark (1996) describes the behaviors that people engage in to carry out joint actions, like a conversation. Extrapolating from Clark at least eight collaborative behaviors can be identified:

- Connection – locating with whom to collaborate and how to contact them
- Transmission – sending a message
- Notification – alerting the intended party of an incoming transmission
- Identification – designating the sender, receiver, and subject of a transmission
- Common Ground Preservation – establishing and maintaining a shared context and meanings in transmissions
- Confirmation – notifying the sender of a transmission that it has been received
- Synchronization – orchestrating actions to facilitate joint action
- Election – group process of selecting among alternatives

Each type of coordination requires a different subset of collaborative behaviors.

Consider a situation, where an MIA team must compare and combine analyses to validate target characteristics (like its location) whenever one analysis is insufficient. The occasions when such combination is needed may be unpredictable as well as just which members need to coordinate.

If the team coordinates through mutual adjustment, they will need to identify with whom to connect, notify them when information has been sent, transmit and identify the nature of the information, confirm that the information has been received and any subsequent synchronization of when to respond to it.

In contrast, if they can standardize on a shared database, with a standardized schema, with synchronized postings, then additional human actions for connection, notification, confirmation, and synchronization can be virtually eliminated. So, technology (in this case a shared database) actually can facilitate moving from the more numerous (and therefore more costly) mutual adjustment behaviors to less expensive (and faster) standardization.

At this point, we can see that the effectiveness of different tools to support coordination depends on (1) the type of coordination used to perform a task, (2) how many of that type's required collaboration behaviors are supported by the tools, (3) how well that support is implemented in terms of human factors and cognitive usability, but also (4) can the tool facilitate moving to a new task concept of operation with less expensive coordination.

4. Types of Task Processes[1]

Thompson (1967) identified three general types of task processes: *long-linked*, *mediating*, and *intensive*.

Long-linked processes require the completion of various task activities over time, like an assembly line. The overall MIA is a long-linked process in that collection must precede analysis, which precedes production.

Mediating processes link together individuals or groups that want to be interdependent for their mutual benefit, like a broker mediates between those who to buy and sell stock. In MIA, one agency may play a mediating role connecting those that have target intelligence with those that have strike resources.

Intensive, task processes are directed toward changing an object, where the specific actions taken depend on feedback from the object. Military operations are intensive processes, where the next operation against a target is dependent on the effects of earlier operations.

At this point, one can see a relationship between coordination and task process (long-linked and standardization, intensive and mutual adjustment), but this relationship is not deterministic. The other organizational and environmental dimensions must be considered as well. Also, as noted in the previous section, technology can change this relationship too.

5. Types of Interdependence

Thompson (1967) identified three general types of interdependence among unit personnel and organizational units: *pooled*, *sequential*, and *reciprocal*.

In *pooled* interdependence, each team member or unit provides a discrete contribution to the whole by collating (or pooling) its obtained information and knowledge. Conceptually, this is represented in the MIA task by individual intelligence analysts contributing to a shared database. Analyst A collects his intelligence, Analyst B collects hers, and the pooled products create a common picture. Although the final product depends on the activities of each analyst, the individual analysts' work is not necessarily dependent on each others' activities.

In *sequential* interdependence, however, the product of one unit (or person) is dependent upon the output of another. This is illustrated by a Request for Information (RFI) process. The responding agency takes no action unless a request is received; the requesting agency can not proceed until its request is fulfilled.

[1] Called *technologies* by Thompson

Finally, in *reciprocal* interdependence, units pose critical contingencies for each other that have to be resolved before taking action. Operations and logistics often have a reciprocal interdependence. Whether or not different operations can be undertaken depends on the availability of certain resources and, in turn, the availability of those resources depends on previous and planned operations. Therefore, operations and logistics pose critical contingencies for each other that have to be addressed reciprocally during planning.

6. Situation Awareness

Endsley (1995) has identified three levels of situation awareness (SA).

Level-1 SA is the perception of information. For example, it is having the awareness of where different battlefield objects (enemy and friendly) are located on the battlefield at different times.

Level-2 SA is the comprehension of meaning. It addresses what the Level 1 situation awareness means currently; for example, what actions the enemy is currently capable of performing.

Level-3 SA is the projection of the situation over time. It is the awareness of what could happen in the future under various contingencies.

Level 1 is the basic awareness of available information. It answers the question, "What information do we have about the enemy?" or "Where are the friendly forces?" It is information that can be placed in a database (or pooled) for use by others because it has a global, non-situated frame of reference. In contrast, Level-2 and level-3 SA address the meaning of the information in the present and future with respect to available courses of action. Level-2 and level-3 SA require a situated frame of reference with respect to available courses of action. This makes pooling level-2 and level-3 information across organizations problematic, and so interdependence regarding information at these levels tends to be sequential or reciprocal. This can be seen in the operations-logistics situation described previously

At this point, we have enough of a framework to describe how task characteristics determine whether each team member requires complete or partial situation awareness. Distributed team members performing long-linked tasks using pooled interdependence and standardized coordination only require partial Level-1 SA because they only need to generate Level-2 and level-3 SA from their own perspective for the team to perform well. In contrast, distributed team members performing an intensive task using reciprocal interdependence and coordinating through mutual adjustment to each others' actions require complete Levels 1, 2, and 3 SA to collaborate effectively. Most team performance research has examined this type of task (e.g., McNeese, et al., 2001).

7. Task Environment

An organization or task process exists within a context, its task environment. Thompson (1967) identifies two dimensions that are critical to the way an organization is structured.

The first is the *stability* of the environment – how quickly the elements in the environment change. Our discussion of situation awareness suggests that this dynamism can be considered at the three different levels. For example not only how quickly the battlefield entities change (level 1), but also how sensitive the situation (level 2) is to those changes, and how sensitive the projected future (level 3) is to changes in the situation.

The second dimension is *heterogeneity* – how many different kinds of entities (and by analogy situations and futures) does the organization need to deal with. Thompson proposes that in order to reduce uncertainty to manageable levels, organizations should divide their environment into subdivisions that are as stable and homogenous as possible, and they should create separate organization units (e.g., different INTs) to deal with each subdivision.

Two potential benefits of collaborative technology is permitting teams to (1) respond faster and, thereby, deal with more dynamic situations than previously possible (e.g., more mobile targets), and (2) facilitate collaboration among more units addressing different subdivisions of the environment, thus creating greater capabilities.

8. Conceptual Evaluation Metrics

These concepts regarding organizations, their behaviors and environments provide a framework for evaluating the effectiveness of collaborative tools to support joint tasks. Summarizing the considerations discussed above suggests that effectiveness can be considered from two major perspectives. First, given a joint task process' concept of operations (CONOP), how well does a tool (or suite of tools) support the collaborative behaviors required by that CONOP? Second, and perhaps more importantly, given a joint task objective, does a tool (or suite of tools) facilitate a task CONOP that improves the performance to cost ratio over past CONOPs under previous technology?

Coordination via mutual adjustment requires more collaborative behaviors than standardized or planned coordination. Does the tool support all the collaborative behaviors required for the particular type of coordination required by the task? And even if the tool supports the behaviors, how well does it support them from a human factors perspective? If the tool is not easy to use, it will not effectively support the required collaborative behaviors. Similarly, to what extent and how well does a tool support the necessary task transmissions? Supporting the development and confirmation of shared SA is a critical task transmission for distributed collaborative teams, but there are others (e.g., the rationale for course of action development and evaluation) that may be important to evaluate given the task environment and level of interdependence among organizational units.

It is common for personnel to learn only the minimum necessary features for using a tool. We have even seen this happen where team members are trained on how to operate a tool's buttons and menus, but not how to effectively use it to address the required behaviors of the task (let alone how to change the CONOP of the task). Therefore, from the first perspective above, a tool can appear to be ineffective, even if it effectively supports required collaborative behaviors and task transmissions, because team members do not know how to use the tool within the best task context.

From the second perspective, one should evaluate the extent to which the current task CONOP is the best task CONOP given available technology. Or to say it differently, can the task be done differently given the new collaborative technology? As was suggested in the different MIA coordination alternatives discussed previously, that task could be done expensively using mutual adjustment, or less expensively through standardization facilitated by a shared database.

One also needs to evaluate both performance and cost. Does the collaborative technology help the team perform better and faster than it could without the technology? Is the performance enhancement comprehensive, leading to improvements in all aspects of the information and decision requirements? Is it timely, not just faster, in terms of ensuring that the requirements are met within the required timeframe given the stability of the task environment? On the other hand what are the costs, in terms of coordination, communication, and task processes? Conceptually, one can measure coordination costs by measuring the number and frequency of the different types of collaboration behaviors required to perform the task, communication costs by assessing the types and amount of information transmitted, and process costs by the number and types of task steps.

Collaborative technology has the potential to improve outcome performance while reducing coordination, communication, and process costs. But it depends on developing the best task CONOP for performing the joint task and its component subtasks, given the collaborative tools and the best way to use them in the task context.

The goal of all technology development is to improve task performance; our conceptual evaluation framework is directed toward providing feedback to help developers achieve that goal in the more complex joint task environment.

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