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CONCEPT MAPS AND WAGON WHEELS: MERGING METHODS TO IMPROVE THE UNDERSTANDING OF TEAM DYNAMICS

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Abstract. The study of team performance using knowledge elicitation methods can result in the proliferation of large amounts of data. While methods such as the Wagon Wheel Method have been devised to facilitate knowledge elicitation, they often underspecify analysis protocols for dealing with large datasets. Moreover, the representation of the analysis poses challenges for transforming the knowledge gained during elicitation into applications. This paper explores the merging of the Wagon Wheel Method with Concept Mapping to enhance the study of team dynamics and performance. Recommendations for new elicitation, analysis, and representation techniques are offered using notional and real-world datasets. The resulting merged method can be useful for developing and presenting both overarching and intimate knowledge of teams.

1 Introduction

Knowledge elicitation about team dynamics hinges on an important principle: the knowledge elicitor's understanding of the team will be broader and deeper than that of any of the members of the team under study. A primary advantage of studying teams is to provide just this overarching and intimate look at the way teams operate in both effective and ineffective ways.

However, any serious study of team performance will result in an abundance of data. Methods of Cognitive Task Analysis have been developed to enable the elicitation of team dynamics, yet analysis methods are often underspecified, or complicated by the sheer volume of data (Klinger & Hahn, 2002; 2003). Even with a well-specified protocol for analysis, a challenge remains in conveying in a meaningful way the knowledge gained—that is, in moving from analysis to representation. This is particularly challenging if the purpose of conveying the knowledge is to inform an application of it, perhaps for organizational redesign, or developing training or information technology support systems. Static representations (e.g., organization charts) can often portray the breadth of understanding, but can be limited in the depth to which they can demonstrate what has been learned. Dynamic representations (e.g., process models), while enabling demonstration of the "way things work," can also be limited to presenting a singular view of the knowledge gained, even when animations are used.

What the "knowledge analyst"—the person who makes use of the knowledge elicitor's[1] products—needs to explore and represent the breadth, depth, and dynamics of his/her understanding of teams is an analysis method that:

- enables multi-level analysis and representation of his/her knowledge elements—from the data to its highest abstractions;
- enables re-combinable views of those knowledge elements; and
- enables static representations without extracting them from their context.

This paper describes the merging of two knowledge elicitation and analysis methods—Concept Mapping and Wagon Wheel Method—to advance the state of the science in understanding teams and teamwork. Concept Maps are meaningful diagrams that are used to represent and convey knowledge (Crandall, Klein, & Hoffman, in preparation). The Wagon Wheel Method makes explicit how teams communicate. The new merged method brings together the representational format and knowledge elicitation probes of the Wagon Wheel Method and the "propositional coherence" of Concept Mapping to address the needs of the knowledge elicitor and analyst studying teams. I also demonstrate features in CmapTools[2] (Cañas *et al*., 2004), a concept mapping utility that enables analysis of teams using large datasets while incorporating the analysis guidance of the Wagon Wheel Method. I suggest that this merged method enables a deeper understanding of team dynamics and provides the knowledge analyst with powerful representations to convey what he/she has learned.

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[1] For the purposes of this paper, I treat the "knowledge elicitor" and "knowledge analyst" as two separate actors in the study of team dynamics. The knowledge elicitor collects data on team dynamics, while the knowledge analyst seeks to analyze and represent the data. In actual practice, these roles are often not separate.
[2] http://cmap.ihmc.us/

2 Concept Mapping

As Hoffman notes in Crandall et al. (in preparation), Concept Maps "can be created by individuals who wish to lay out their own knowledge or… scaffold knowledge elicitation interviews with domain practitioners." In the context of this paper, the knowledge needing to be laid out is that of a knowledge analyst studying teams.

A primary differentiator between Concept Maps and other types of diagrams is the notion of propositional coherence. A concept map is a graphic display of concept names connected by directed arcs encoding propositions in the form of simplified sentences (Cañas, Ford, Brennan, Reichherzer, & Hayes., 1995). Concept Maps involve nodes and links. Concepts are represented in nodes, and their relationships to other concepts are specified by the links between them. Thus, node-link-node triples in Concept Maps form propositions; they can be read as stand-alone simple and meaningful expressions. When all of the triples in a Concept Map are well-formed propositions, the Concept Map is said to be "propositionally coherent" (Crandall et al., in preparation). Propositional coherence is an important aspect of the merged method.

3 Wagon Wheel Method

The Wagon Wheel Method can be used to elicit data for a number of purposes and in a wide variety of settings. It was developed by Klein Associates Inc. to enable an understanding of how teams communicate, and has been employed in a number of domains. The Wagon Wheel Method "provides a quick and easy snapshot of team communications. The goal of the method is to identify the main communication channels existing for each position on the team and the nature of those communications" (Klinger & Hahn, 2003, p. 21). It is useful for dissecting information flow and identifying roles and functions, information requirements, types of information passed between team members, sources of information, decision and course of action impacts, criticality of information, and the impact of poor information flow. It can be used with highly experienced and novice subjects, in distributed and co-located teams, and in both one-on-one and group data collection sessions.

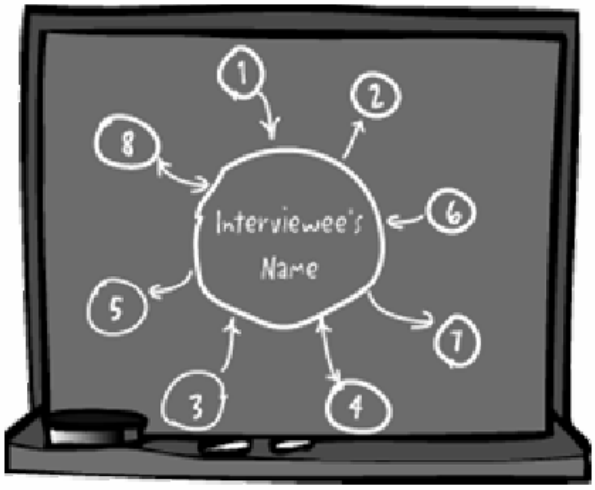

Figure 1. Wagon Wheel Method. The interviewee is the central node in a description of communication that is drawn during an interview.

Klinger and Hahn (2003) provide a detailed protocol for conducting the Wagon Wheel Method. As illustrated in Figure 1, the Wagon Wheel provides a look at a team from the perspective of individual team members. Each team member is interviewed about the other members with whom they interact. This knowledge elicitation procedure provides copious data as to the nature of the interactions by probing team members with questions such as:

- *What type of information is passed?*
- *From where did you receive the information you are transmitting?*
- *From where did he/she receive the information he/she is transmitting to you?*
- *Did you modify the information in any way? (The goal of this question is to determine if the information was simply passed in its original form or if it was altered, filtered, prioritized, etc., in any way.)*
- *What decisions does this information affect?*
- *How do you know they received the information?*
- *How do you know when to provide them with this information?*
- *Would you consider this piece of information to be critical to the team's success?*
- *What is the impact to the team if this communication line is broken?*

4 Merging Methods

The two methods, then, include key features for supporting the knowledge elicitor and analyst studying teams. The Wagon Wheel Method provides data collection protocols for eliciting knowledge and a representation format. Concept Maps require the knowledge elicitor to specify the relationships between nodes, or in the case of teams, team members.

4.1 Elicitation

The propositional coherence principle in Concept Maps provides a first step toward developing a new elicitation method. At their most basic structure, teams are groups of individuals who stand in some relationship to each other. Each team member's relationship with all of the other team members can, in some way, be specified, even if the specification is a null set (i.e., "has no relationship with").

Concept Maps can be useful in representing team organization and the nature of the relationships between team members by using the Wagon Wheel Method to guide elicitation. Knowledge elicitation can make use of Concept Maps to represent the data from the teams under study (see Hoffman in Crandall et al., in preparation, for guiding protocols for using Concept Maps in this way). Klinger and Hahn (2003, p. 21) suggest an analog approach for conducting the Wagon Wheel Method:

> The Wagon Wheel Method is best applied in a one-on-one interview setting. It is necessary to have a whiteboard or some other common point of reference for the elicitor and the interviewee to record the communication patterns.

Thus, one approach for knowledge elicitation that stems from merging methods is to make use of Concept Mapping during knowledge elicitation. The elicitor would "set up the parking lot" (Hoffman in Crandall et al., in preparation, p. 86) with the interviewee in the center and the teammates with whom he/she interacts around him/her in nodes. The knowledge elicitation session would proceed by capturing the answers to the Wagon Wheel probes in the links between nodes, as suggested in Figure 2. The directions of connections might also provide an opportunity to represent the directionality of information flow. And process interactions can also be represented. Concept Maps of each interaction could also be built post-elicitation, if the knowledge elicitor opts to use the analog whiteboard method. All of the maps can then be linked together to create a "knowledge model" of the entire team interaction.

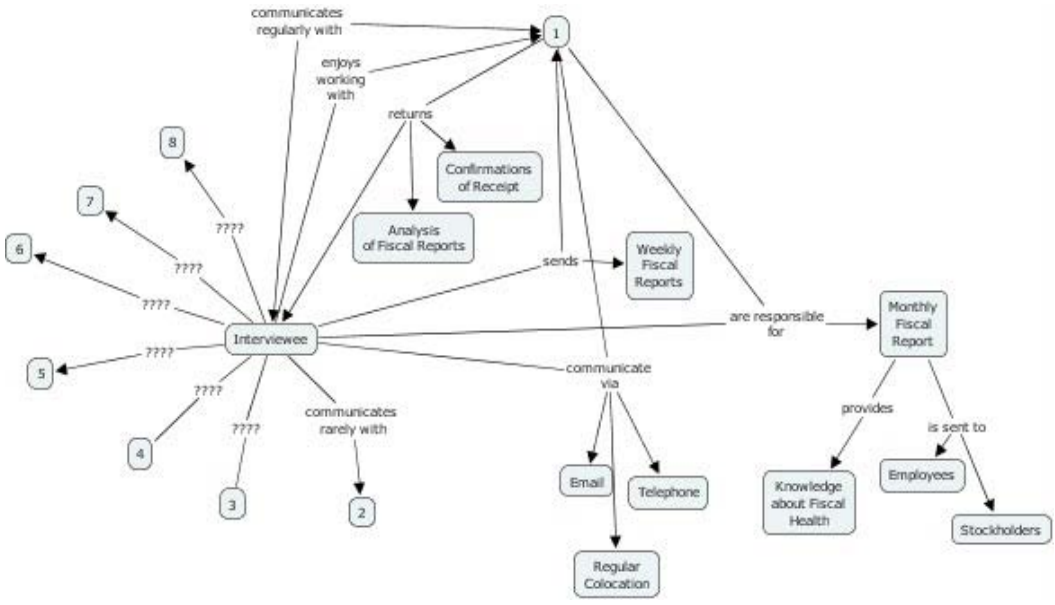

Figure 2. Using Concept Maps during elicitation.

4.2 Data Analysis

Whether capturing the knowledge elicitation with Concept Maps or using the analog whiteboard method, the real value added by merging the methods can be seen in data analysis. For data analysis, Klinger and Hahn (2003) recommended that analysts "develop the Wagon Wheel representations for each interview and then set them side-by-side. Viewing them together provides an overall view of the communications pattern. Although it can be helpful to combine the representations into one, [Klinger] found that for complex organizations this simply produced a spaghetti-like image that provided little or no data." The merged method provides a leap forward from this analysis process.

During analysis, the links emerge as the primary focus. The merged method takes the Wagon Wheel format and requires the knowledge analyst to specify the links between concepts, or team members. The Wagon Wheel calls for the elicitation of data elements in categories of information (e.g., *What type of information is passed? From where did you receive the information you are transmitting?).* An analytic judgment about these categories may serve as the link between nodes, and/or the analyst may create multiple links between concepts to represent different aspects of the interaction. Figure 3 demonstrates this level of abstraction. The data underlying the specification is not presented, but specifying multiple links provides a look at the nature of the interaction between the team members *from the point of the interviewee*. Using CmapTools the data supporting the specification of the links can be captured at the link by attaching resources (e.g., documentation of the Wagon Wheel interview, links to Concept Maps derived during knowledge elicitation).

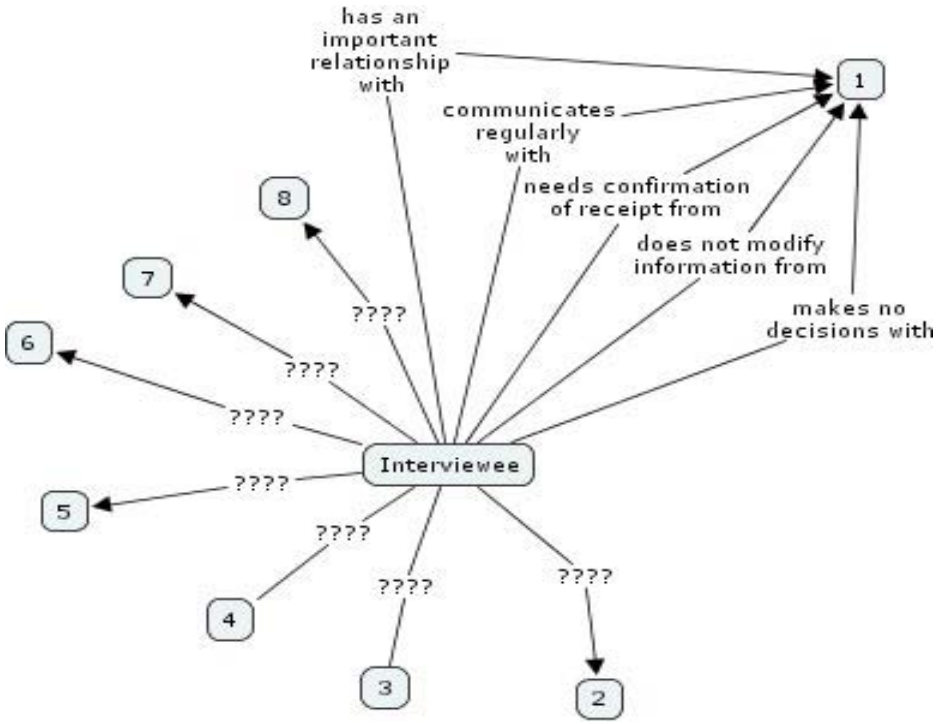

Figure 3. Using Concept Maps during analysis—first level of abstraction.

4.2.1 Nesting as an Analytic Technique

While exploring the data at this abstracted level is useful for gaining an understanding of interactions *between individual team members*, an even higher level of abstraction may be called for to truly get a feel for the workings of the team. CmapTools provides a number of features to support this type of analysis. Because multiple links may be specified between nodes, a still higher abstraction from the data can be specified. Nested nodes provide the option of building multiple links between nodes, then "combining" the links (read: children, in CmapTools parlance) and specifying the title of the cluster (read: parent, in CmapTools parlance). Figure 4 shows how this level of abstraction would be useful for exploring the team. Nesting can be used for a higher level of abstraction geared toward "typifying" interactions amongst team members. To perform this analysis

technique, the cluster of links could be nested, thereby requiring the analyst to specify the relationship into a concise, propositionally coherent triplicate. That is, upon analysis of the data, the nested link reflects a more highly specified relationship. This analysis proves particularly useful for streamlining the data into an application-ready representation, as it requires the analyst to capture the "essence" of a relationship.

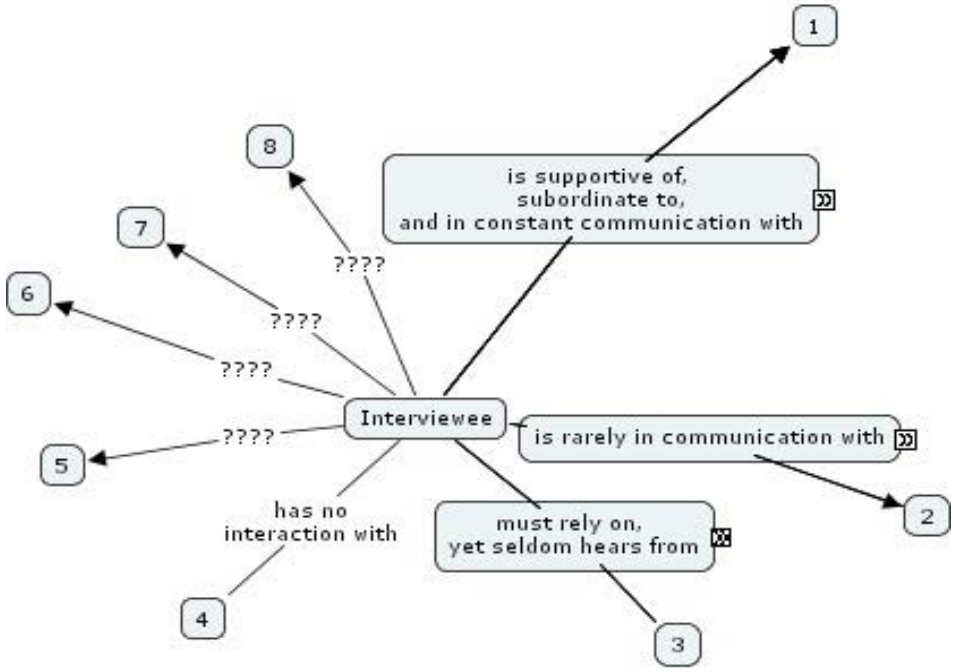

Figure 4. Using Concept Maps during analysis—second level of abstraction.

CmapTools also enable the importing of large datasets. Of particular interest for the merged method is the facility to import tab delimited text. Wagon Wheel interview data, or other data that indicates relationships between team members, may be captured into this format, then imported into CmapTools to create analysis-ready Concept Maps. Figures 5-7 present this approach via Concept Maps created with a dataset.

In February 2003, Klein Associates Inc. participated in an exercise at the Battle Command Battle Laboratory, Ft. Leavenworth, Kansas, USA. The experiment focused on the interactions among members of a brigade-level command cell (read: team), and was geared toward understanding how the members interact, and may interact in the future. Data gleaned from a collaboration support tool (GroupWise Systems) were collected during an experiment. Participants were required to enter data into the system regarding the nature of their interactions with other cell members—that is, qualitative statements characterizing their interactions with other cell members. The tool collected the data and produced it in spreadsheet format. The spreadsheets were reformatted into tab delimited text and imported into CmapTools to produce multiple Concept Maps, one for each participant. To create a "Super Concept Map" of the entire dataset, multiple Concept Maps were manually merged.

Much like the Wagon Wheel Method, the Concept Maps included the participant as one node, all of the team members with whom he/she interacted as other nodes, and his/her inputs to the collaboration tool as the links. Figure 5 demonstrates this from the perspective of the Plans Officer. It is immediately apparent from this view with whom the Plans Officer interacted in the cell. For cell/team members with whom he/she did not interact, no data were entered; thus no links were created.

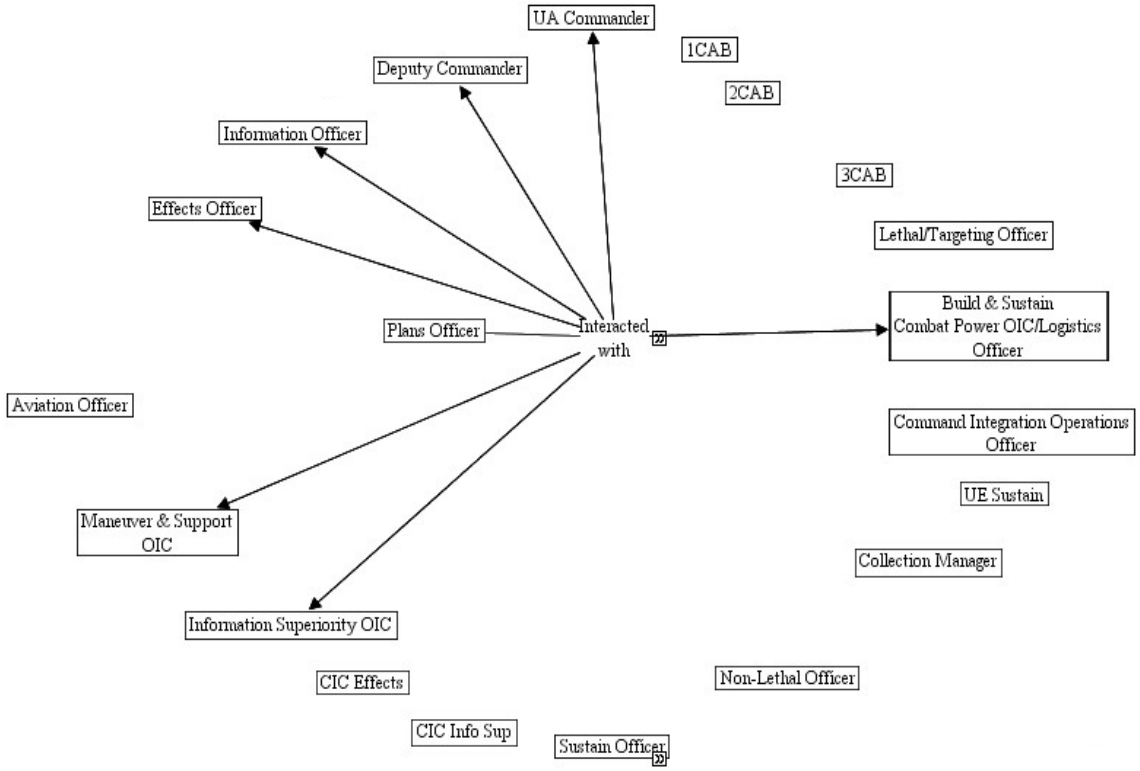

Figure 5. Using Concept Maps during analysis—imported dataset, plans officer view.

The contrasting view in Figure 6 from the UA Commander instantly demonstrates that he interacted with different team members.

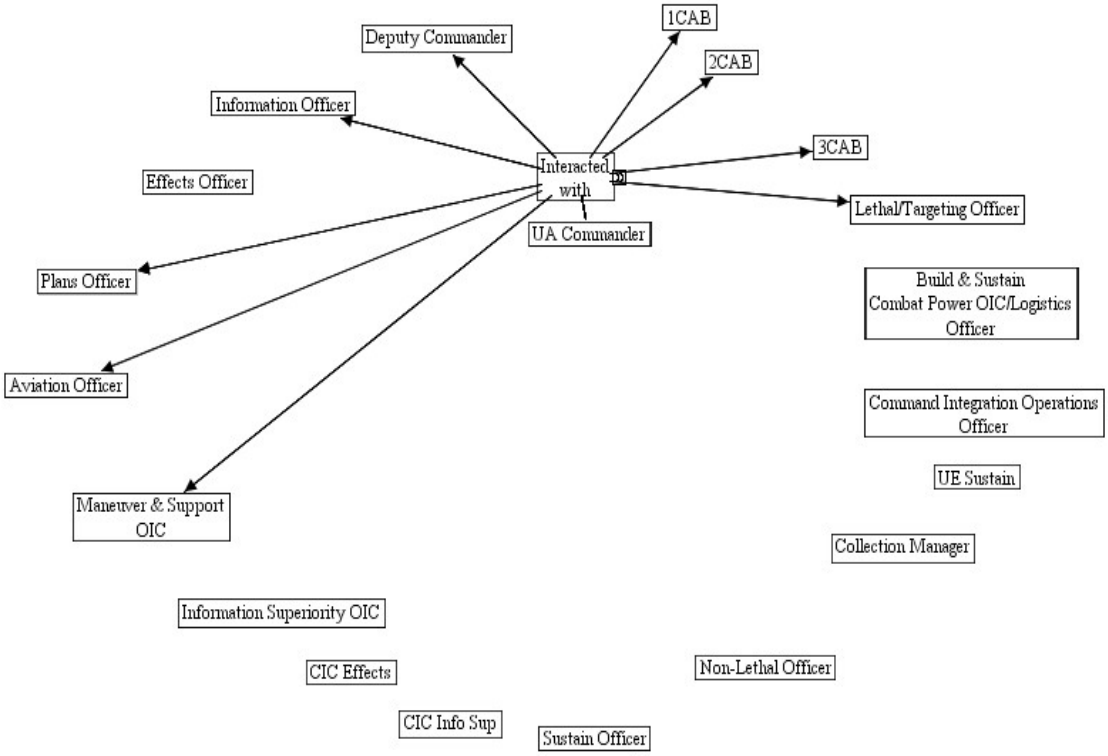

Figure 6. Using Concept Maps during analysis—imported dataset, UA Commander's view.

At this level of analysis, the data of each interaction is captured in the nested link, seen in Figure 7 for the UA Commander and his interactions with "1CAB." The nature of his interactions—as captured in his statements entered into the collaboration tool—are all captured under the nested link "Interacted with." Thus, they can be inspected during analysis on a case by case basis, or directly compared to other interactions of interest by placing them side by side.

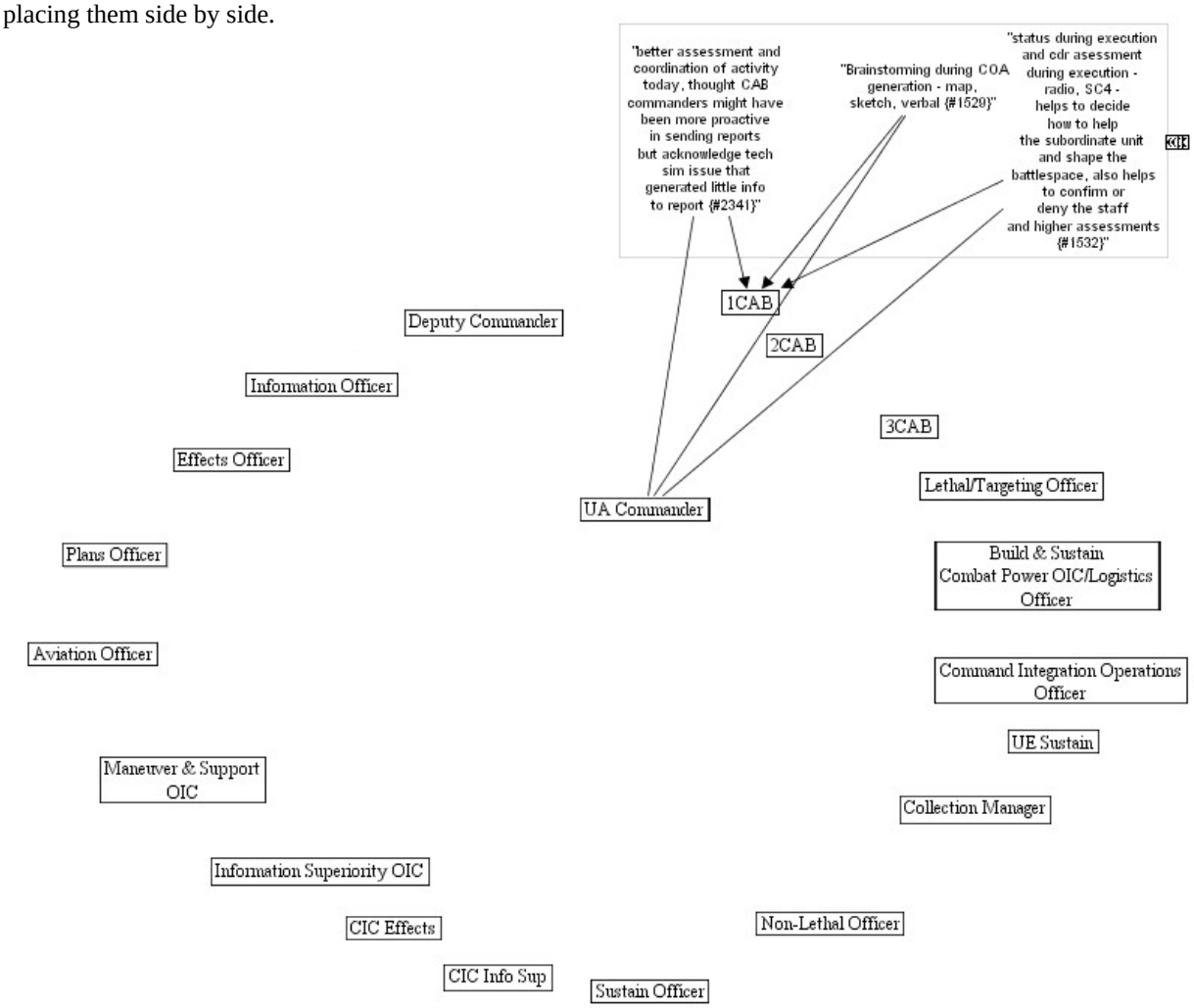

Figure 7. Using Concept Maps during analysis—imported dataset, UA Commander's interactions with 1CAB view.

5 Representation: Static Representations, and Dynamic Demonstrations Using CmapTools

As Figures 2-7 suggest, Concept Maps provide useful representations of team communications. Any interaction, or indeed interactions, between team members can be captured and displayed in a static representation. The advantages over other static representations include:

- Use of natural language (as opposed to a pre-specified modeling language)
- Appropriate specification of relationships (as opposed to wiring diagrams and organization charts that link but do not specify relationships between concepts)
- Representation of various levels of context (as opposed to the "all or nothing" analogue method of setting wagon wheels against each other).

CmapTools also provide the capability to create dynamic demonstrations. By merging multiple Concept Maps, and related resources, the knowledge analyst has the entirety of his/her dataset and analysis available. Relationships can be called into high relief, and demonstrated upon demand. Indeed, Figures 5-7 were created from the "Super Concept Map" noted above by hiding some relationships while highlighting others to produce static representations. The same "Super Concept Map" can be used to present analysis points of interest in a dynamic fashion. This self-contained, highly accessible knowledge model can prove invaluable when interacting with application developers who may want to see various levels of analysis, as well as the data elements.

6 Cautionary Notes

While the merged method clearly provides a leap forward for the Wagon Wheel Method, it must be noted that it presents at least two challenges to the emerging thought on the principles of Concept Mapping. First is the notion of morphology. While some suggest that Concept Maps should reflect a morphology "like hierarchies" (Hoffman in Crandall et al., in preparation, p. 80), others are less enthusiastic about this requirement (Cañas, personal communication, 2003). Clearly, the Wagon Wheel Method format is incompatible with this requirement.

Another challenge stems from the nested node analysis method enabled by CmapTools. Figure 7 shows the children within the nested node. Individually, these children violate the notion of propositional coherence. However, as a nested node in which the link is specified (either as an analytic statement or simply as a generic category, such as "interacted with"), propositional coherence is restored. The cautionary tale here is that the analysis product is not a Concept Map until all of the triples are well-formed propositions. This can also mark the end of the analysis!

7 Conclusion

The Wagon Wheel Method and Concept Mapping emerged out of separate fields of inquiry, for different purposes. This paper suggests that the study of teams and teamwork can be greatly enhanced by merging the best of both worlds at the stages of knowledge elicitation, analysis, and representation. The resulting merged method provides for new analytic techniques and representations that can be useful for developing and presenting both overarching and intimate knowledge of teams.

8 References

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