

*ARMY RESEARCH LABORATORY*



# **A Human-Centered Command and Control (C2) Assessment of an Experimental Campaign Planning Tool**

**by Jeffrey T. Hansberger and Craig Schreiber**

**ARL-TR-6900**

**April 2014**

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**Jeffrey T. Hansberger and Craig Schreiber**  
**Human Research and Engineering Directorate, ARL**

| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              |                         |                               | Form Approved<br>OMB No. 0704-0188                         |                                                           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-------------------------|-------------------------------|------------------------------------------------------------|-----------------------------------------------------------|
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| 1. REPORT DATE (DD-MM-YYYY)<br>April 2014                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              | 2. REPORT TYPE<br>Final |                               | 3. DATES COVERED (From - To)<br>January–December 2007      |                                                           |
| 4. TITLE AND SUBTITLE<br>A Human-Centered Command and Control (C2) Assessment of an Experimental Campaign Planning Tool                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |              |                         |                               | 5a. CONTRACT NUMBER                                        |                                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |                         |                               | 5b. GRANT NUMBER                                           |                                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |                         |                               | 5c. PROGRAM ELEMENT NUMBER                                 |                                                           |
| 6. AUTHOR(S)<br>Jeffrey T. Hansberger and Craig Schreiber                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |              |                         |                               | 5d. PROJECT NUMBER                                         |                                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |                         |                               | 5e. TASK NUMBER                                            |                                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |                         |                               | 5f. WORK UNIT NUMBER                                       |                                                           |
| 7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)<br>U.S. Army Research Laboratory<br>ATTN: RDRL-HRM-D<br>Aberdeen Proving Ground, MD 21005-5425                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |              |                         |                               | 8. PERFORMING ORGANIZATION<br>REPORT NUMBER<br>ARL-TR-6900 |                                                           |
| 9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |              |                         |                               | 10. SPONSOR/MONITOR'S ACRONYM(S)                           |                                                           |
|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |                         |                               | 11. SPONSOR/MONITOR'S REPORT<br>NUMBER(S)                  |                                                           |
| 12. DISTRIBUTION/AVAILABILITY STATEMENT<br>Approved for public release; distribution is unlimited.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |              |                         |                               |                                                            |                                                           |
| 13. SUPPLEMENTARY NOTES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |              |                         |                               |                                                            |                                                           |
| 14. ABSTRACT<br>The Defense Advanced Research Project Agency (DARPA) and the Joint Forces Command (JFCOM) developed a suite of decision support tools to enhance the capability of commanders and staffs to plan and execute effects-based campaigns. The complex environments in which commanders and staffs must operate brings in other elements besides military issues—such as political, economic, social, information, and infrastructure (PMESII). In order to better assess, understand, and explore the relevant and important issues across these operational dimensions, DARPA and JFCOM have developed the Conflict Modeling, Planning, and Outcomes Experimentation (COMPOEX) program tool suite to support the commander and staffs (Corpac, P. S.; Frisbie, K.; Saur, J.; Gingrich, J. R. Integrated Battle Command Experimentation: Evaluating Transformational Concepts and Cutting Edge Technology in an Operational Environment. Command & Control Research & Technology Symposium; CCRTS: San Diego CA, 2006). Across the development of this tool suite, multiple limited objective experiments (LOEs) were conducted to test and assess the progress and effectiveness of one or more of the tools. This report describes the LOE addressing the Campaign Planning Tool–Light (CPT–L) and its results. |              |                         |                               |                                                            |                                                           |
| 15. SUBJECT TERMS<br>COMPOEX, planning, operations, PMESII, DIME, tool effectiveness, tool usability, situation understanding, shared situation understanding, workload, cognitive maps, collaboration, Pathfinder, social network analysis                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |              |                         |                               |                                                            |                                                           |
| 16. SECURITY CLASSIFICATION OF:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |              |                         | 17. LIMITATION<br>OF ABSTRACT | 18. NUMBER<br>OF PAGES                                     | 19a. NAME OF RESPONSIBLE PERSON                           |
| a. REPORT                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | b. ABSTRACT  | c. THIS PAGE            |                               |                                                            | Jeffrey T. Hansberger                                     |
| Unclassified                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  | Unclassified | Unclassified            | UU                            | 38                                                         | 19b. TELEPHONE NUMBER (Include area code)<br>256-273-9895 |

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## 1. Overview

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The Defense Advanced Research Project Agency (DARPA) and the Joint Forces Command (JFCOM) developed a suite of decision support tools to enhance the capability of commanders and staffs to plan and execute effects-based campaigns. The complex environments in which commanders and staffs must operate brings in other elements besides military issues—such as political, economic, social, information, and infrastructure (PMESII). In order to better assess, understand, and explore the relevant and important issues across these operational dimensions, DARPA and JFCOM have developed the Conflict Modeling, Planning, and Outcomes Experimentation (COMPOEX) program tool suite to support the commander and staffs (Corpac et al., 2006). Across the development of this tool suite, multiple limited objective experiments (LOEs) were conducted to test and assess the progress and effectiveness of one or more of the tools. This report describes the LOE addressing the Campaign Planning Tool–Light (CPT–L) and its results.

The COMPOEX LOE 2-1 was designed to test how well the CPT–L was able to capture a plan through a computer-mediated tool without providing additional workload and requirements on the users. The primary objective was examined through an analysis of both the planning process and the planning product produced within the one-day event. The results in the areas of planning, setting objectives and alternatives, and situation understanding show that the CPT–L was as effective—if not more effective—in facilitating the *planning process* compared to a team using more traditional tools and methods. The quality of the *planning product* produced was not able to be fairly compared due to several unanticipated confounds of the experiment directly affecting them and therefore creating an unfair comparison. None of the results alone provide definitive results, but the converging nature of the planning process data all in the same direction suggests a beneficial role of the CPT–L in the planning process. In order to effectively assess the impact of the CPT–L on the product of the planning process, additional training for CPT–L users is required to create equal expertise with the tools being used across both teams and equal amounts of planning time and manpower available is also required.

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## 2. Introduction

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In order to explore and consider the full range of military and nonmilitary capabilities across different levels, a much broader approach that considers other elements other than military issues must be taken. The PMESII elements related to the region and situation need to be considered by the commander and staff during planning and mission preparation. In order to facilitate the

consideration of a much wider realm of issues, effects, and implications, DARPA and the JFCOM collaborated in the design of the COMPOEX tool suite. One of the tools intended to support and augment PMESII planning is the CPT-L.

The CPT-L was designed to augment strategic planning by creating an easy to use interface that promotes collaboration across lines of efforts within the planning framework. The CPT-L tool allows the planner to define relevant PMESII actions and effects across various courses of actions if there are more than one (e.g., governance, economic, rule of law). The interface is similar to Microsoft Project\* as actions and effects are placed on a user-defined timescale with durations identified for each action (figure 1). The specific CPT-L capabilities designed to improve planning are:

1. A semistructured environment for planning tasks (e.g., drawing lines of effort, defining objectives, defining durations, defining interdependencies).
2. Ability to visualize and merge multiple lines of effort.

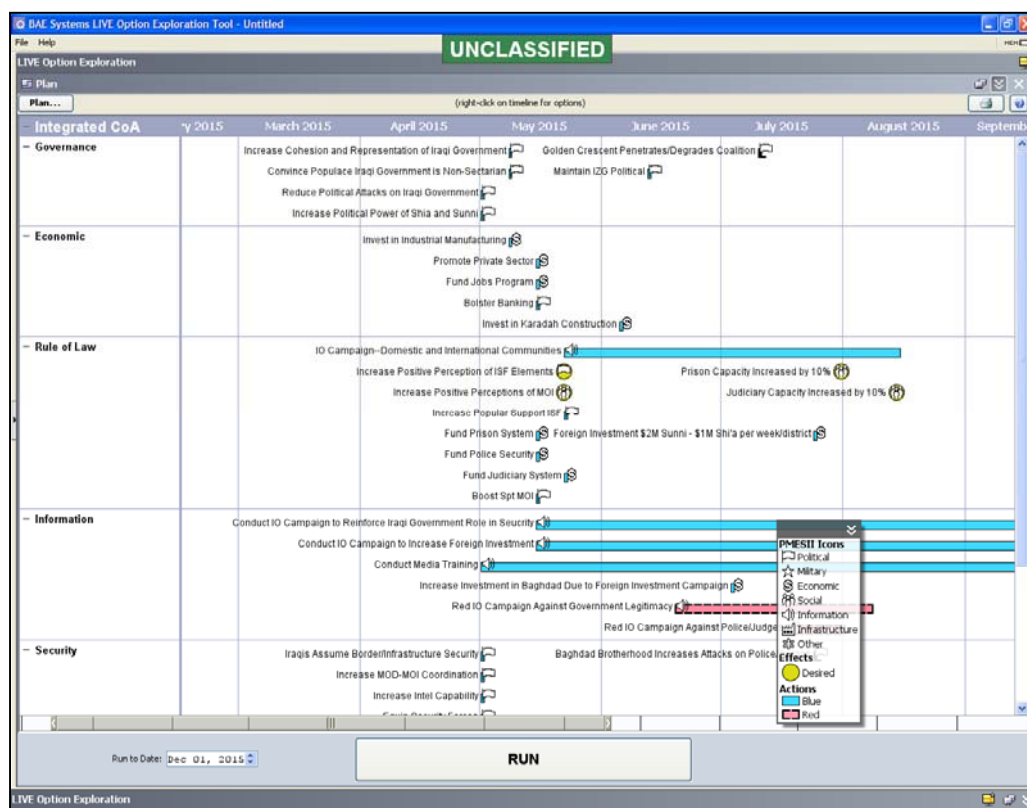


Figure 1. Example of the CPT-L interface.

These capabilities are hypothesized to positively influence several general functions of Command and Control (C2) or mission command identified by Van Creveld (1985), which have

\* Microsoft Project is a trademark of Microsoft Corporation.

also been tied to the theoretical distributed cognition framework (Hansberger, 2008). The semistructured environment is hypothesized to improve performance by facilitating the user's ability to manipulate data and therefore reduce workload. The ability to visualize and merge multiple lines of effort is hypothesized to improve identifying objectives and working out alternative means for obtaining those objectives along with improving the planning teams' situational understanding. Both capabilities are hypothesized to positively influence the actual planning process (figure 2). Three of the four identified C2 functions were tested in this study including data manipulation, planning, and situation understanding.

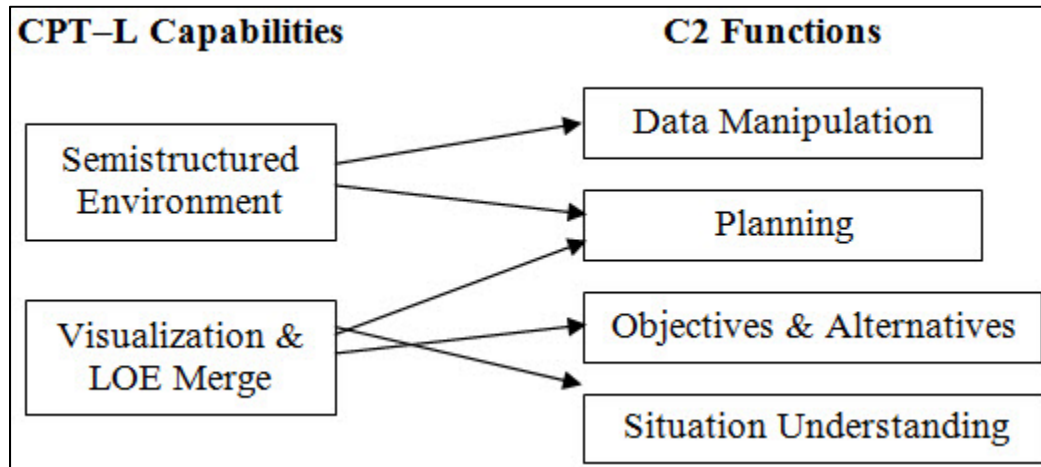


Figure 2. CPT-L capabilities mapped to general C2 functions.

### 3. Method

#### 3.1 Participants

There were a total of 11 participants for LOE 2-1. They consisted of four Senior (Sr.) Mentors and seven active military planners and were divided into two teams of five and six members with a supervisor over both groups. The two groups represented the experimental (team with the CPT) and control (team without the CPT) groups. The two groups were designed to have an equal number of members; however, one member of the experimental team was not able to attend and there was not adequate time to obtain a replacement. Team members were divided across the teams to balance domain expertise, quantity of experience, and Sr. Mentor/Planner status. Among the Sr. Mentors for each team, one had an extensive military background and the other had an extensive government (non-Department of Defense) background.

### **3.2 Materials**

Each team had access to six computers with Microsoft Office\* (including MS Project) installed, Internet access for the CPT–L team only to enable the CPT–L (no access to external Internet sites), and a projector connected to one of the six computers. There were whiteboards and corkboards provided for the non-CPT–L team along with Post-it\* notes. Each team was located in separate rooms. A digital camera was used to capture whiteboard drawings and use of the corkboards. The pictures were used by the researchers to analyze the planning process and outcomes.

### **3.3 Design and Procedure**

An experimental versus control group design was implemented. The manipulation was the planning tools provided to each team, the experimental team had the CPT–L and the control team did not have the CPT–L. The dependent variables examined include variables for planning, data manipulation, situation understanding, and usability. Training developed by BAE Systems on the CPT–L was conducted at the beginning of Part I for the CPT group and at the end of Part I for the non-CPT group.

The training session lasted for 15 minutes (min) and was presented to the CPT–L team as a slide presentation without active participation by the CPT–L members. Additional time that approached 45 min with the CPT–L developers was required before the CPT–L members felt comfortable with the tool and began entering planning data. This occurred at the beginning of the planning task.

Each planning team was asked to review read-ahead materials that describe the Chad scenario situation and background information. They were given a brief overview of the experiment plan during the orientation (figure 3). In the read-ahead materials, the team members received the policy aims, interim states to be achieved, four lines of effort, and some pre-established objectives and effects. The overall planning task was to begin planning for a comprehensive strategy of transformation across four lines of effort (political, security, rule of law, and political economic), which lasted for 4 hours (h) and 15 min and extends across the CPT/Control Planning and Transference and Combine, Sequence, and Deconflict portions of the timeline (figure 3). The plenary session at the end involved both groups discussing their experiences with and without the tools.

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\*Microsoft Office is a trademark of Microsoft Corporation.

\*Post-it is a registered trademark of 3M.

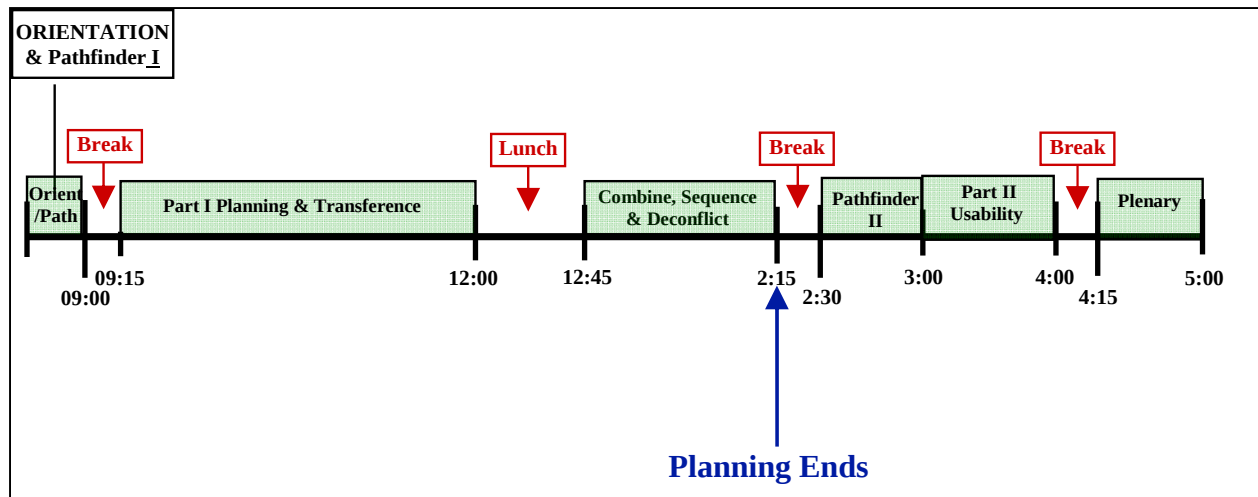


Figure 3. LOE day one timeline.

### 3.4 Planning Measures

#### 3.4.1 Observer Ratings (Product Focus)

The final plans from both teams were presented to two subject matter experts (SMEs) in the same format. The SMEs evaluated the two plans while blind to the experiment conditions. The SMEs evaluated the plans across six planning-relevant dimensions that included: (1) Consistency, (2) Robustness, (3) Conflicts, (4) Comprehensiveness, (5) Probability for plan success, and (6) Plan Quality (see appendix).

#### 3.4.2 Social Network Analysis

Social network analysis is based on network theory, which uses graphs as a representation of symmetric or asymmetric relations between discrete objects (Scott, 2000). The graph is a mathematical structure to represent pairwise relations between objects. Placed within a social context of humans and their interactions, a social network is a set of individuals (i.e., nodes) connected through social interactions such as face-to-face or email communication (i.e., links). The analysis of these social networks consists of a family of relational methods to systematically uncover patterns of interconnectedness.

### 3.5 Data Manipulation Measure

#### 3.5.1 Workload

The CPT-L was designed to modify the way planners interact and manipulate information and plan relevant data through its semistructured planning environment. The CPT-L interface was hypothesized to reduce the workload of the participants using the tool. Members of both teams completed the National Aeronautics and Space Administration (NASA) Task Load Index (TLX) subjective evaluation of their workload after their planning activities (Hart and Staveland, 1988).

NASA TLX is a subjective workload assessment tool that allows users to perform subjective workload assessments on operator(s) working with various human-machine systems. NASA TLX is a multidimensional rating procedure that derives an overall workload score based on a weighted average of ratings on six subscales. This can be completed in a short amount of time through a simple computer program.

- “Mental demand” refers to how much mental and perceptual activity was required (thinking, deciding, calculating, remembering, looking, searching, etc.) during the task. The respondent should consider whether the task was easy or demanding, simple or complex, or exacting or forgiving.
- “Physical demand” measures the required physical activity in relation to whether the task was easy or demanding, slow or brisk, slack or strenuous, or restful or laborious.
- The amount of experienced time pressure is measured by the “temporal demand” subscale. It addresses issues such as whether the pace of interaction was slow and leisurely, or rapid and frantic.
- “Performance” refers to how successful respondents think they were in accomplishing the goals of the task set by the experimenter, and how satisfied they were with their performance in accomplishing these goals.
- The criteria of “effort” requests the respondents to assess how hard they had to work (mentally and physically) to accomplish the level of performance they achieved.
- Finally, evaluation of the “frustration” level measures how insecure, discouraged, irritated, stressed, and annoyed versus secure, confident, relaxed, and complacent subjects felt during the task.

### **3.6 Situation Understanding Measure**

#### **3.6.1 Pathfinder**

The visualization capabilities of the CPT–L were intended to improve the awareness and understanding of its users as it displays multiple LOEs in a chronological fashion with interdependencies across LOEs. The Pathfinder methodology was used to evaluate the progression of understanding for both teams from pre to postplanning. It was also used to measure the degree of shared understanding among the members of each team and how that changed over time.

#### **3.6.2 Pathfinder Coherence**

One of the Pathfinder measures employed is the measure of data coherence. The coherence measure reflects the consistency of the data. Coherence is based on the assumption that relatedness between a pair of items can be predicted by the relations of the items to other items in the set (Interlink, 2004). Past research has found that the coherence measure often correlates with

expertise or degree of learning if examined over time (e.g., Housner et al., 1993; Gualtieri et al., 1996).

### **3.6.3 Pathfinder Networks**

The Pathfinder networks (PFnets) allow for the visual representation of the associative network among the situational concepts in a network form. The PFnets represent an individual's understanding or situational model of the targeted concepts that were included in the Pathfinder rating process.

There were two primary confounds that developed within the experiment that could influence the results when the two groups are compared. The first confound is the unequal participant numbers between the groups of five for the CPT-L team and six for the non-CPT-L team. The reduction of 16.7% manpower for the CPT-L team put that group at an immediate disadvantage. The second confound is what resulted in unequal planning times between the two teams. Even though the same amount of time was allotted for both teams, the additional training time (approximately 45 min or approximately 17.7% of total planning time) required by the CPT-L team and two instances of lost data by the CPT-L team, led to approximately about 90 min of one team member's time, which put the CPT-L team at an even greater disadvantage.

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## **4. Results and Discussion**

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### **4.1 Missing Data**

One participant in the non-CPT-L team had missing data for the Pathfinder and workload measures for unknown reasons. However, technical issues with the computer used for this participant is suspected as the cause of this missing data. Two additional non-CPT-L members' data was excluded from analysis. The non-CPT-L leader's Pathfinder data was excluded due to very low-coherence scores pre and post *and* a strong decline in coherence from pre to post. The coherence measure reflects the consistency of the data. The coherence of a set of data is based on the assumption that relatedness between a pair of items can be predicted by the relations of the items to other items in the set. Past research has indicated that coherence scores of less than 0.20 suggest the participant did not take the task seriously or there was some error in the input of the Pathfinder ratings. The coherence score for this individual was 0.12 and -0.13, respectively, for pre and postscores.

Another of the non-CPT-L team member's data was excluded from both the Pathfinder and Workload analysis. In addition to extremely low-coherence on the Pathfinder pretest (-0.12), there was no score for the post-test due to the same value entered for each of the 135 ratings, and observational data that the participant did not take the measure task seriously. This individual's workload data was more than two standard deviations lower than the group's and was also

excluded from analysis. It is recommended that future participation by this person is accompanied by clear instructions on the importance of the measures and close monitoring of his responses.

Overall, there were three members of the non-CPT-L group who were missing or excluded from the Pathfinder analysis ( $n = 3$ ). There were two members of the non-CPT-L group who were missing or excluded from the workload analysis ( $n = 4$ ).

## **4.2 Planning**

Planning was evaluated through three analysis techniques. Two of these techniques focused on the product of the planning process, while the third focused on the planning process itself.

### **4.3 Plan Depth (Planning Product)**

Depth-of-plan was defined by the number of objectives, effects, actions, resources, interdependencies, and nodes identified in each of the final plans. Each planning element was given a weight of one, with the exception of the interdependencies. Interdependencies were given a weight of two, in order to represent the higher level of importance of the interdependencies to the overall plan.

The non-CPT-L plan was entered into the tool in order to assess the depth of both plans using the same criteria mentioned above. The overall depth scores were practically the same (CPT-L = 97; non-CPT-L = 94) between the two teams. However, the distribution of the various elements is different, particularly among the number of objectives, effects, and inter-LOE dependencies (i.e., dependencies across LOEs) identified in their plans (figure 4). The CPT-L team identified more effects and inter-LOE dependencies, while the non-CPT-L team identified more objectives in their planning.

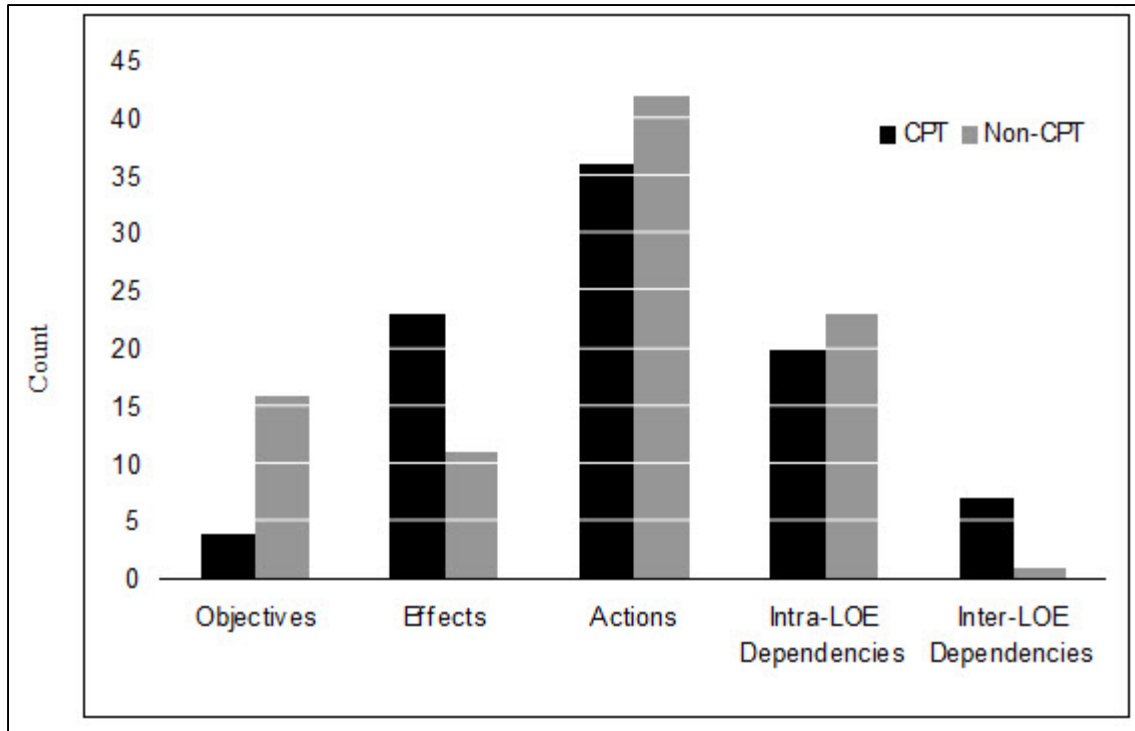


Figure 4. Plan depth across plan elements between the CPT-L and non-CPT-L teams.

#### 4.3.1 Observer Ratings (Planning Product)

The SMEs evaluated the plans across six planning-relevant dimensions that included: (1) Consistency, (2) Robustness, (3) Conflicts, (4) Comprehensiveness, (5) Probability for plan success, and (6) Plan Quality (see appendix). Intraclass correlation was used as a measure of inter-rater reliability (IRR) between the evaluators and displayed a lower than desired value of  $r = 0.42$  (where 0.70 is acceptable). There was a significant difference in the evaluator mean scores across the six dimensions; evaluator one had a mean score of 3.1 and evaluator two had a mean score of 2.1 ( $t = 2.79$ ,  $p = 0.01$ ) on a five-point scale. Future evaluators should be involved in IRR training to increase their IRR skills. Both evaluators, however, showed the same basic pattern of evaluations across the two groups, rating the non-CPT-L group equal or higher for each planning dimension and overall.

The mean score across both SME evaluators showed a higher rated evaluation for the non-CPT-L group (CPT-L = 2.0, non-CPT-L = 3.1;  $t = -3.4$ ,  $p < 0.01$ ). Figure 5 shows the evaluation means across both SMEs. Figure 6 shows the mean evaluator scores broken down by each planning dimension and displays consistently higher evaluated scores for the non-CPT-L plan.

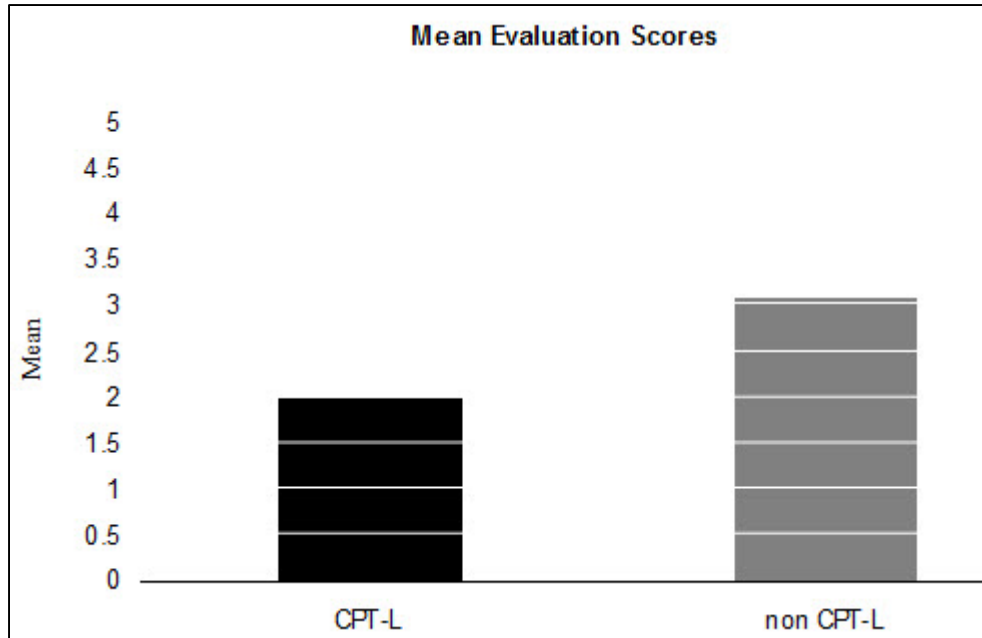


Figure 5. Overall mean evaluations across both SME evaluators with a significant difference between the two groups.

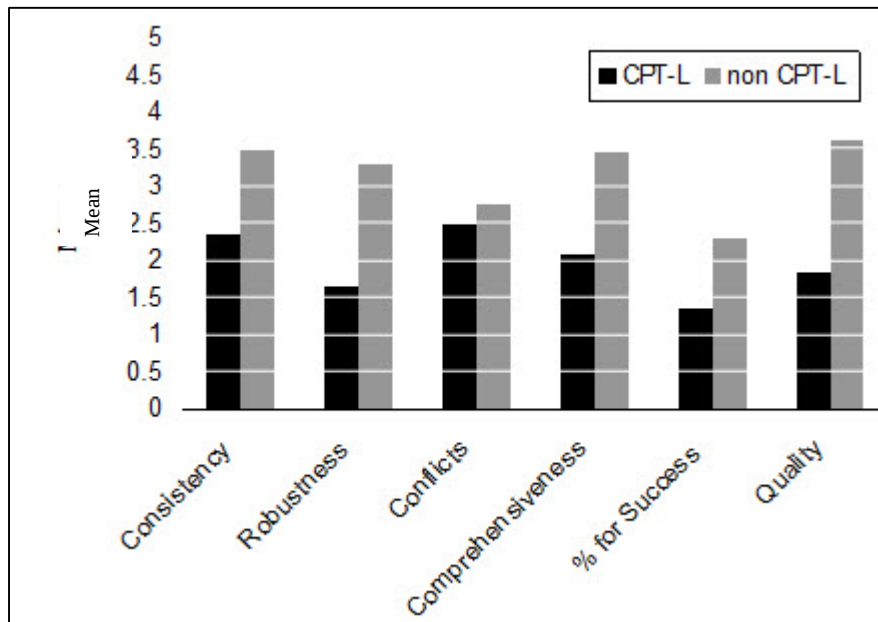


Figure 6. Mean evaluation scores broken out by each plan dimension.

Follow-up interviews were done with each of the SME evaluators to provide further explanation of the evaluations. The evaluators were fairly consistent in their impressions of each of the plans. Both evaluators agreed that the non-CPT-L plan had a greater level of detail that was provided through explanatory text embedded in each of the planning components (i.e., actions, effects, and objectives). The additional planning component text was represented in four different areas for each planning component: (1) Resources, (2) Assumptions, (3) Metrics, and (4) Description. The evaluators felt that the greater amount of explanation in these areas allowed a better understanding of the planners' intentions and allowed the identification of a consistent thread throughout the non-CPT-L plan that was not evident in the CPT-L plan.

An examination of the explanation text that was included in each of the two plans was conducted to further explore the comments from the SME evaluators. A striking difference was evident in the amount of text present in each of the two plans (figure 7). The non-CPT-L plan had dramatically more text in every category and 528% more text overall. This can be directly attributable to the differences the evaluators observed between the two plans.

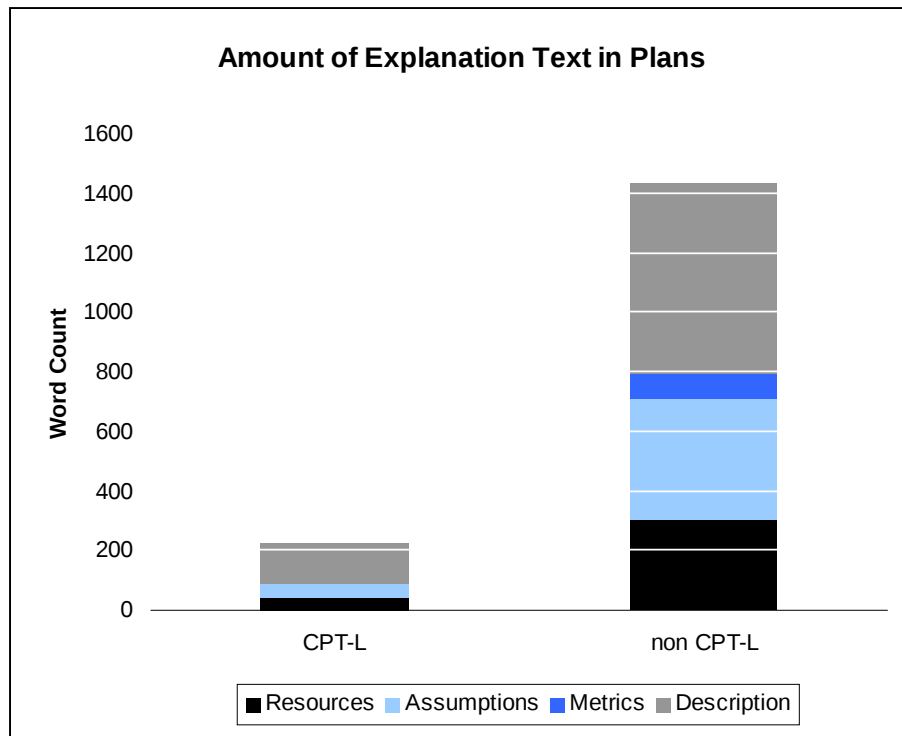


Figure 7. Amount and type of accompanying text embedded in the planning components for each plan.

Both evaluators saw merit in the CPT-L plan and did not see any strategic or general approach deficiencies. When asked how the CPT-L plan could be improved, one evaluator suggested, "allotting more time" in order to provide the detail found in the non-CPT-L plan. The inclusion of explanatory text to each planning component appears to be heavily dependent on the time and manpower available. The CPT-L team had confounds working against both of these factors that

impaired at least 20% of the overall planning time available and reduced the manpower of the CPT-L by 17% compared to the non-CPT-L team. Considering that the confounds directly affected the factors necessary to provide the level of detail found in the non-CPT-L plan, a clear conclusion on the quality of the two plans and the differences between them cannot be made based on this data. Since there is not a fair comparison among the planning product of the teams, further examination of the process of planning and intermediate products (e.g., mental models) will be examined.

#### **4.3.2 Social Network Analysis (Planning Process)**

Social network data was collected by observation. The observations recorded two types of collaborative interactions: (1) when individuals spoke face-to-face as dyads or subgroups and (2) when individuals spoke to the team as a whole. Additionally, observations recorded the length of each interaction, which provides a means for assessing the strength of the interactions between dyads and for assessing the amount of face-to-face collaboration that took place. The data was coded in the following manner to produce distinct categories for strength of interaction tie between each dyad or pairs of individuals: 0 min = 0, 1–10 min = 1, 11–20 min = 2, and so on. A higher coded number relates to a stronger interaction.

Figure 8 shows the dyadic and subgroup coded interactions by team. CPT-1 and non-CPT-7 are the leaders of each respective group. The line weights represent the amount of interactions between any two individuals. The interaction between CPT-2 and CPT-6 is very strong, as these individuals worked together on the same line of effort. The CPT-L team's verbal communication structure is very centralized (around the leader, CPT-1) and is typically very efficient for routine problems (Shaw, 1964). It was expected that the amount of overall CPT-L communications would be less compared to the non-CPT team communication, but for the CPT-L team structure to resemble more of a fully connected network structure—this was not the case. There are a couple of possible explanations for this result.

1. The CPT team spent considerable time trying to understand and use the tool. The time spent by team members interacting with the software developers may have limited cross-functional interactions.
2. The tool supported collaborative activities, which alleviated the need for face-to-face interactions across functions.

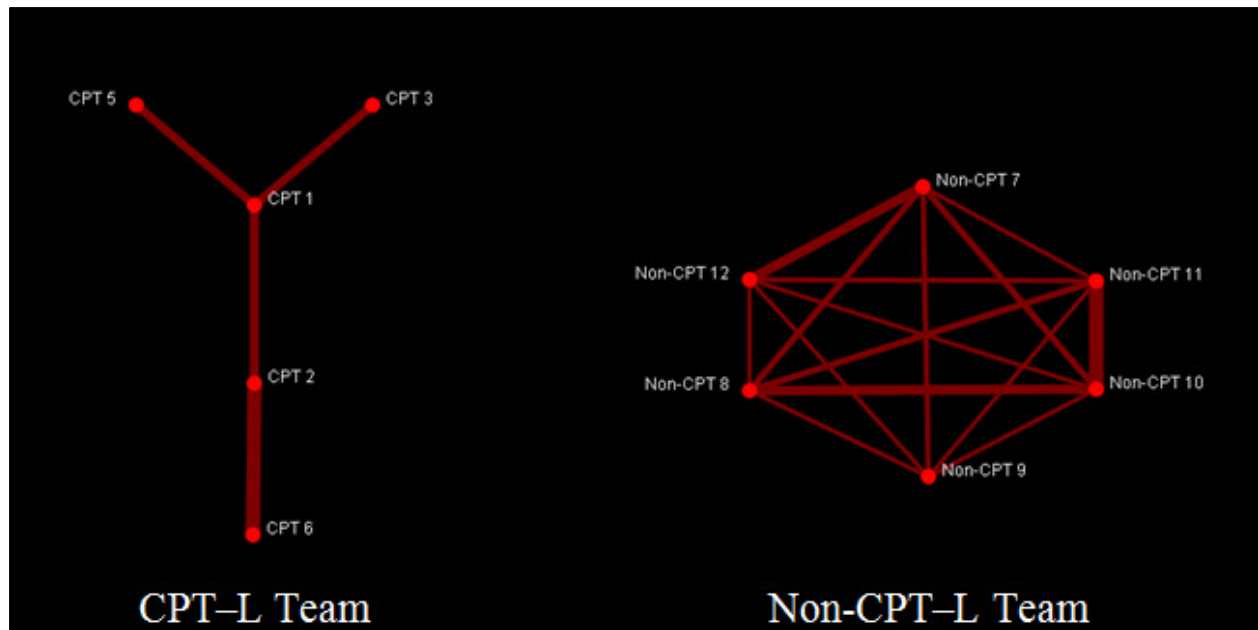


Figure 8. Dyadic and subgroup coded interactions by team.

The non-CPT-L team displayed a fully connected verbal communication structure that is typically conducive for complex tasks that require extensive collaboration (Shaw, 1964). The strong interactions found between non-CPT-7 and non-CPT-12 along with non-CPT-10 and non-CPT-11 represent pairs of individuals working on the same LOE together. The difference in the communication structures also is evident in the density of each team's networks. The difference in density between the two teams (CPT-L team = 0.4, non-CPT-L team = 1.0) indicates a much higher level of verbal communications among the non-CPT-L team.

The higher level of verbal communications by the non-CPT-L team was only evident in the dyadic interactions between team members. When team interactions are included, the CPT-L team displays a greater amount of time spent for team interactions (figure 9). This could be due to the CPT-L providing a big-picture to all team members, which allowed them more time to discuss planning issues as a group. For example, the non-CPT-L group had just finished putting together a graphic combining the individual LOEs by experiment end. This did not allow them much time to discuss the big-picture and draw dependencies. In contrast, the CPT-L team was able to reach an integrated planning state that considered the input of each of the LOEs earlier and allowed a focus on the dependencies among individual LOEs.

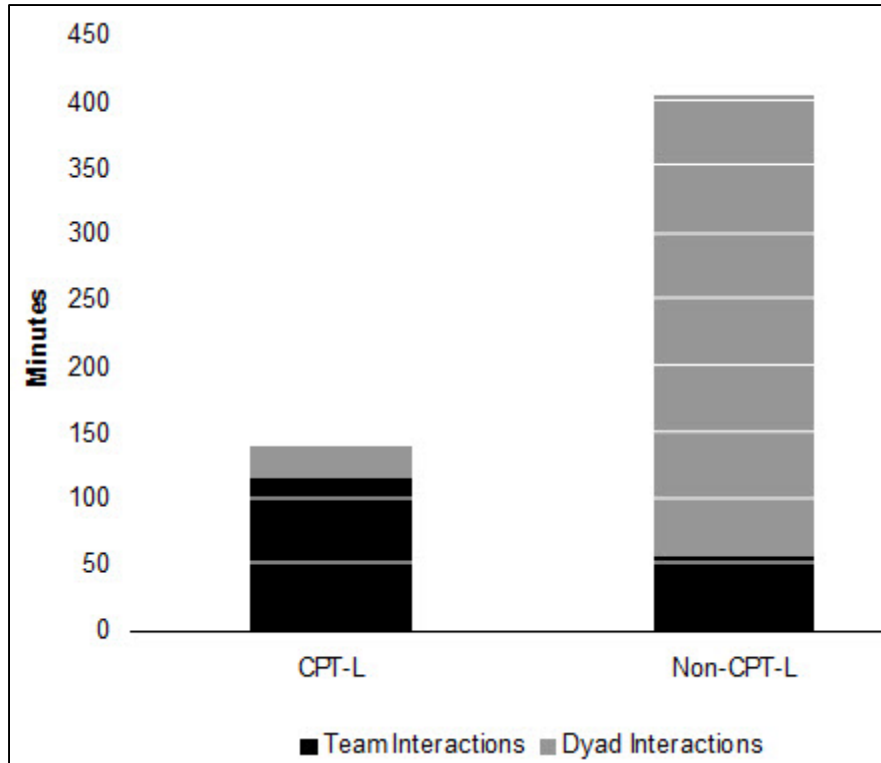


Figure 9. Total minutes of team and dyad interactions by team.

Further analysis into the team interactions shows the individual contributions in the team interactions (figure 10). As expected, the formal leaders of each team dominated the discussion time. Contributions were made by other team members as depicted in figure 10.

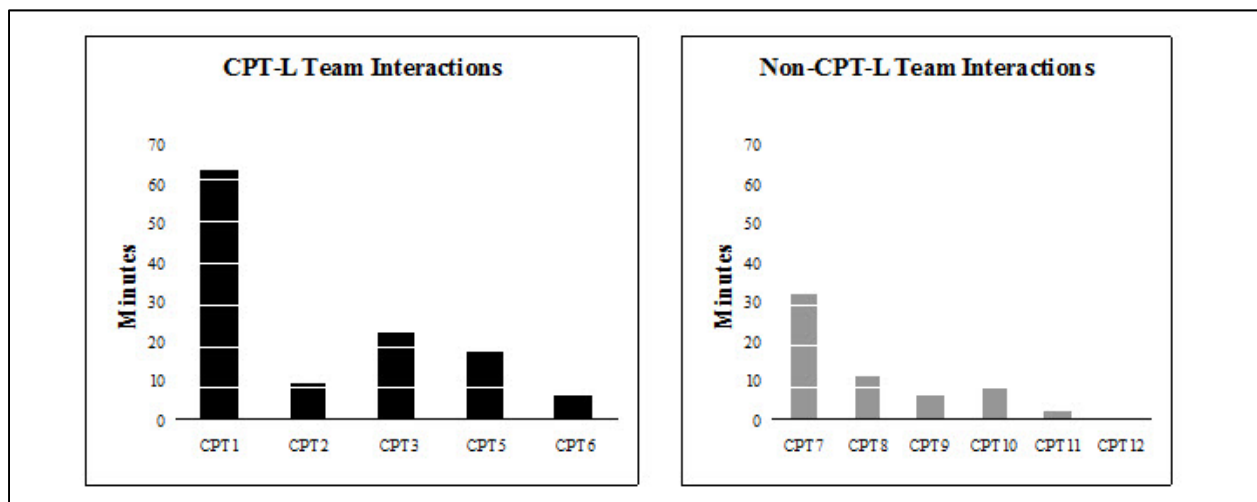


Figure 10. Total minutes within team interactions by individual team members.

### 4.3 Data Manipulation

The workload results across both teams show no differences except for the area of physical demand (figure 11). The CPT-L team showed significantly less physical demand compared to the non-CPT-L team, although both teams reported a low amount of physical demand overall. It is worth noting that even with the need for extended training and some loss of data, there was no significant difference between the two groups on the frustration dimension. Within the CPT however, there were a few individuals that reported a high level of frustration. When divided by age groups consisting of a below 60 group and a 60 and above group, there was a large difference between the two groups (below 60 = 23.3; above 60 = 67.5). Even with such few participants, this strong correlation ( $r = 0.87$ ) between age and frustration was significant ( $t = 3.09$ ,  $p = 0.05$ ). This finding highlights an age difference of comfort and familiarity with computer tools and interfaces that can exist between generations or age groups (Borghans and Weel, 2002). In such cases, the older population does not have the same familiarity with such tools and therefore experiences more frustration with their use.

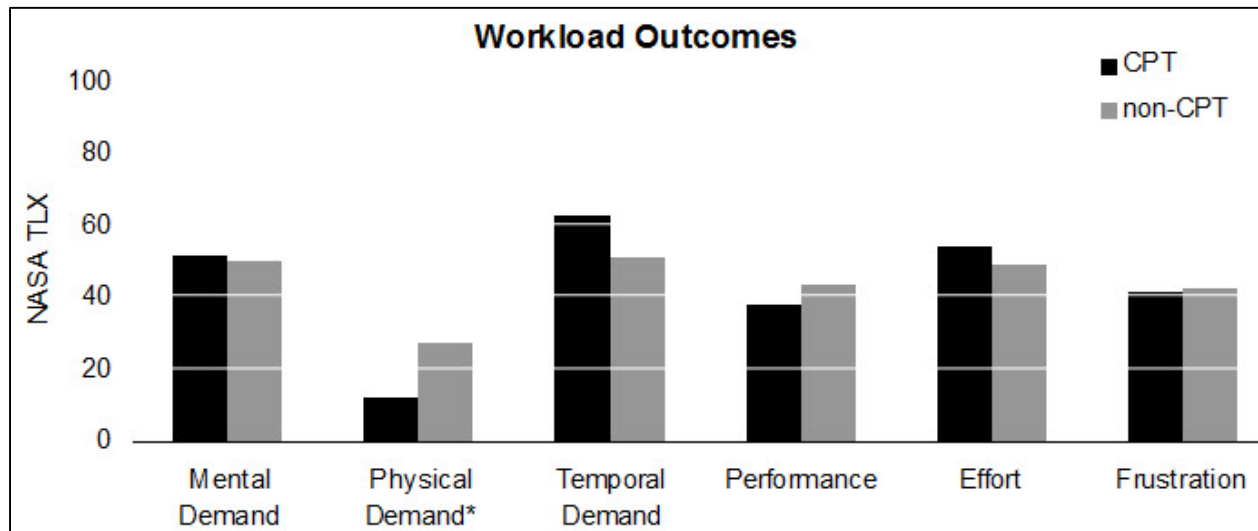


Figure 11. NASA TLX workload results for both the CPT-L and non-CPT-L teams. The difference in the Physical Demand is the only significant difference.

### 4.4 Situation Understanding

#### 4.4.1 Pathfinder

The Pathfinder metric (Schvaneveldt, 1990) elicits associative memory networks and provides information structures revealing the underlying organization of the data. These networks can be statistically compared across time with each other or against a benchmark network. Pathfinder data is collected by asking the individual to provide a series of relational scores across the targeted topics and issues (figure 12). Seventeen concepts (table 1) were used, which created 136 ratings between all possible pairings of the concepts. The resulting information structures can then be visualized and empirically analyzed.

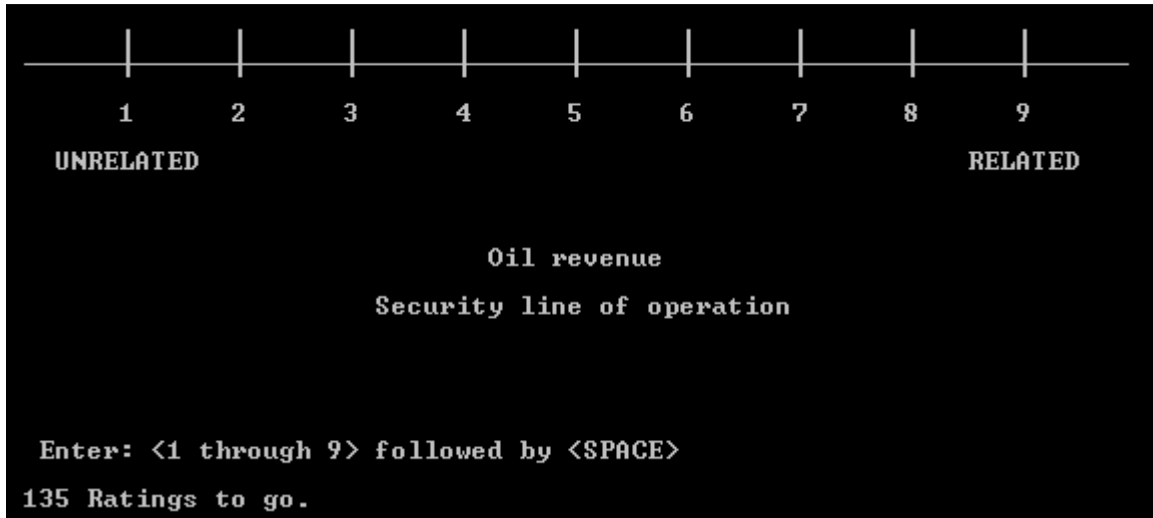


Figure 12. Pathfinder rating task.

Table 1. Pathfinder scenario-specific concepts.

| Pathfinder Concepts               |                       |
|-----------------------------------|-----------------------|
| Political line of effort          | Darfur rebels         |
| Security line of effort           | UN Coalition          |
| Rule of law line of effort        | Oil revenue           |
| Political economic line of effort | Regional stability    |
| World Bank                        | Economic growth       |
| Sudan                             | Civil war             |
| President Deby                    | Legitimate government |
| Zaghawa                           | President Chiroc      |
| Ethnic tension                    | —                     |

#### 4.4.2 Coherence Measure

The premeasure of coherence for the CPT–L and non-CPT–L teams shows, as expected, approximately the same level of situational expertise. However, the trend from pre to postplanning shows greater learning achieved by the CPT–L group (figure 13), with little improvement evident among the non-CPT–L team. Although a larger sample is needed to test for statistical significance, this finding suggests that the CPT–L facilitated learning of the situation and environment in spite of confounds mentioned above that put the CPT–L at a disadvantage (i.e., one less member and technical/training issues). Figure 14 highlights the slightly higher average coherence score for the CPT–L team at the 2nd or postmeasure of coherence.

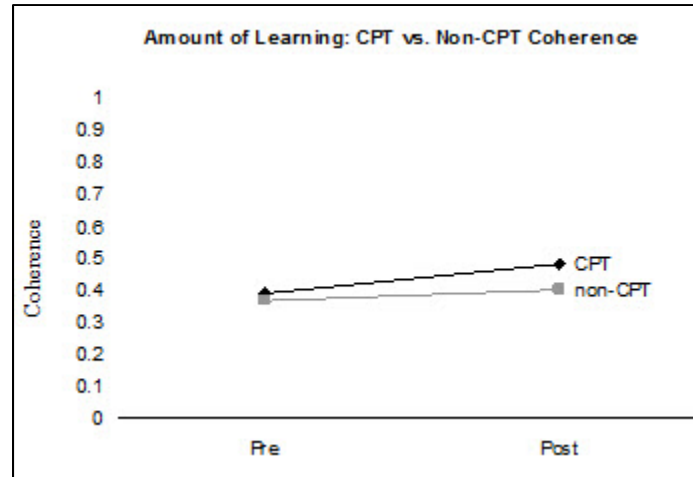


Figure 13. Average coherence scores over time representing the amount of learning achieved by each team.

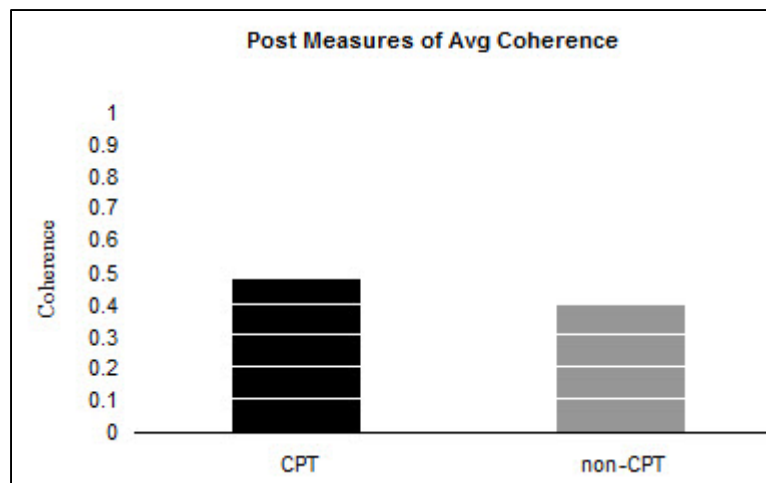


Figure 14. Average postcoherence scores between the CPT-L and non-CPT-L teams.

#### 4.4.3 Pathfinder Networks

The PFnets can be quantitatively compared with one another to evaluate the degree-of-similarity between them and therefore evaluate the degree-of-similarity of one individual's or group's understanding to another. The similarity measure compares the number of links in common between two PFnets (Interlink, 1994). Identical networks provide a similarity score of one, while networks that share no links provide a similarity score of zero. The comparison of the pre-PFnets for both teams show a small amount of similarity (24%) between the two teams (figure 15a and 15b). An examination of the post-PFnets for both teams shows a large increase between the two teams at 44% (figure 16a and 16b). This increase suggests that even though the two teams were using different tools in the planning process, their understanding or perception of the situation is gaining in similarity and on a path of convergence.

Examination of the PFnets within the same team from pre to postmeasurements gives an indication of the degree-of-change within that team's perception of the situation from before and after the planning period. The CPT-L team had a similarity score of 54% (figures 15a and 16a) from its pre and postmeasurements, while the non-CPT-L team had a similarity score of 13% (figures 15b and 16b). These results suggest that there was only moderate change within the CPT-L team from pre to post while the non-CPT-L, with a very low-similarity score, had considerable change across the same time period. There was no "gold-standard" or "ground-truth" PFnet available to compare the accuracy of both teams' post-PFnets.

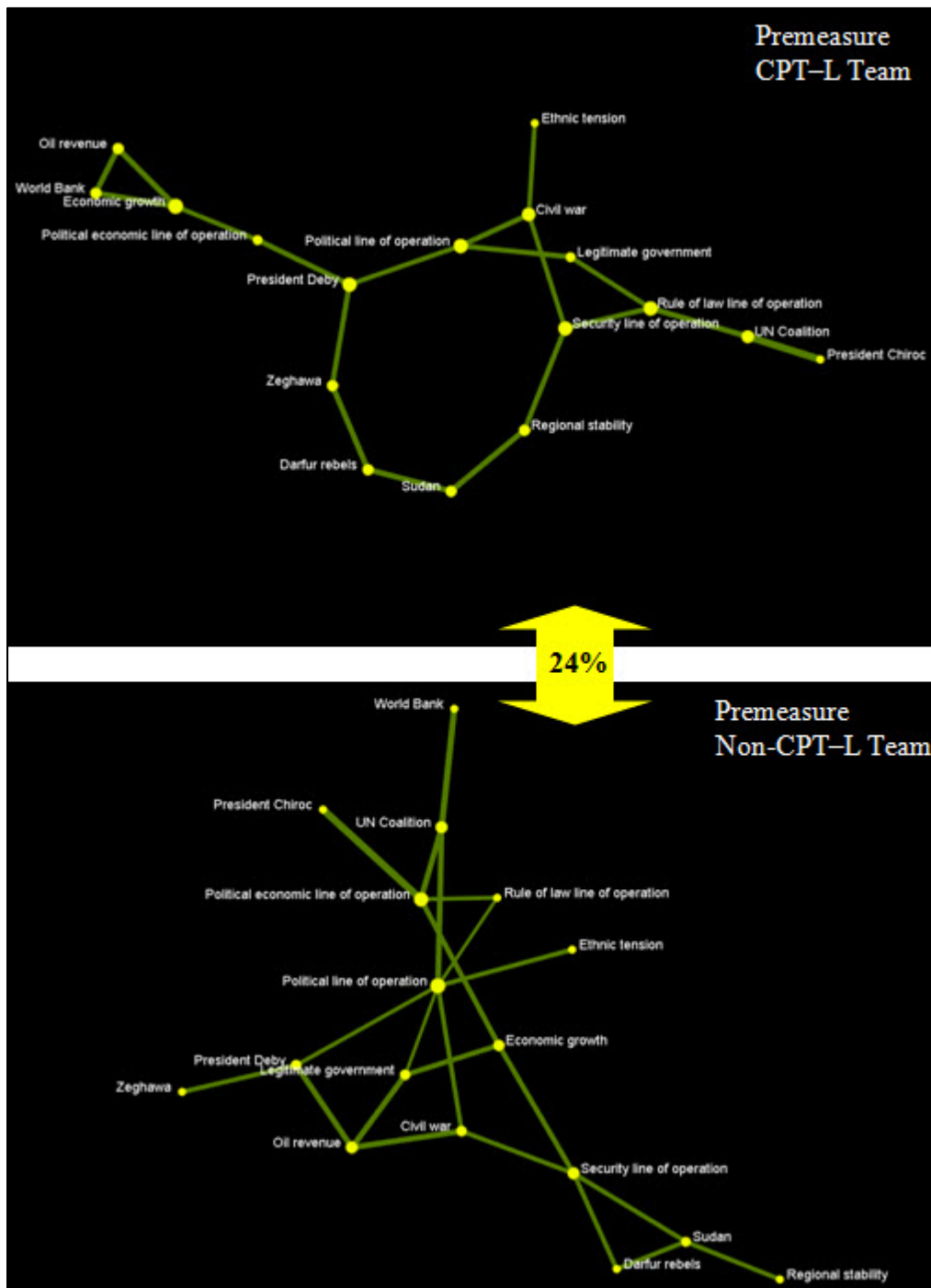


Figure 15. The premeasure PFnets for the CPT-L and non-CPT-L with a 24% similarity between the two PFnets.

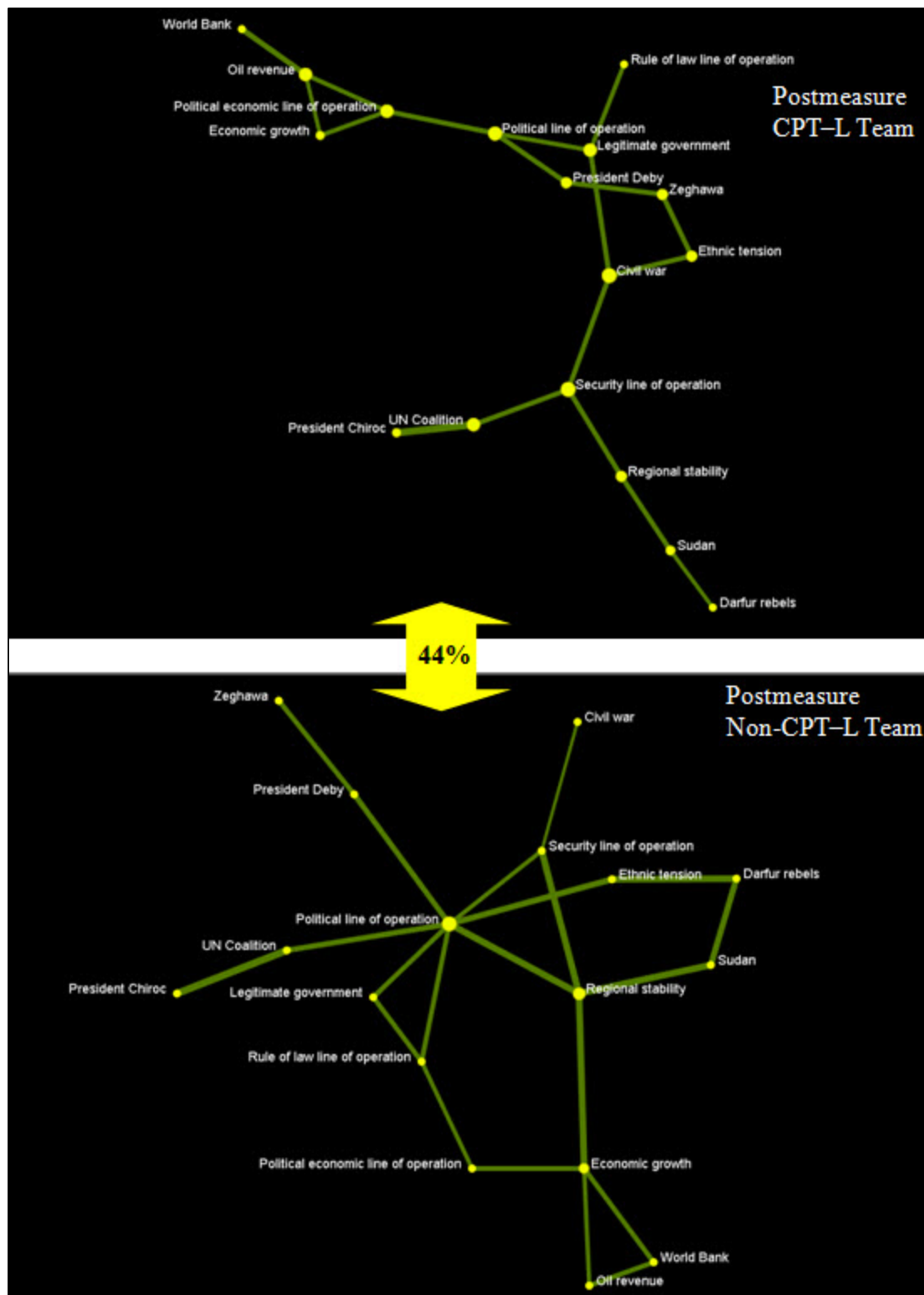


Figure 16. The postmeasure PFnets for the CPT-L and non-CPT-L with a 44% similarity between the two PFnets.

#### 4.4.4 Qualitative Pathfinder Results

Along with the quantitative analyses that have been presented with the PFnets, a qualitative analysis of the PFnets can be done to examine the content and relationships represented by the PFnets. Basic social network analyses have been applied within the PFnet visualization including the concept of line weights representing the strength of the connection between nodes and the node size representing the degree centrality. Degree centrality is defined as the number of nodes adjacent to a given node. Concepts that are highly central represent a core or high-importance element for the overall structure or situation. For example, the non-CPT–L team had the “political line of effort” as a central element in the pre-PFnet (figure 15b) and was joined by the “political economic line of effort” as an accompanying central concept in the post-PFnet (figure 16b).

Within the PFnets, a concept can be focused on in order to identify how the individual or group is defining or envisioning that concept by the direct relationships existing with the focus concept (figure 17). Once the concept has been isolated, it can be easily compared to that of other individuals or groups for differences among the concept focus.

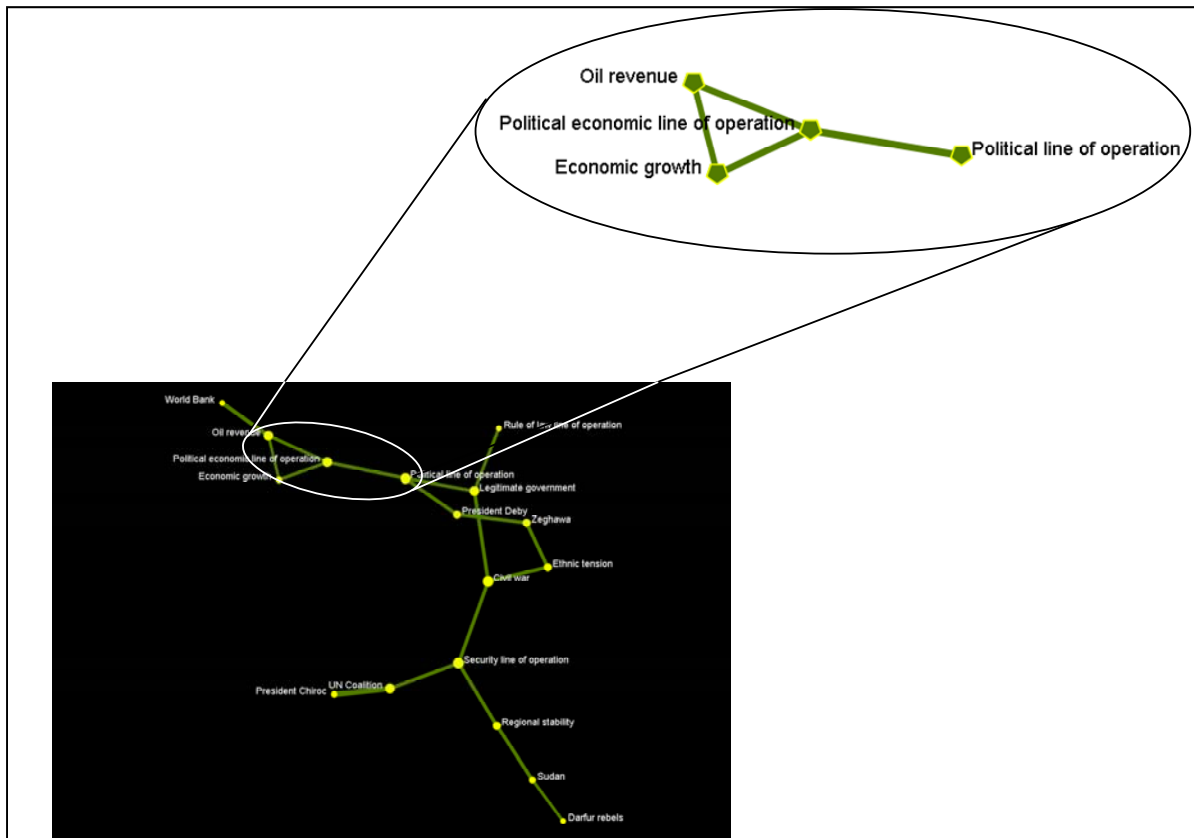


Figure 17. Focus on the concept of Political economic line of effort, which highlights all of the direct linkages associated with this concept.

Two examples of different perspectives of the same concept between the CPT–L and non-CPT–L teams are presented here. The first example focuses on the “political economic line of effort.” As shown in figure 18, the two teams share the relationship with “economic growth” and have a link to another line of effort. However, that line of effort is different between the two teams—the CPT–L team had a relationship between the “political economic line of effort” and the “political line of effort,” while the non-CPT–L team had a relationship with the “rule of law line of effort.” The other example is on the “regional stability” concept where the non-CPT–L team’s perspective possesses all relationships of the CPT–L team concerning regional stability as well as two others, to include the “political line of effort” and “economic growth” (figure 19).

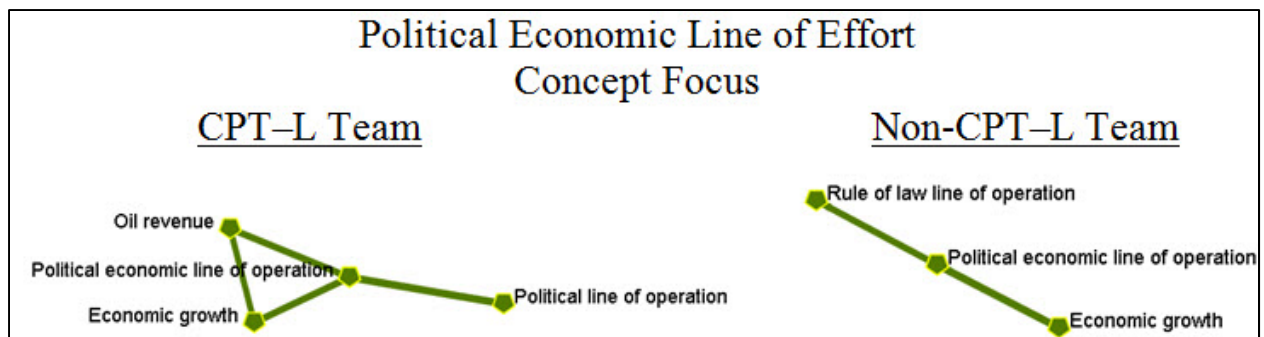


Figure 18. Concept focus on the “political economic line of effort” highlighting the differences between the two teams.

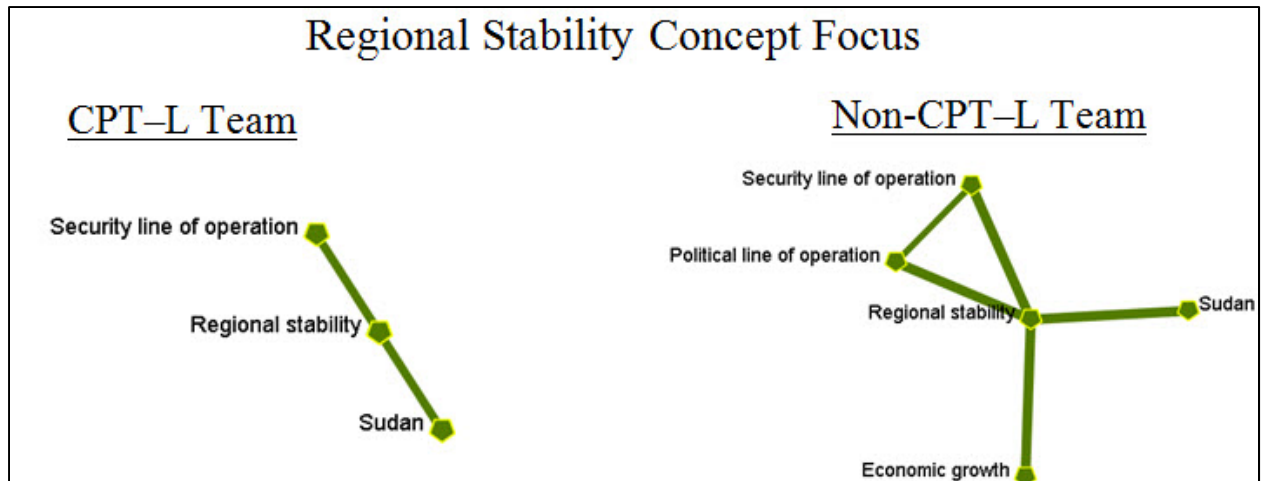


Figure 19. Concept focus on the “regional stability” highlighting the differences between the two teams.

## 4.5 Shared Understanding

Pathfinder similarity measure was examined among team members to quantitatively assess the shared situation awareness between team members of the same team. The Pathfinder similarity scores between every team member were averaged for the pre and postmeasures to compute the shared understanding within a team. This measure of interteam congruency provides a quantitative measure of shared understanding and when examined over time, can provide information on how well the team is coming together or drifting apart in their understanding and awareness of the situation. As expected, given equal teams, both teams scored approximately the same on the premeasure of shared situation awareness (figure 20). However, the CPT-L team again showed an increase over time, suggesting that the CPT-L team members are becoming more congruent with one another in their understanding and awareness of the situation. The non-CPT-L team, on the other hand, shows no sign of improved shared situation awareness from pre to postmeasurement. It is worth noting again that in spite of the unique challenges the CPT-L team faced, they were able to show slight signs of improvement over the planning period.

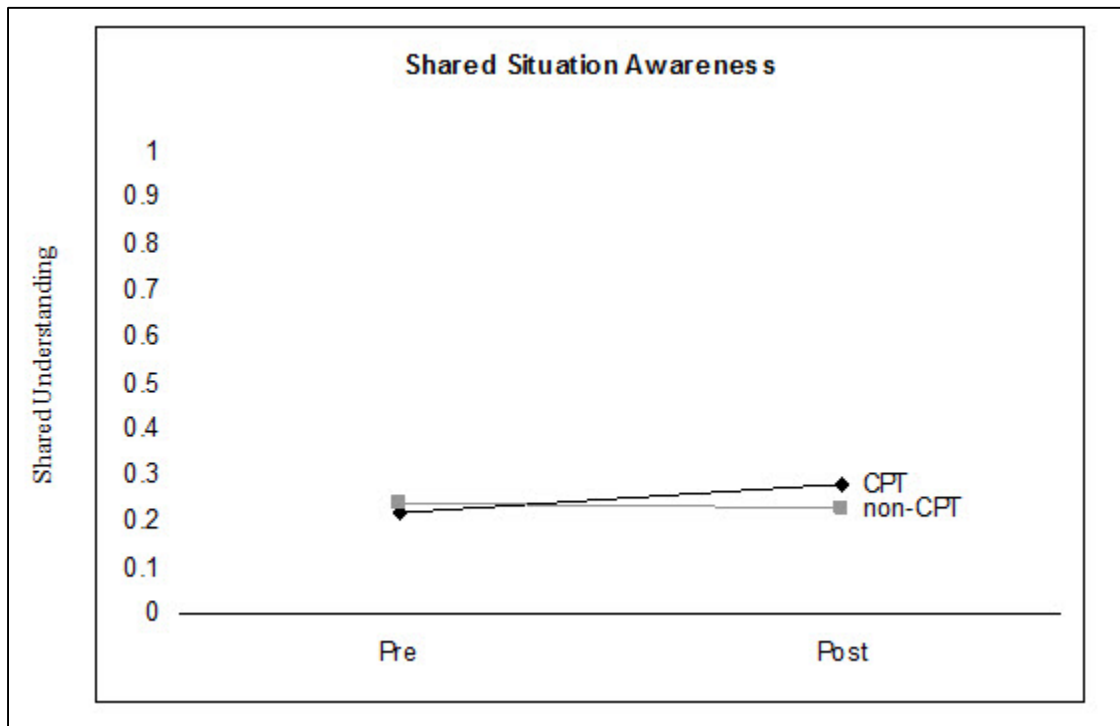


Figure 20. Pathfinder interteam similarity scores representing team shared situation awareness.

## 4.6 Subjective Data Results

Feedback from the team members of both groups were collected during the plenary session at the end of the day. This session was led by two moderators to elicit opinions, experience with and without the CPT-L, and recommendations for improvement. Most plenary comments related to usability and visualization design issues with the CPT-L, which will be covered more fully in Part II: CPT-L Usability. There were two comments concerning the appropriateness of an

experimental design for this event considering the current maturity of the tool and the amount of training provided. It was expressed that given the early development stage of the CPT–L, it might have been better to have more users interacting with the tool and providing input in its use over an experimental and control design. Many participants, particularly from participants who used the CPT–L during planning, expressed optimism in the potential capabilities of the tool but felt there were usability issues that still needed to be resolved before that potential of the tool will be fully realized.

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## 5. Conclusions

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The primary experimental hypothesis of this LOE was that the CPT–L would effectively facilitate team planning without increasing the workload of its users. The results in the areas of planning, setting objectives and alternatives, and situation understanding show that the CPT–L was as effective—if not more effective—in facilitating the *planning process* compared to a team using more traditional tools and methods. The quality of the *planning product* produced could not be fairly compared due to the confounds of the experiment. The results from the area of data manipulation showed that there was no increase in workload across any of the six dimensions measured and actually was significantly lower for the physical workload measure compared to the non-CPT–L team.

The early developmental state of the CPT–L appeared to create more of a user-testing session than a pure-planning session for the CPT–L team. This issue was compounded with the limited and noninteractive training provided to the CPT–L team members. These issues introduced challenges to the CPT–L team that were not intended and were not also shared by the non-CPT–L team. Combined with fewer team members than the non-CPT–L, the CPT–L was placed at a significant disadvantage compared to the non-CPT–L team. Considering these disadvantages, it is therefore surprising that the CPT–L team displayed converging evidence of higher performance and greater improvement in the planning process compared to the non-CPT–L team. The converging evidence ranging from the reduced workload, higher gains in understanding, and slight improvement in shared situation awareness evident in the CPT–L team all point toward the possible advantages of using the CPT–L. Any of these results alone does not provide definitive results; but the converging nature of these data in the same direction—especially considering the disadvantages mentioned above—suggests a beneficial role of the CPT–L in the planning process. In order to effectively assess the impact of the CPT–L on the product of the planning process, additional training is required to create equal expertise with the tools being used across both teams and equal amounts of planning time and manpower available is required.

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## 6. References

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## **Appendix. COMPOEX Plan Evaluation Form**

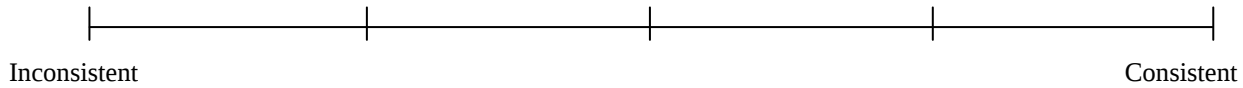
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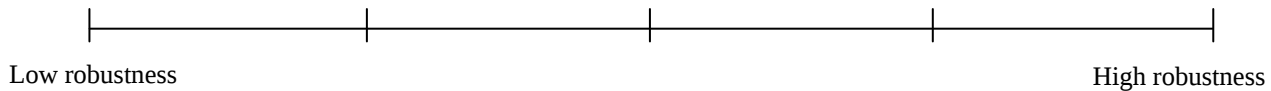
This appendix appears in its original form, without editorial change.

Directions: Please review both Plan A & Plan B provided. Rate each plan among the planning dimensions below by placing an **A** on the scale for Plan A and a **B** on the same scale for Plan B. If the exact same rating is given for both plans, please place one letter on the appropriate position on the scale and the other letter directly above it.

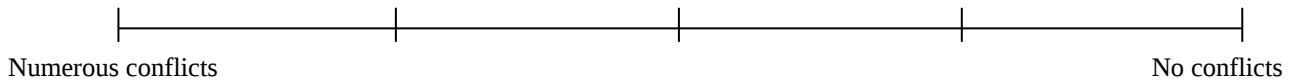
**Consistency:** Correspondence or agreement among the parts of the plan from the Line of Effort down to the actions or resources.



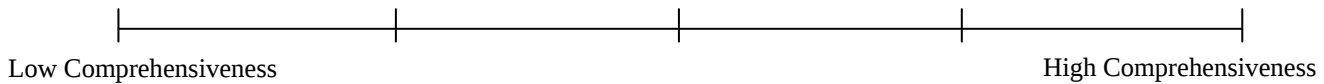
**Robustness:** The resilience of the plan or how well it supports planned actions before replanning is needed.



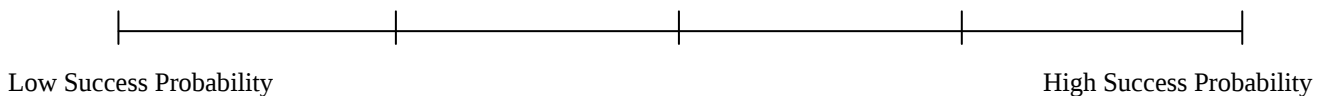
**Conflicts:** The degree conflicts are present among the planning components (e.g., across Lines of efforts, objectives, actions, etc...)



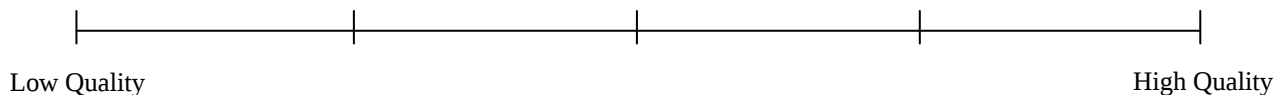
**Comprehensiveness:** Inclusion of many relevant planning components (e.g., across Lines of efforts, objectives, actions, etc...) both in breadth (lines of efforts) and depth (down to the resource and node level)



**Probability for plan success:** The judged probabilistic chance of success of the plan



**Plan Quality:** A combination of all plan dimensions above, the overall evaluation of the plans



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## List of Symbols, Abbreviations, and Acronyms

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|         |                                                              |
|---------|--------------------------------------------------------------|
| C2      | Command and Control                                          |
| COMPOEX | Conflict Modeling, Planning, and Outcomes Experimentation    |
| CPT-L   | Campaign Planning Tool-Light                                 |
| DARPA   | Defense Advanced Research Project Agency                     |
| h       | hour (s)                                                     |
| IRR     | inter-rater reliability                                      |
| JFCOM   | Joint Forces Command                                         |
| LOE     | limited objective experiment                                 |
| min     | minute (s)                                                   |
| NASA    | National Aeronautics and Space Administration                |
| PFnets  | Pathfinder networks                                          |
| PMESII  | political, economic, social, information, and infrastructure |
| SME     | subject matter expert                                        |
| Sr.     | Senior                                                       |
| TLX     | Task Load Index                                              |

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