Developing an instrument for measuring shared understanding

Peter Berggren
FOI
peter.berggren@foi.se

Björn JE Johansson
FOI
bjorn.j.e.johansson@foi.se

ABSTRACT

The paper discusses the need for an easy-to-use, easy-to-administer measure that can capture shared understanding in a team of professionals working together towards a successful performance. In the paper the development of such a measure is described using two empirical studies. Command-and-Control tasks are complex and often dynamic, and a way of capturing the degree of which a team of individuals have a common understanding of priorities in such a task is imperative.

Two studies are presented. In the first study students participated in a microworld experiment where they tried to rank order pre-determined factors in order to measure shared understanding. In the second study officers from the Swedish Armed Forces participated in an exercise where they rank ordered self-generated factors.

Keywords:

Teams, command and control, shared understanding, team performance

INTRODUCTION

A concept shared by many models of command and control, independent of whether we are discussing military or civilian C2, is that situational awareness (SA) is an important precursor for successful decision making. In distributed C2, which is the most common form in crisis response, the focus often lays on shared situational awareness and task understanding since a major problem in joint operations is to synchronies activities with other units. This can only be achieved if the different actors have roughly the same understanding of what is going on (shared SA), share the same priorities and have the same goals in mind, something that in most cases is to be realized by the aid of a common operational picture (COP).

Technically, a COP mostly consists of a representation of the operational area (a map), own units and identified other units and areas of interest. In a crisis management situation, a COP would typically comprise of the crisis area, unit positions, damage assessment and resources like medical facilities, food supplies, evacuation routes etc. As a crisis response operation also typically involve a multitude of organizations, a loosely coupled C2 structured striving towards several, sometimes conflicting, goals, an understanding of other actors priorities become crucial in order to organize and control work flows. The understanding of the COP depends not only on the data presented in it, but is closely connected to organizational goals, training and current objectives. How a COP is interpreted, and hence how well the users manage to establish a "shared" SA, varies greatly depending on personal experience, training, culture etc (McCann & Pigeau, 2000) and perceived earlier events in the course of action (Clark, 1996; Johansson & Hollnagel, 2007). The individual interpretation of a COP and to what extent it overlaps with other actors interpretation/understanding is thus the "shared understanding" in a team of actors (see figure 1.).

To what extent this is possible to achieve is a central question in crisis management as successful crisis response depends heavily on successful coordination of activities. It is also a time-critical activity involving a large number of persons that leaves little room for negotiation of meaning. The level of shared understanding is commonly seen as a pre-cursor of successful performance, and is therefore often the focus of scientific investigation. Command teams' shared understanding of common operational pictures has been measured in a multitude of ways; direct observations, questionnaires, subjects matter experts evaluations, all of them more or less valid and reliable assessments (Durso & Dattel, 2004; Salmon et al., 2007; Salmon et al., 2006).

Reviewing Statement: This paper has been fully double blind peer reviewed.

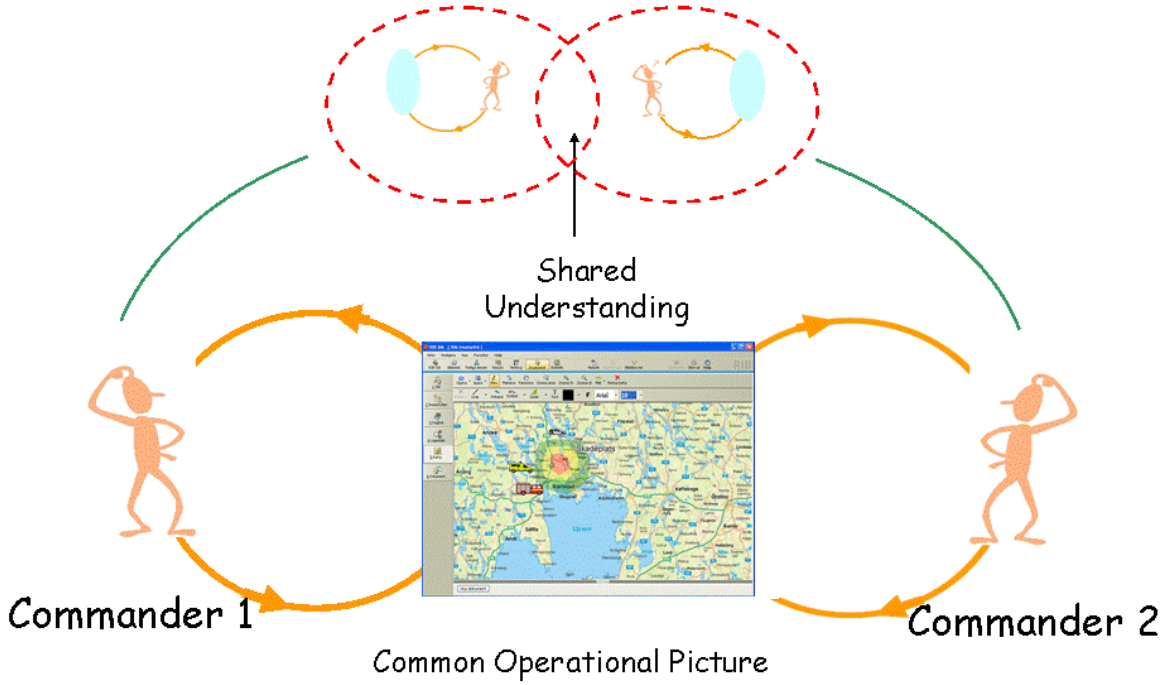

Figure 1. Shared understanding and the COP.

As pointed out above, a shared understanding of the common operational picture can be described in terms of situational awareness (Endsley, 1995). On a team level this is sometimes called team situation awareness, and sometimes called shared situation awareness (Endsley and Jones,1997). There are several terms and concepts that are similar to team- or share SA, like team mental models, shared cognition etc, (Brannick et al, 1997; Mohammed et al, 2000; Salas et al, 2004; Salas et al, 2008) but we have chosen to use the term "share understanding". From a scientific point of view, it is challenging to assess to what extent a COP is understood in the same way as there is no actual manifestation of the phenomenon. In very specific situations, it may be possible to asses based on outcomes of actions taken by individuals striving towards the same goal, but even then it is based on assumptions on behalf of the researcher. There are also practical problems associated with such measures; either the preparation is taking a considerable amount of time or the measures are only usable in the very specific situation that the measures are developed for.

Purpose

The purpose with this paper is to demonstrate how a shared priorities measure for shared understanding was developed into a usable and easily handled measure of a command teams' shared understanding of the common operational picture. The basic method suggested is that several persons that work jointly towards a shared goal individually rank order a number of items that they consider important in the current situation. Two different ways of doing this were tested, one where the items where fixed and one where the participants had to both create the initial list of items. In either case, shared understanding is seen as a function of the number of overlapping items between the individuals. Thus, if two persons rank items in the same order, this is seen as evidence of shared understanding.

METHOD

Two different data collections where the teams' shared understanding are used to demonstrate how the measure was developed over time. One where a first attempt to use a rank ordered priorities list was employed, and a second one where the list had been developed into a more easy to use collection method.

EXAMPLE 1, A FOREST FIRE FIGHTING SCENARIO

An experiment was conducted were 24 teams consisting of three members participated in a study with the purpose to study how shared understanding was related to situational awareness. Shared understanding was assessed by utilizing lists of factors that the subjects were to rank in order of perceived importance. Situational awareness was measured using subjective assessments by the participants. Team performance was measured both subjectively and from simulation log files. The experiment was performed in the C3Fire micro world experimental platform. Microworld simulations have been used in a number of studies on team decision-making and performance (Svenmarck and Brehmer, 1991; Howie and Vicente, 1998; Granlund, 2002, 2003; Granlund and Johansson, 2003; Jobidon et al., 2006). Microworlds have also been used to study cultural differences in teamwork (Lindgren and Smith, 2006a, 2006b), as well as to test new ideas and effects concerning ICT in command and control (Johansson et al., 2000, 2005). For an elaborated discussion about the use of microworlds in research, please see Brehmer and Dörner (1993) and Brehmer (2004). The C3Fire microworld simulates forest fire-fighting. In the C3Fire microworld participants, participants' organization and communication structures can be set up in accordance with the research goal. The user interfaces and communication tools can be individually set-up for all participants. The "world" in C3Fire is comprised of a number of quadratic cells, which, apart from representing different types of terrain, can take different states (not burning, burning, closed out, burned out). These states are generally used as a measure of performance in the microworlds simulating fire-fighting tasks (Svenmarck and Brehmer, 1991).

Participants

24 team with 3 participants in each team participated in this study (ranging from 18 to 36 years old, average age 23.7). The participants (all except one) were students at the University of Linköping. Each participant in a team had a distinct role (in charge of fire fighters, water supply and fuel supply), hence coordination and collaboration was necessary to succeed in the task.

Task

The three participants were commanding a fire fighting organization and were to close out a forest fire. The forest fire develops dynamically and will evolve independently of the participants' actions, i.e. if the participants do not act, the fire will soon be out of control. The dynamics come from varying types of terrain that will burn more or less fast, changes in wind direction etc. Further, in order to succeed they also had to collaborate and coordinate their actions. Coordination was demanded as the fire-fighting units depended upon the water trucks and the fuel trucks in order to remain operational. The water and fuel trucks in turn had to move to certain positions in order to fill up water and fuel in their tanks. What the simulation looked like can be seen in Figure 1.

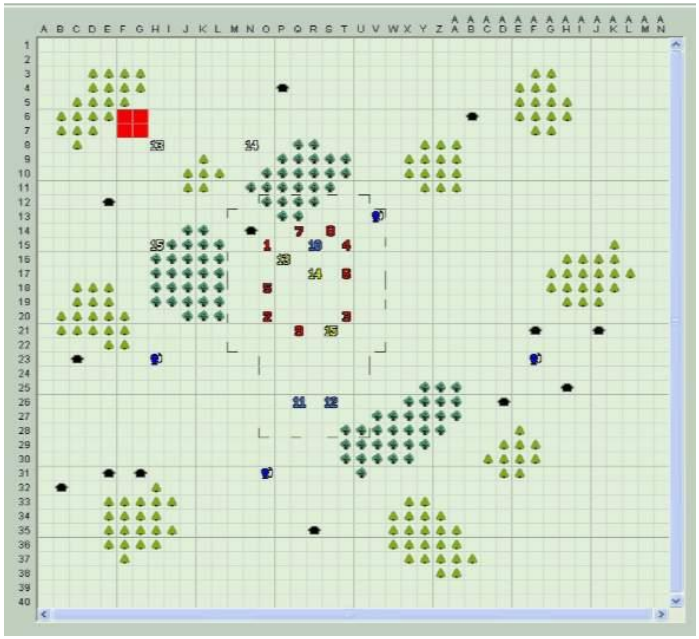

Figure 1. Screen from C3Fire scenario.

Design

Each team participated in four scenarios. Scenario A (can see all vehicles and a map of the entire forest and fire), B (can only see own vehicles but see a map of the entire forest and the fire), C (see all vehicles and only fire around them) and D (can only see own vehicles and only fire around them). In this paper only scenario A (called Full vision) and D (called Limited vision) are compared.

A map with a 40x40 grid was used. Each participant controlled five vehicles. Type of vehicles for each participant can be seen in Table 1. Each vehicle had a field of view that corresponded to 5x5 grid squares around each vehicle.

Vehicle	**Participant X**	**Participant Y**	**Participant Z**
Fire fighting	5	2	2
Water truck		3	
Gas truck			3

Table 1. Fire fighting vehicle distribution

Apparatus

The C3Fire software was run on 4 desktop computers, one for each participant and one as the game server.

Measure

Shared understanding was measured using pre-defined factors that were considered to reflect important aspects of the scenario. The factors were defined in collaboration with a subject matter expert. Approximately 16 hours was spent on developing these factors. There were three rank order questions with pre-defined factors; one with four factors, one with five factors, and one with six factors. These were constructed in order to see if the number of factors had an impact on the result. Situation awareness was measured using subjective assessments. Team performance was measured both subjectively, and from system recordings.

The scenario was paused every seven minutes for the participants to individually answer a questionnaire which included the rank order questions.

Scoring

The team's correspondence score of the ranked factors was calculated using Kendall's measure of concordance (Kendall, 1939).

Result

Comparing the outcome in terms of performance from the system recordings between the two conditions, there was no difference ($F_{(1,46)} = 0.88$, ns).

The distribution for the shared understanding measure can be seen in Table 2 below.

Condition		Mean	Std dev
Full vision	5 factors	0.57	0.32
	6 factors	0.54	0.27
	4 factors	0.57	0.27
Limited vision	5 factors	0.62	0.28
	6 factors	0.62	0.29
	4 factors	0.63	0.28

Table 2. Distribution for measures of shared understanding.

No significant differences were found when comparing the two conditions on the measure of shared understanding for neither of the

A correlation matrix between the measures of shared understanding for all factors and the system recording's measure of Team performance showed no significant results (see Table 3).

Condition		r
Full vision	5 factors	-0.21
	6 factors	0.06
	4 factors	-0.03
Limited vision	5 factors	0.28
	6 factors	0.04
	4 factors	0.07

Table 3. Correlation between measures of shared understanding and team performance from system recordings.

The subjective ratings of shared situation awareness (SA) and subjective ratings of team performance can be found in Table 4, below.

Condition		Mean	Std dev
Full vision	Shared SA	4.9	1.3
	Team performance	4.9	1.4
Limited vision	Shared SA	4.4	1.3
	Team performance	4.4	1.3

Table 4. Distributions for shared SA and team performance .

Conclusion

The different shared priorities measures did not show any significant findings. There are several reasons that are possible. A) The factors were not good enough. B) The participants were not familiar enough with the task. 3) The instrument is not measuring what is intended.

EXAMPLE 2, USING PROFESSIONALS

Considering explanation A and B from the paragraph before, we decided to test another way of utilizing the instrument (A) and also letting professional participate in an experiment (B). Using three teams with three members, a study where a novel measure of shared understanding was performed. The measure consisted of self-generated factors important to the team in order to be successful as team. The experiment was performed at the Swedish Armed Forces' Crew Training Facility (BTA) in Skövde.

Participants

Nine officers from the Swedish Armed Forces participated. They were all trained tank commanders. The participants were split up into three teams, each team controlling a tank. Each team consisted of a commander, a pilot, and a shooter. The three commanders were the command team of the tank company, one as a company commander, the other two as platoon leaders.

Task

The participants were engaged in a peace enforcing mission and were coordinating and collaborating their actions to hinder enemy activity.

Design

A within group design was used with two conditions. Condition A) same command method– all teams used the same C2-system and radio vs B) mixed command methods – one team used radio and paper map while the other teams used the C2-system and radio.

Apparatus

The experiment was performed at the Swedish Armed Forces' Crew Training Facility (BTA) in Skövde. It is a simulator platform with three tank cabins and an instructor station (IOS), where three tank crews can train together in the same virtual environment. In each tank the positions of the commander, the pilot, the shooter, and the loader can be trained. The tank cabins are the same size as of the Swedish Tank 122.

Measure

Shared understanding was measured using participant defined factors. One of tank the commanders was asked to generate five factors that were important for the company to resolve its task. Since all tank commanders were part of the company command team it was assumed that the factors should be relevant for all of them. The order of the generated factors were then scrambled and distributed to the other tank commanders who were asked to rank the factors in order of importance. Team performance was measured both subjectively, and by the instructors running the scenario.

Scoring

The team's correspondence score of the ranked factors was calculated using Kendall's measure of concordance (Kendall, 1939).

Result

There was no difference between same command method vs mixed command method ($F_{(1,4)} = 2.0$, ns) using team performance as dependent variable.

When the shared priorities measure (as a measure of concordance) was correlated with team performance gave that r=-0.60 (ns)

Comparing same command method vs mixed command method, using the shared priorities measure as dependent variable showed a significant difference ($F_{(1,4)} = 15.28$, $p<0.05$). Same command method gave a more unified agreement on the shared priorities (M=0.65) where mixed command method showed lower level of agreement on shared priorities (M=0.35).

Conclusion

The shared priorities measure of shared understanding did not correlate with team performance. Yet, this time the instrument managed to discriminate between the different conditions.

GENERAL DISCUSSION

The two studies have not shown any statistically valid correlation between the shared priorities measure and performance. There are a number of plausible explanations to this. Firstly, the measure of performance might have been too broad, i.e. there are other factors that are more important pre-cursors of success in the terms it was measured. Secondly, the rank order items presented may have been irrelevant – there could be other items that are of more importance.

Also, no objective measure of performance existed in the second study. This could be important as it is difficult to assess performance in dynamic environments subjectively. The reliability of the subjective measure may simply be too low to record any differences between the conditions.

Although, the shared priorities measure of shared understanding might be a feasible way ahead. It did discriminate between two conditions. The measure is easy to use, quick to utilize, and is easy to understand.

CONCLUSION

A shared priorities measure of shared understanding was introduced, tested, altered and tested again. There were no significant correlations with measures of team performance. When performing the experiment with professionals in their own environment doing tasks that they were familiar with, the measure discriminated between different conditions. This can indicate that this measure might be able to capture different levels of concordance in teams. Yet, this calls for further investigation. To continue this work is important since an easy to use, valid and reliable measure of shared understanding would be a big step forward for C2-research, and would be of benefit for the crisis management community, both in terms of training and in terms of assessment.

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