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Abstract

This article presents a protocol for assessing team performance in terms of control based on cognitive systems engineering theory. The protocol changes the focus of team performance assessment from good and bad behaviours towards team activity. By using Hollnagel's Contextual Control Model (COCOM), a protocol is developed so that team activity can be described as four control modes. Data is collected through observation and questionnaires and is analysed in time intervals. Each time interval is then given a control mode. Based on how the control mode changes over time the performance of the team can be assessed. The protocol was tested in a pilot study where commanding staff exercises were analysed. The results show that the protocol can be used to identify differences in team performance. The study also gives empirical validity to COCOM in that the loss of control in emergencies corresponds to an opportunistic or a scrambled control mode.

Keywords

Team performance, COCOM, control, assessment, crisis management

1   Introduction

Team performance assessments are frequently performed in safety critical industries such as aviation, nuclear industry, shipping and health care. Assessments are performed for different reasons such as to measure effects of training (Helmreich, Merritt and Wilhelm 1999; Salas et al. 2008; Salas, Wilson, Burke and Wightman 2006) new technological interfaces, or for reasons of safety and quality control (Leva, Cahill and Kay 2010; Catchpole, Mischra, Handa and McCulloch 2008; Catchpole et al. 2008).

Most of the methods for team performance assessment have revelled different theoretical assumptions for such a complex investigation. Motivational theorists suggest strong correlation between individual motivational shortcomings and performance (such as empathy, leadership, social skills) (English, Grifith and Stulman 2004; Hanashiro and Queiroz 2005; Jordan, Field and Armenakis 2002; Salas and Fiore 2004). Cognition researchers appeal to explain team performance from the investigation of micro-cognitive factors of humans mind (such as, attention management, memory, knowledge, situation awareness) and macro-cognitive factors in teams (such as, communication, shared mental models and coordination) (Klein, Feltovich, Bradshaw and Woods 2005; Letsky, Werner, Fiore and Smith 2008).

In this sense, highly complex industries, such as aviation, have been suggesting the use of methods that combine motivational and cognitive factors to assess and discuss team performance. The main assumption is that it is possible and easier to analyse team performance from observing the behaviour of individual team members, than trying to enter the human's mind to understand its cognition (Baker and Dismukes 2002; Flin and Martin 2001). Consequently, Behavioural Markers, Line Operation Safety Audits, and NOTECS' Behavioural Checklists are among the most used approaches to evaluate team performance by the use of behavioural observations of team members (Baker, Mulqueen and Dismukes 2001; Fletcher et al. 2004; Flin and Martin 2001; Helmreich, Klinect and Wilhelm 1999; Van-Avermaete and Kruijsen 1998). In short motivational and cognitive factors are used for assessing individual- as well as team performance in a variety of domains. While some approaches stop at the individual level (to assess the individual team member) others are assessing how the motivational and cognitive factors of the individuals affect the performance of a whole team. However regardless of whether the focus of analysis is the individual or the team the same assumptions (of the potential of using motivational and cognitive factors) are used as the basis of analysis.

An alternative approach called joint cognitive systems' theory (JCS) has argued for the need of investigation of cognition as a situated and a distributed phenomenon (Hollnagel and Woods 1983; Woods and Hollnagel 2006). This view is a reaction against the behavioural theory that kept the mind locked as a *black box*, and to the first cognitive revolution, that equated cognition with the processing of information by a mind separated from the world (inspired by contemporary technology, first radio then computer) (Hollnagel and Woods 2005).

JCS changes the view from seeing individuals and artefacts, ranging from a hammer to autopilot, as separate parts of a system or a team to seeing them as a joint agency. Of course, the individuals and artefacts are still

physically separated but not functionally. According to JCS view it is more important to describe the functioning of a joint system rather than seeing the parts as separate entities only interacting with each other (Hollnagel 1998; Hollnagel and Woods 2005).

In the light of JCS the difference between tasks can rather be seen as that different levels of control are needed for the various performances. The focus is therefore shifted from *cognition in the mind* to *cognition as a co-agency process control* of a working situation (Henriqson, Saurin and Bergström 2010; Hollnagel 2002). In this sense, performance is equated to the systems' capacity of control and it can be described by a cycle, which offers a good base to study human co-agency and team control because: (a) Actions are seen together – actions build on previous actions and anticipate future actions. (b) Focus is on anticipation as well as response – performance depends on what went on before and what is expected to happen next. (c) Users are seen as parts of a whole – there is focus on co-agency and how actions and events are mutually dependent. (d) Influence of situation or context is direct – context can affect the user's way of working. (e) Models are functional rather than structural – the emphasis is on performance rather than internal processes (Hollnagel and Woods 2005).

In this paper we are interested in the JCS of a team working to maintain control in complex and dynamic situations and we specifically ask the question: how can team performance be assessed in terms of control?

1.1   Control

In order to answer the research question the concept of control needs to be operationalised. Cognitive systems theory has adopted a cybernetics approach with control defined as circularities of feedback and feedworward. This combines the cybernetic notion of regulation (Ashby 1959; Woljter 2009), the Perceptual Cycle defined by Neisser (1976) and Hutchin's ethnographic accounts on distributed cognition (Hutchins 1995a; Hutchins 1995b). In CSE control emerges from the interaction of human-task-artefact, it is goal oriented and dependent on the context of the activity. One way in which Hollnagel and Woods (2005) have operationalised the concept of control, as a mixture of feedback and feedforward, is the Contextual Control Model (COCOM). Here control characterizes the orderliness of performance and can be described using four control modes: *the scrambled mode*, *the opportunistic mode*, *the tactical mode* and *the strategic mode*, outlined in Figure 1 below. Other parameters that can be used to characterize the control modes are the degree of information seeking and the evaluation of decision alternatives, the following of rules and known procedures, and the number of available plans. In COCOM, control can be described as the ability to maintain a control mode despite disturbing influences, as well as the ability to regain a control mode should control have been lost (ibid.).

3

Control mode	Number of goals	Subjectively available time	Evaluation of outcome	Selection of action
Strategic	Several	Abundant	Elaborate	Based on models/predictions
Tactical	Several (limited)	Adequate	Detailed	Based on plans/experience
Opportunistic	One or two competing goals	Just adequate	Concrete	Based on habits/association
Scrambled	One – not necessarily task relevant	Inadequate	Rudimentary	Random

Fig. 1 Characteristics for the four control modes in terms of number of goals, available time, evaluation and how actions are selected (Hollnagel and Woods 2005, p. 148)

Noteworthy is that Hollnagel and Woods do not suggest that any control mode would be more preferable than another. Instead level of control is seen as context specific and transitions between control modes are important aspects of the adaptions that guarantee resilience in complex environments.

1.2 Protocol design criteria

The team performance assessment-protocol should in particular be based on COCOM (Hollnagel and Woods 2005). By using this model and its concrete definitions of control modes, the team's actions can be categorised according to the definitions of the modes. COCOM also offers a definition of what characterises loss of control, which is common in escalating situations.

The context should be an important factor in the protocol. The CSE view emphasises that actions can only be understood in the context in which they take place (ibid.). The protocol should therefore be designed to be used in the context where the actions normally take place, as opposed to classical psychological laboratory experiments. The influence from the assessor should also be minimal.

The protocol should not be limited to a certain field of use and should thus be generic. Team performance assessment is of interest for numerous fields where human lives can be at risk in escalating situations, for example aviation, fire services and health care. The protocol should also be user friendly, easy to update and give comparable results.

In summary, the protocol should

- be based on control in general and on COCOM in particular
- be used to assess performance in its natural context
- be generic
- be user friendly
- be easy to update
- give comparable results.

1.3   Variables for team performance assessment

Even though the view of a team as a joint agency, rather than separate parts and behaviours, was established well over twenty years ago, there are few methods of team performance assessment based on the theories of JCS. Additionally, we aimed to develop a protocol for team performance assessment based on the COCOM operationalisation of a cognitive system's level of control working in a complex and dynamic environment. The protocol was developed using a design science perspective first assigning the design criteria, followed by developing the protocol, testing it in a pilot study, and finally evaluating whether the design criteria were met.

In order to develop the protocol, the COCOM parameters were first divided into two categories: observable and not observable.

- Observable: information seeking, evaluation of decision alternatives, the following of a procedure, the effect of a powerful indicator.
- Non observable: number of goals, subjectively available time, evaluation of outcomes, available plans, selection of action.

As available time is a main parameter for deciding control modes (Hollnagel and Woods 2005, p. 163), each parameter's relation to available time needs to be considered.

- **Information seeking.** If time is not limited, information can be sought extensively without the need of filtering. If time on the other hand is limited, the information seeking also becomes limited, if not negligible.
- **Comparison between decision alternatives.** When there is unlimited time, decision alternatives can be compared more thoroughly than if time is limited. If time is limited, the first acceptable alternative might be chosen, if there are any alternatives at all.
- **Following of a general procedure.** If the time available is rather satisfying, then there is time to assess the situation and thereafter follow a known procedure, if such procedure for the specific situation exists. When time becomes limited, the situation cannot be assessed and hence a proper procedure cannot be followed.
- **Attraction of attention from a powerful indicator.** When time is limited, chances have to be taken because there is no time to plan for doing anything better. Dominant features of the environment, for

example an alarm, can attract the attention and ongoing actions or plans might be interrupted. If time is unlimited, the causes and effects of the alarm can be evaluated before decisions are made.

- **Number of goals.** If time is very limited, there is only time to work towards one basic goal, such as maintaining physical integrity. As time becomes less limited, more goals can be pursued in order to accomplish the given task.

- **Prediction of future events.** It is important to be able to predict future events for the ability to stay in control, because the prediction determines the choice of actions. If time is limited, it becomes more difficult to make predictions about the future.

- **Evaluation of outcomes.** When time is not limited, outcomes can be evaluated so that future actions can be chosen to better fit the situation. If time is limited, there is no time available to do this evaluation.

- **Subjectively available time.** The parameter of subjectively available time is an important parameter for deciding control modes (Hollnagel and Woods 2005, p. 163), which also is shown in the descriptions of the other parameters above. Lack of available time can be caused by unexpected events, which disrupts ongoing activities and plans.

2   Method

The team performance assessment protocol was tested in a pilot study conducted at MSB College Revinge in Sweden on May 17th, 18th and 19th of 2010.

2.1   Participants

The participants in the pilot study were all taking a nine-week course for fire officers given at MSB College Revinge. They were experienced fire fighters and had also worked as fire officers at a lower level for several years. The participants can be described as highly experienced in terms of on-scene incident command, but of less experience in the roles of a commanding staff with the aim of supporting the on-scene personnel. However their experience of on-scene incident command implied that they were used to taking "a step back" to overview and direct rather than being directly involved in the technical operation. A total number of 23 persons took the course in the spring of 2010 and 22 participated in the commanding staff exercises. They were divided into two groups with eleven members respectively. The splitting was made by the instructor responsible for the course and was based on the members domicile. Group 1 had eleven members who were working at fire services in northern Sweden while Group 2 had eleven members working in southern Sweden.

2.2   Equipment

Two video cameras and three digital voice recorders were used to record the session. The cameras were used in the two larger rooms in the commanding staff training building. For the two smaller rooms and for recording of the counter play, the digital voice recorders were used. Computers connected to the internet were available in all rooms to enable information seeking. The computers also had software installed such as Bfk (for dispersion calculations). The participants also had access to books of reference regarding hazardous goods. Telephones

were available in all rooms for communication with participants in other rooms and with the counter play. One radio was also available for communication with the counter play.

2.3   Task

The general task of a commanding staff applies well to the parameters to be analysed in the protocol. For example, a commanding staff should handle information, make assessments and suggest action alternatives to the commander as well as evaluate outcomes. It is also a fact that the more complex the situation is, the more complex to work of the commanding staff becomes (Svensson 2007).

The overall aim of the task for the specific scenarios studied was for the team to act as a commanding staff supporting a fire officer in charge of an accident. The commanding staff was said to be working from a remote head office and they could not visit the scene in person. To get information about the case they would have to communicate by telephone or radio with the staff on scene (that is the counter play). They could also seek information from other sources, such as from the meteorological institute for information about the weather. Two scenarios (A and B) were used and each group played both scenarios.

2.3.1   Scenario A

The first scenario was a plane crash. An airplane with 85 passengers had crashed in a remote area near a lake. The main objectives of this task were for the commanding staff to

- Plan for taking care of injured and dead
- Analyse airplane evacuation strategies
- Give information to media and to the public
- Coordinate the rescue action with the coast guard, the Swedish Maritime Administration and sea rescue service
- Organise resources and staff on the scene and in the commanding staff

To solve the situation the team would at least have to seek the following information:

- Weather information from the Meteorological institute
- Physical availability to the crash site from the fire officer in charge
- Handling of evacuation from the fire officer in charge
- The number of injured that could be attended from the hospital
- Coordination of the rescue action from the Swedish Maritime Administration

2.3.2   Scenario B

The second scenario was an accident on a highway exit involving a truck loaded with hazardous goods. For this task, the main objectives of the commanding staff were toAnalyse the situation and plan for different developments of the situation

- Plan for the worst case
- Plan for evacuation

- Give information to media and to the public
- Organise resources and staff on the scene and in the commanding staff

To solve the situation the team would at least have to seek the following information:
- Weather information from the Meteorological institute
- Filling degree, transport documents, destination and experts on chemicals from the road carrier company
- Closing of roads from the police
- Information about the accident from the fire officer in charge
- Information about chemicals from books and databases

The objectives and the information needed were not given directly to the participants. Instead the fire officer in charge (the counter play) provided this throughout the session. But it would be possible for the participants to foresee these objectives and the need for information and thus plan in advance. In order to be able to handle the escalating situation, some degree of anticipation was necessary.

2.4 Procedure

The procedure for the pilot study was as follows:

Day 1
1. The participants were informed about the pilot study and were given the opportunity to oppose the recording of the sessions.
2. A two hour lecture was held focusing on what a commanding staff is, how it can be organised and how the work of a commanding staff is initiated.
3. The participants were then divided into four groups and undertook a one-hour training session focusing on the initiation of the commanding staff. All four groups discussed the training session together. This session was not recorded nor analysed.

Day 2 (Group 1) and Day 3 (Group 2)
4. A one hour lecture was held focusing on procedures and tools which the participants were recommended to use during the session.
5. The participants were asked to carry out the plane crash task (Scenario A). The session lasted for approximately one hour.
6. After the session the participants answered the questionnaire and they were debriefed by the instructor after filling in the questionnaire.
7. Another one hour lecture was held under which more tools and procedures were presented.
8. The participants were asked to carry out the hazardous goods accident task (Scenario B). The session lasted for approximately two hours.
9. After the session the participants were debriefed by the instructor and were then asked to answer the questionnaire.

2.5   Data collection procedure

Numerous techniques are available for data collection. Observations were used so that the evaluator defines the control mode of the team during the session, without having to interact with the members. To make it even easier to categorise the performance into control modes, the sessions were video and audio recorded and analysed afterwards.

Because some of the most important COCOM parameters, such as available time and the ability to make predictions about the future are not easily observable, the observation was chosen to be complemented with a questionnaire for the team members to fill in. By doing this, the non observable parameters can also be taken into account when categorising performance into control modes. The questionnaire was also chosen so that it was used in the debriefing session interviews to help on further clarifications.

The participants filled in the questionnaires after the session. Each team member first answered the questionnaire individually. Thereafter, the team answered only one questionnaire together. This is because it is the team as a whole and their performance that is relevant, not what each individual perceived. The purpose of filling in questionnaires individually at first was so that contrasts between participants could be identified and it was also made it easier for the team to fill in a common questionnaire when each member already had though the questions through.

The questionnaire was designed with eight questions to be answered about observable and non-observable variables. The questions are answered for two or three different periods of the session, depending on the length of the session. , This was done in order to capture the dynamics of the session. The periods were scenario-specific (e.g. before and after a particular event). The debriefing session when the team filled in the questionnaires was also video and audio recorded so that it could be analysed.

1. During the session we had goals that we worked towards.

	Beginning	Middle	End
Yes			
No			
N/A			

If yes, specify the goals for each time interval:
Comments and clarifications:

2. We think that we had enough time to handle the situation the way we wanted.

	Beginning	Middle	End
Yes			
No			
N/A			

Comments and clarifications:

3. We compared the different decision alternatives that were available and we chose the very best alternative, instead of the first acceptable.

	Beginning	Middle	End
Yes			
No			
N/A			

Comments and clarifications:

4. After accomplishing an action we evaluated the outcome that this action resulted in.

	Beginning	Middle	End
Yes			
No			
N/A			

Comments and clarifications:

5. We were able to predict how the situation was going to develop.

	Beginning	Middle	End
Yes			
No			
N/A			

Comments and clarifications:

6. We sought information to solve the problem and handle the situation in the following extent:

	Beginning	Middle	End
No information seeking			
Just what was needed for the moment			
Both information needed for the moment and information needed for future decisions and actions			
N/A			

Comments and clarifications:

7. We followed rules and procedures that we had learned for this or similar situations.

	Beginning	Middle	End
Yes			
No			
N/A			

If yes, specify the rules and procedures:
Comments and clarifications:

8. We had enough time to use rules and procedures that were appropriate for the situation.

	Beginning	Middle	End
Yes			
No			
N/A			

Comments and clarifications:

9. There was too much information and we could not attend to all of it.

	Beginning	Middle	End
Yes			
No			
N/A			

Comments and clarifications:

Fig. 2 The participant questionnaire

2.6 Data analysis and control classification

The analysis consisted of three parts: observation analysis, questionnaire analysis and the decision of a control mode for five minute intervals, or another appropriate interval depending on the length of the session. The parts will be explained in detail below.

2.6.1 Observation analysis

The evaluator analysed the video in fixed intervals. A five minute interval was chosen as guideline because the protocol aims at identifying control modes and later also transitions between control modes. It was therefore important that the time periods were relatively short. If they were longer, it would be possible that some transitions would be missed. If the periods on the other hand were too short, it is likely that the team would not have had time to seek information, compare decision alternatives and follow rules and procedures.

To link the observable parameters (as defined in chapter 1.3) to the four control modes (see figure 1) the following distinguishable actions were assigned to classify the mode of control of each teamwork parameter analyzed by means of the link between the participants' actions and the on-going operating context. These criteria also allowed the researchers to analyze how performances of teams were carried out in relation to the time frame.

- **Information seeking** *(e.g. questions are asked, computers and books are used for finding information)*
  - • Scrambled: No information is being sought
  - • Opportunistic: Only information that necessarily is needed for the moment
  - • Tactical: Information sought is needed both for the moment and in the future, but is only sought from a limited set of sources.[1]
  - • Strategic: Information is sought for the moment and in the future, and from all sources available.[1]

- **Evaluation of decision alternatives** *(e.g. discussion on priorities)*
  - • Scrambled: There are no alternatives
  - • Opportunistic: The first identified alternative is accepted
  - • Tactical: The alternatives are evaluated
  - • Strategic: The alternatives are evaluated

- **The actions follow a general procedure** *(e.g. steps learned in lectures or during training)[2]*
  - • Scrambled: No
  - • Opportunistic: No
  - • Tactical: Yes
  - • Strategic: No

- **A powerful indicator attracts the attention and ongoing plans are interrupted** *(e.g. an alarm goes off, a telephone rings)*
  - • Scrambled: No
  - • Opportunistic: Yes
  - • Tactical: No
  - • Strategic: No

For each parameter, there was also the option *not observed* indicating that it was not possible to observe the parameter.

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[1] Before each session to be assessed, the number of available information sources has to be defined so that the evaluator knows when all sources available are being used and when only a limited number is used.

[2] Before each session to be assessed, the available procedures have to be defined so that the evaluator knows when such a procedure is being used.

For each five-minute interval of the recording, the evaluator checked the observed actions for information seeking, evaluation of decision alternatives, whether a procedure was followed and if a powerful indicator affected ongoing plans in a protocol.

When the observation analysis was carried out for the entire session the characteristic performance is translated into a control mode (scrambled, opportunistic, tactical or strategic) for each parameter.

2.6.2 Questionnaire analysis

The answer for each question in the questionnaire was transformed to a control mode by the evaluator according to the following coding key.

Question 1b was not answered by the participants but can be answered by the evaluator according to the team's answer to question 1 together with analysing the video recording.

1. **We knew which our goals were for the session and we worked towards them.**
   Yes: tactical, strategic
   No: scrambled, opportunistic
   Don't know: -

   1b. **How many goals were listed in question 1 and at the same time explicitly stated during the session (check the video recording)?**
   One: scrambled
   Two: opportunistic
   More than two: tactical, strategic
   Don't know: -

2. **We think that we had enough time to handle the situation the way we wanted.**
   Yes: tactical, strategic
   No: scrambled, opportunistic
   Don't know: -

3. **We compared the different decision alternatives that were available and we chose the very best alternative, instead of the first acceptable.**
   Yes: strategic
   No: scrambled, opportunistic, tactical
   Don't know: -

4. **After accomplishing an action we evaluated the outcome that this action resulted in.**
   Yes: opportunistic, tactical, strategic
   No: scrambled
   Don't know: -

5. **We were able to predict how the situation was going to develop and we could plan our work in advance.**

    Yes: tactical, strategic

    No: scrambled, opportunistic

    Don't know: -

6. **We sought information to solve the problem and handle the situation in the following extent:**
    No information seeking: scrambled
    Just what was needed for the moment: opportunistic

    Both information needed for the moment and information needed for future decisions and actions:

        tactical, strategic

    Don't know: -

7. **We followed rules and procedures that we had learned for this or similar situations.**
    Yes: tactical

    No: scrambled, opportunistic, strategic

    Don't know: -

8. **We had enough time to use rules and procedures that were appropriate for the situation.**
    Yes: tactical, strategic

    No: scrambled, opportunistic

    Don't know: -

2.6.3 Deciding one control mode for each minute interval

A specific control mode for each minute interval was decided from the observation and the questionnaire analysis together. This was done by filling in a control mode decision protocol, presented in a simplified form in Figure 2, using the control modes that the observation and the questionnaire analysis resulted in.

If Question 1 in the observation analysis (information seeking) indicated a tactical control mode, then *Ta* was written in the box for Observation analysis 1 and the given time interval. Scrambled control mode was indicated by *Sc*, opportunistic control mode was indicated by *Op* and strategic control mode is indicated by *St*. Questions 2, 3 and 4 in the observation analysis could indicate one or more control modes depending on the answer. All control modes were indicated if that was the result from the observation question.

The results from the questionnaire analysis were indicated in the same way apart from one exception. It was the questionnaire that the team filled in together that was inserted into the control mode decision form. The time marks for each of the periods that the questionnaire was answered where found through watching the video recording of the session. If the question was answered as *not observed* or *don't know*, this was indicated with a dash (-).

Thereafter, the number of scrambled, opportunistic, tactical and strategic indications were summarised separately for the observation analysis and the questionnaire analysis for each control mode. If there were two control

modes indicated at the same position in the control mode decision form they were be counted as 1/2 each. If three control modes were in the same position, each control mode was be counted as 1/3. A single control mode was counted as 1. The numbers were be registered in the *sum (observation/questionnaire) column* for each control mode. Dashes were not summarised.

The number of observation analysis indications was four and the questionnaire analysis resulted in nine indications. To make them comparable the sums had to be standardised. If not doing this and adding more and more questions to the questionnaire in the future, the observation with only four indications would have no effect on the final control mode. Thereafter the sums for each control mode could be added and the results were written in the *standardised sum column* for each control mode.

The control mode with the highest sum is the control mode was registered in the most right column (CM=control mode) for each time interval. If two or more control modes had the same sums, all of them were indicated in the CM column.

2.6.4 Performance analysis

The team's performance was assessed using the control mode decision protocol. The control modes indicated in the most right column (CM) can be ranked according to

4. Strategic
3. Tactical
2. Opportunistic
1. Scrambled

where strategic means high control and scrambled means low or no control. The control mode is registered in a team performance assessment diagram for each time interval and the team performance of the entire session can then be assessed with respect to the following criteria:

- The team moves to a lower control mode and does not return to the higher level.
- The team moves to a lower control mode and returns to the higher level.
- The team maintains the same control mode during the entire session.
- The team moves to a higher control mode, maintains it and did not move to a lower control mode earlier in the session.

3   Pilot study results

The results from the pilot study are presented in team performance assessment diagrams (Figures 3-6) with one diagram presenting one session. The procedure of transforming the information from the analyses into a team performance assessment diagram is presented as an example for two time intervals in Scenario A – Group 1.

3.1 Scenario A

3.1.1 Group 1

The team was fluctuating around the opportunistic control mode. At three points they were working in a scrambled control mode. These periods lasted for five minutes at the time. At one moment, the team reached the tactical control mode and stayed there for five minutes.
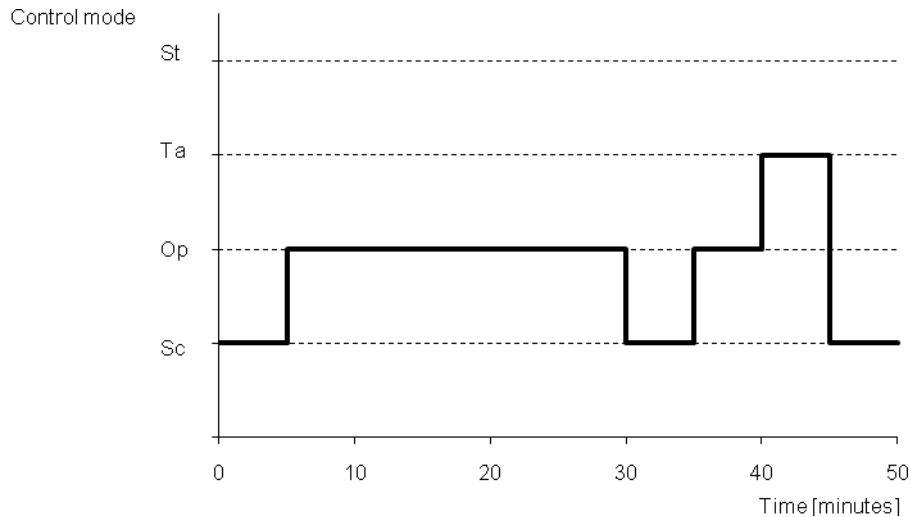

Fig. 3 Team performance assessment diagram for Group 1 – Scenario A

From analyses to a team performance assessment diagram

To clarify how the team performance assessment diagram presented in Figure 3 was retrieved, the steps of the procedure for time intervals 25-30 minutes and 30-35 minutes are shown.

25-30 minutes – observation analysis

Information seeking: the team investigates available recourses from other organisations because the officer in charge asked for the information. This is the only information seeking that can be observed in this time interval and it is information that obviously is needed for the moment only. Therefore, this parameter indicates that the control mode should be opportunistic.

Comparison of decision alternatives: the team sends more rescue units to the accident even though these units were intended to be used to cover up the fire station. There are no discussions on whether there are other units available to be sent to the accident. Thus, this parameter indicates an opportunistic control mode.
The actions follow a known procedure: the team uses commanding staff tools that are appropriate to use in the current situation. This indicates a tactical control mode.

A powerful indicator attracts all attention and ongoing plans and activities are interrupted: this parameter could not be observed and the control mode for this parameter is indicated with a dash (-).

25 – 30 minutes – questionnaire analysis

15

The team answered the nine questions in the questionnaire as follows. By using the coding key presented in Appendix **Fel! Hittar inte referenskälla.**, the answers are transformed into control modes. Question 9 is only included in the questionnaire because it might be of interest to use the answers in future studies. Therefore, the question does not generate a control mode in this study.

1.   During the session we had goals that we worked towards:

            yes → tactical/strategic

1b.   How many goals were listed in question 1 and at the same time

            explicitly stated during the session (check the video recording)?

            2 → opportunistic

2.   We think that we had enough time to handle the situation the way

            we wanted:

            no → scrambled/opportunistic

3.   We compared the different decision alternatives that were available

            and we chose the very best alternative, instead of the first acceptable:

            no → scrambled/opportunistic/tactical

4.   After accomplishing an action we evaluated the outcome that this action resulted in:

            no → scrambled

5.   We were able to predict how the situation was going to develop:

            no → scrambled/opportunistic

6.   We sought information to solve the problem and handle the situation in the following extent:

            information needed for the moment only → opportunistic

7.   We followed rules and procedures that we had learned for this or similar situations:

            yes → tactical

8.   We had enough time to use rules and procedures that were appropriate for the situation:

            no → scrambled/opportunistic

9.   There was too much information and we could not attend to all of it:

            yes

25-30 minutes – control mode decision

Table 1 The observation analysis part of the control mode decision form for 25-30 minutes of Group 1 – Scenario A

	1	**2**	**3**	**4**
25-30	Op	Op	Ta	-

Table 1 presents the control modes that the observation analysis gave for each of the four observation analysis indicators.

Table 2 The questionnaire analysis part of the control mode decision form for 25-30 minutes of Group 1 – Scenario A

	1	1b	2	3	4	5	6	7	8
25-30	Ta/St	Op	Sc/Op	Sc/Op/Ta	Sc	Sc/Op	Op	Ta	Sc/Op

Table Table 2 indicates the control modes that the questionnaire analysis gave for each of the nine questionnaire analysis indicators.

Table 3 The sums (observation/questionnaire) part of the control mode decision form for 25-30 minutes of Group 1 – Scenario A

	Sc	Op	Ta	St
25-30	0/2.8	2/3.8	1/1.8	0/0.5

In Table 3 the number of scrambled, opportunistic, tactical and strategic control modes is summarised for the observation analysis and the questionnaire analysis respectively. This means that for the observation analysis the sum of scrambled control modes is 0 and the sum from the questionnaire analysis for scrambled is 2.8. For the questionnaire analysis, in this case, question 2, scrambled, is counted as 0.5 and opportunistic as 0.5. For question 3 scrambled is counted as 0.33, opportunistic as 0.33 and tactical as 0.33.

Table 4 The standardised sums part of the control mode decision form for 25-30 minutes of Group 1 – Scenario A

	Sc	Op	Ta	St	
25-30	0.31	0.92	0.45	0.05	Op

When standardising the sums from Table 4 above, the observation sum is divided by four and the questionnaire sum is divided by nine. These ratios are then added. For example, the standardised sum for scrambled is calculated as: $0/4 + 2.8/9 = 0.31$ and the standardised sum for opportunistic is calculated as: $2/4 + 3.8/9 = 0.92$. The control mode with the highest standardised sum is indicated in the CM column, in this case opportunistic.

25 – 30 minutes – team performance assessment diagram

The control mode in the team performance assessment diagram for the current time period 25 – 30 minutes is the one indicated in the CM column: opportunistic.

30-35 minutes – observation analysis

Information seeking: the team experiences problems with the internal information flow and no information is sought. Therefore, this parameter indicates that the control mode should be scrambled.
Comparison of decision alternatives: this parameter could not be observed and the control mode for this parameter is indicated with a dash (-).

The actions follow a known procedure: the team uses commanding staff tools that are appropriate to use in the current situation. This indicates a tactical control mode.

A powerful indicator attracts all attention and ongoing plans and activities are interrupted: this parameter could not be observed and the control mode for this parameter is indicated with a dash (-).

30 – 35 minutes – questionnaire analysis

The team's answers to the questionnaire for the 30 – 35 minute time interval are the same as for the 25 – 30 minute interval and are not presented again.

30-35 minutes – control mode decision

Table 5 The observation analysis part of the control mode decision form for 30-35 minutes of Group 1 – Scenario A

	1	2	3	4
30-35	Sc	-	Ta	-

Table 5 indicates the control modes that the observation analysis gave for each of the four observation analysis indicators.

Table 6 The questionnaire analysis part of the control mode decision form for 30-35 minutes of Group 1 – Scenario A

	1	1b	2	3	4	5	6	7	8
30-35	Ta/St	Op	Sc/Op	Sc/Op/Ta	Sc	Sc/Op	Op	Ta	Sc/Op

Table 6 **Table** indicates the control modes that the questionnaire analysis gave for each of the nine questionnaire analysis indicators.

Table 7 The sums (observation/questionnaire) part of the control mode decision form for 30-35 minutes of Group 1 – Scenario A

	Sc	Op	Ta	St
30-35	1/2.8	0/3.8	1/1.8	0/0.5

In Table 7 the number of scrambled, opportunistic, tactical and strategic control modes is summarised for the observation analysis and the questionnaire analysis respectively. This means that in the observation analysis the sum of scrambled control modes is 1 and the sum from the questionnaire analysis for scrambled is 2.8. For the questionnaire analysis, in this case, question 2, scrambled, is counted as 0.5 and opportunistic as 0.5. For question 3 scrambled is counted as 0.33, opportunistic as 0.33 and tactical as 0.33.

Table 8 The standardised sums part of the control mode decision form for 30-35 minutes of Group 1 – Scenario A

	Sc	Op	Ta	St	
30-35	0.56	0.42	0.45	0.05	Sc

When standardising the sums from Table 8 above the observation sum is divided by four and the questionnaire sum is divided by nine. These ratios are then added. For example, the standardised sum for scrambled is calculated as: $1/4 + 2.8/9 = 0.56$ and the standardised sum for opportunistic is calculated as: $0/4 + 3.8/9 = 0.42$. The control mode with the highest standardised sum is indicated in the CM column, in this case scrambled.

30 – 35 minutes – team performance assessment diagram

The control mode in the team performance assessment diagram for the current time period 30 – 35 minutes is the one indicated in the CM column: scrambled.

3.1.2   Group 2

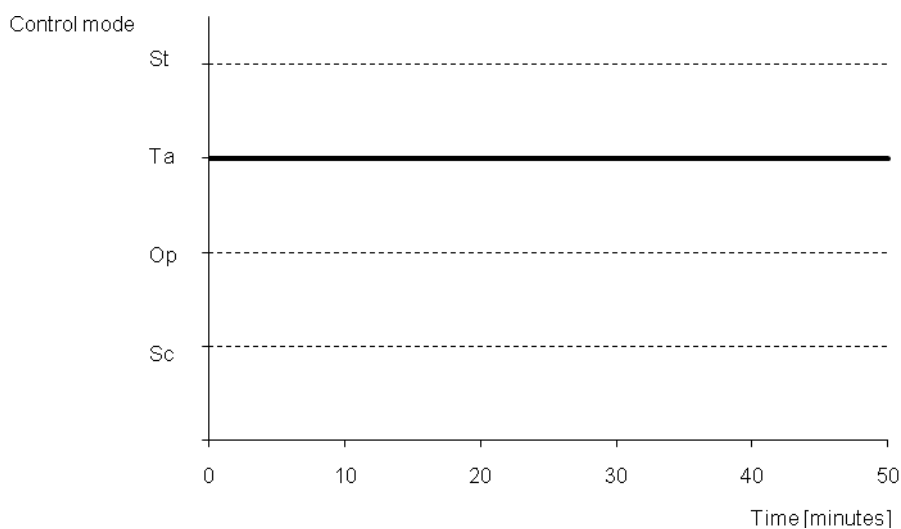The team worked in a tactical control mode for the entire session.

Fig. 4 Team performance assessment diagram for Group 2 – Scenario A

3.2   Scenario B

3.2.1   Group 1

The team worked in a tactical control mode for the major part of the session. For two five minute intervals they worked on a level somewhere between tactical and opportunistic.
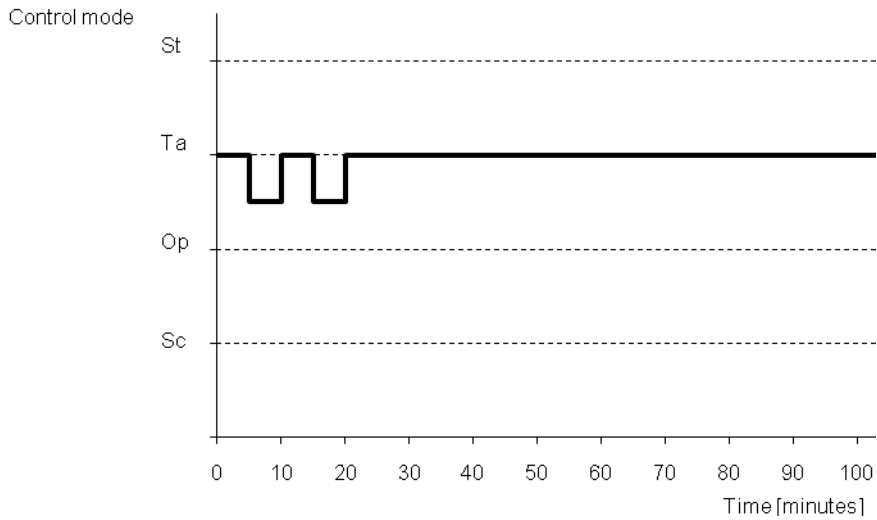
Fig. 5 Team performance assessment diagram for Group 1 – Scenario B

3.2.2   Group 2

The team worked in a tactical control mode for the major part of the session. At one point they were working on a level somewhere between tactical and strategic. This period lasted for five minutes.
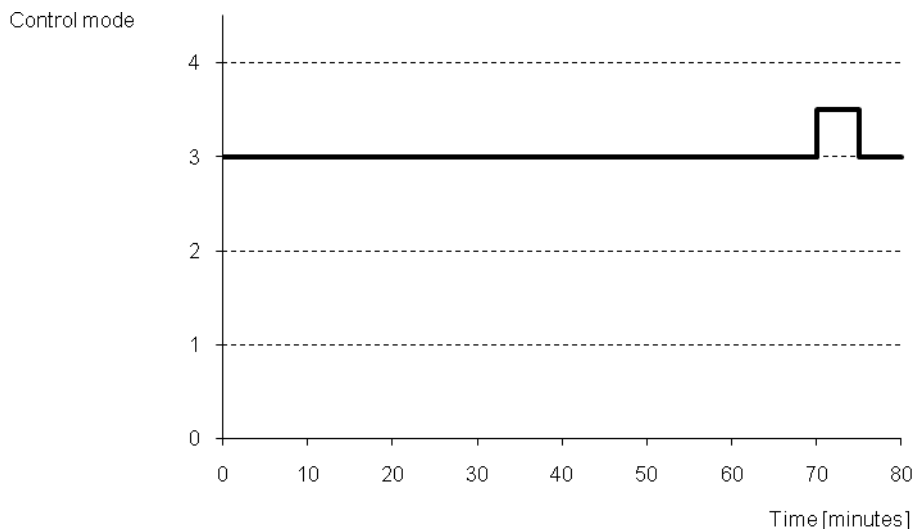

Fig. 6 Team performance assessment diagram for Group 2 – Scenario B

3.3   The impact on result of length of time interval

The results from the sensitivity analysis on time intervals are presented in Figure 7 to Figure 10. Each diagram shows the team performance assessment diagram based on five and ten minute intervals respectively for one session.
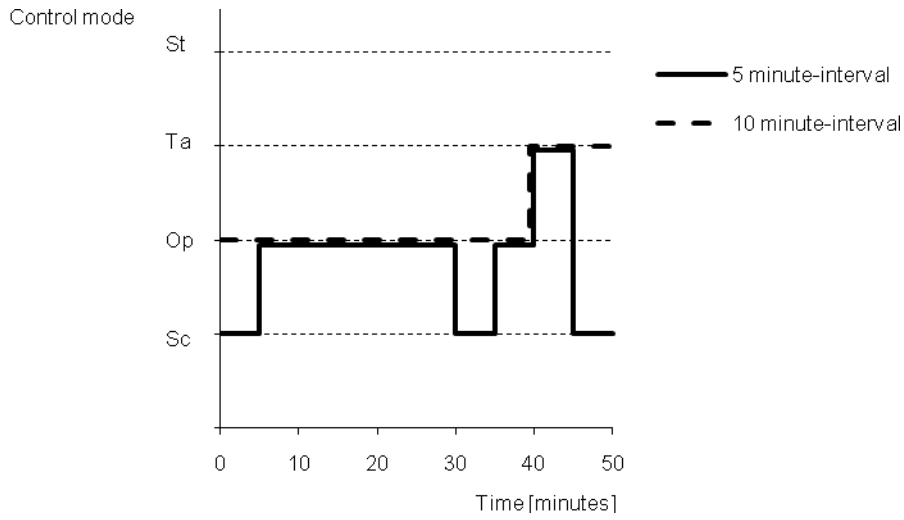
20

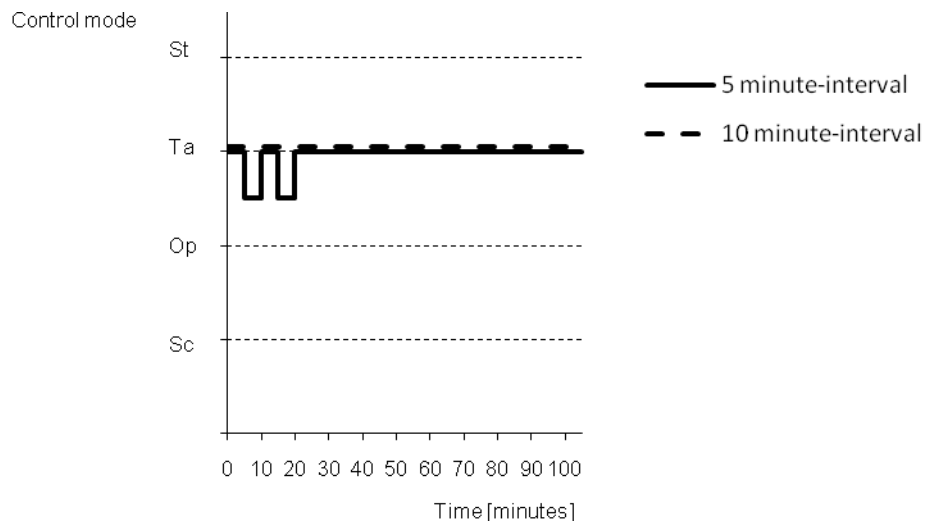**Fig. 7** Sensitivity analysis on time intervals for Group 1 – Scenario A

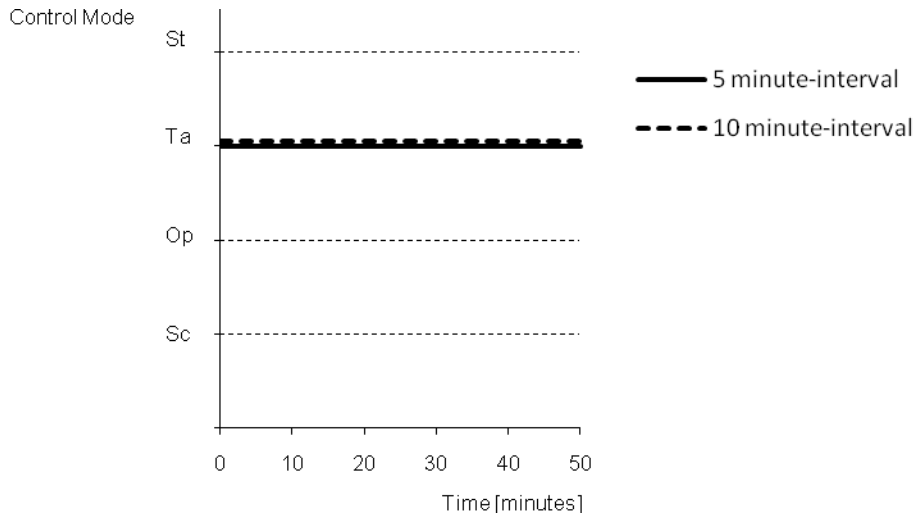**Fig. 8** Sensitivity analysis on time intervals for Group 1- Scenario B

Fig. 9 Sensitivity analysis on time intervals for Group 2 – Scenario A
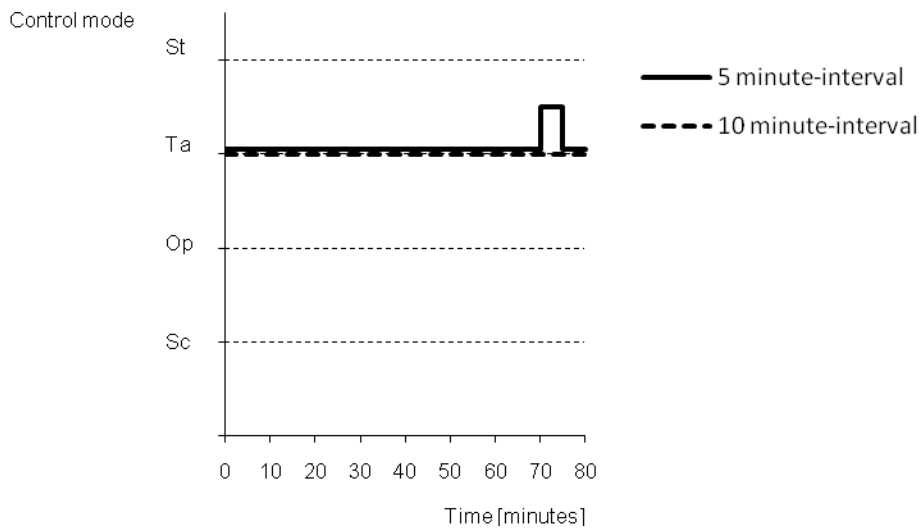

Fig. 10 Sensitivity analysis on time intervals for Group 2 – Scenario B

4　Discussion

Through the development of the team performance assessment protocol the objective of the work has been met and the protocol also gives an answer to the research question *How can team performance be assessed in terms of control?*

In relation to the now widely used behavioural marker protocols the protocol developed in this work assesses the performance without using terms such as thoroughly, effective or properly that need to be interpreted by the evaluator. The protocol presented in the article also tries to avoid the limitations of the behavioural marker system, for example observer bias and overload.

A control mode is of course not something that objectively can be observed but something that is constructed by the evaluator through the observation. However, the construction of control modes is based on observing parameters in the team's activity that are clear and unambiguous. Also, the result of the assessment is not presented in terms of good and poor, which is the case for protocols designed to assess behaviours.

4.1   Discussion about team performance

The scrambled and strategic control modes should not be frequently occurring (Hollnagel 1993a) while performance in general is likely to be a mixture of opportunistic and tactical control modes (Hollnagel and Woods 2005). The result of the pilot study shows that most time is spent in the opportunistic and tactical control modes while little or no time is spent in scrambled and strategic. Thus, the results from the pilot study are in line with the theories of Hollnagel and the performance of the teams could be considered to be normal.

When the teams analyzed in the pilot study loose control the control mode becomes scrambled if they were working in an opportunistic control mode before, and if the former control mode was tactical it becomes opportunistic, or even scrambled at one point. This can be seen in Scenarios A and B for Group 1 (Figures 3 and 5). Hollnagel (1993b) states that loss of control in emergencies corresponds to opportunistic or scrambled control modes and if control is regained it will typically be on the tactical level, which is in line with the losses of control that occurred in the pilot study.

Group 1 and Group 2 worked on the same control mode (tactical) during most of Scenario B, except for during ten minutes when Group 1 worked on a lower control mode somewhere between tactical and opportunistic. For Scenario A the differences between the control modes between the two groups are larger and they only worked on the same control mode (tactical) for five minutes at the end of the session.

A question that needs to be raised in future studies is whether control as measure of team performance actually can be coupled to outcome measures (e.g. mission success, task completion speed and goal fulfilment). Such an analysis has not been included in the aim of the present study but is of great importance for the argument of future use of control measures rather than traditional behaviour assessments.

4.2   Discussion about the use of the protocol

The scenarios used in the pilot study both involved escalating situations, which was desirable when analyzing a protocol to be used to assess team performance in escalating situations. However, the counter play adjusted the scenarios somewhat between the two groups depending on how well the teams performed. The reason for this was that the counter play wanted the participants to become stressed over the situation. Thus, if the team handled it in a satisfactory way, the counter play stressed the scenario even more and presented stressful information more frequently.

The participants were beginners at working as a commanding staff. This made them insecure about the procedures and rules that were available and they did not explicitly state any goals for their work. It should be

easier to verify whether procedures and rules are followed if the participants have some experience and are fully aware of the procedures and rules they ought to follow. The protocol should therefore not be used for assessing team performance when team members are complete beginners, unless the purpose is to compare the performance of novices and experts.

With so many as eleven participants (and another two in the counter play) there were many persons and actions to record. The large number of persons also created a lot of extra noise (from moving chairs et cetera), which later became disturbing during the analysis. It is recommended that the number of persons in a session is limited.

The questionnaire was presented in English for the first session of day 2 (Group 1 Scenario A). The participants had difficulties understanding the questions and in order to complete the questionnaire the questions had to be translated into Swedish ad hoc. For the remaining three sessions the entire questionnaire was translated into Swedish beforehand. The participants appreciated this. It is thus recommended to translate the questionnaire to a language that the participants are familiar and comfortable with.

The participants gave remarks on questions 1 and 7 in the questionnaire. A question where the answer *yes* results in that the answer has to be elaborated may cause false answers to the question (*no* or *don't know* when the actual answer would be *yes*). This problem did not occur in this pilot study but the evaluator should be observant and look for this when the participants are debriefed after the session.

Question number 3 regarding comparison of decision alternatives was the question most frequently not answered or answered *don't know*. Questions number 7 and 8 regarding the use of rules and procedures were also among the questions less frequently answered. This was the fact regardless of the language of the questionnaire. Thus, it should not depend on whether the participants had difficulties understanding the question in the first scenario for Group 1 when the questionnaire was in English.

One reason as to why question number 3 frequently was not answered or answered *don't know* could be that this was a commanding staff exercise. Their task was not to make any decision but to retrieve decision alternatives and present them to the officer in charge. But if question number 3 generates similar patterns in future studies it should be considered to reformulate or remove the question.

Questions number 7 and 8 might be less frequently answered due to the lack of experience from the participants in this field. For most of the participants it was the first time that they encountered commanding staff work. They may therefore not have had any experience of the rules and procedures appropriate for such work. They did have approximately three hours of lectures regarding commanding staff work before the sessions but this might have been too little or too close to the sessions. The instructors responsible for the exercises also stressed that this short introduction to commanding staff work would not make the participants full fledged commanding staff members. It would only give them a starting point for future training in the field.

Concerning the specifications of goals, rules and procedures in questions 1 and 7 it could be said that they were answered in the individual questionnaires but not in the team questionnaire. Answering the individual questionnaire takes time, especially when the answers shall be clarified. It could be an idea to have the specifications only on the questionnaire of the team as the clarifications are of more importance and interest for that questionnaire. By doing so, more focus is put on the team questionnaire and less on the individual.

Recording what was said in the counter play was valuable as it enhanced the understanding of the situation. All parameters in the observation analysis form could not be seen in all time intervals. This was expected as time intervals were kept relatively short. It might be so that in other types of environments more parameters can be identified during the same time interval.

Having four parameters to look for in the observation analysis was enough. Looking for more parameters would make it easier for the evaluator to miss something or become confused or stressed by the task.

A difficulty arose during the observation analysis due to ambiguity in the alternatives in relation to *not observed* in the observation analysis form. It was for example difficult to separate *no information seeking* from *not observed*. In the pilot study it was chosen to indicate *no information seeking* when the participants clearly just passively sat and waited for information to come to them instead of actively seeking information. When the team members were busy with other tasks, the information seeking parameter was marked *not observed*. The difference between the two alternatives and how they shall be used have to be clarified for the future.

If the evaluator is experienced in analyzing the performance using the parameters in the observation analysis form and if the team only uses one room for the session it might be an idea to do the observation analysis without recording the session. The evaluator could then fill in the form while watching the team perform in real time.

The time available for filling in the questionnaires during the pilot study was limited. The situation therefore became stressed and no clarifications or comments were left on the questionnaire of the team. This made the questionnaire analysis somewhat difficult. Especially when the teams in question 1 had stated that they worked towards goals but did not specify them. During the analysis it was chosen to use the team's positive answer to working towards goals for control mode decision in question 1. In question 1b on the other hand, the answer could be zero goals at the same time as the team had answered yes to question 1. Guidelines for how this situation is going to be handled must be available for future use of the protocol.

Another problem that arose during the questionnaire analysis was how to decide a control mode for question 1b if the number of goals was zero. Today, the key says that one goal corresponds to scrambled, two to opportunistic and three or more to tactical and strategic. For the pilot study zero goals were chosen to correspond to scrambled control mode, as having zero goals could be seen has having little control. Another solution for future studies could be that zero goals results in a dash (-).

Questions 1 and 1b regarding goals were difficult for the participants to answer and for the evaluator to specify a number of goals. The truth might be that it is rare for teams to explicitly set up goals for their work. If the same difficulties arise in future studies, it maybe should be considered to reformulate or removing questions 1 and 1b from the protocol. But it would also be possible to change the way teams work so that they set up goals to a greater extent instead of changing the questionnaire. Having defined goals could be something that could enhance team performance and thus be desirable.

In this pilot study the teams did not see the questions before the first session. When they were to fill in the questionnaire after the second session, they had obviously seen the questionnaire before. There was a difference in how the team discussed the questions after the second session compared to after the first. It seemed as if they reflected more over the questions the second time. The reason could be that when the team knew the questions beforehand, they had the possibility to reflect about their performance in terms of the questions during the session. This should give higher validity to the team's answers to the questionnaire. For future studies, it might therefore be a good idea to present the questionnaire to the team before the session.

During the pilot study the evaluator, together with an instructor, were present in the room where the participants were working. The impression from the pilot study is that this did not affect the team and their performance. They were most of the time fully engaged in the task and did not seem to pay attention to the instructor and the evaluator. But it is obviously impossible to know how the teams would perform in the pilot study if nobody except the team members was present in the room. If, however, the evaluator can be present in the room without affecting the team it would be a benefit. For example an evaluator being present in the cockpit during a regular flight could assess the performance of pilots.

The six design criteria were evaluated one at the time. The purpose was to identify which design criteria that had been fulfilled by the protocol and which had not. Below we give a short discussion on the adherence of each design criteria.

- **The protocol shall be based on control and COCOM**
  The protocol is based on COCOM. No modification of the protocol is needed for this criterion.
- **The protocol shall be used in natural context**
  The commanding staff training building at MSB College Revinge is built to be as similar as an ordinary commanding staff space as possible. The protocol can therefore be used in a training environment built to be a copy of the natural environment (not a laboratory). No modification of the protocol is needed for this criterion.
- **The protocol shall be generic**
  Nothing can be said about this design criterion at the moment as the protocol only has been tested in a fire service environment. Further studies have to be conducted in other fields (with a variety of parameters such as number of participants and environmental noise) to verify the fulfillment of this criterion.

- **The protocol shall be user friendly**

  The protocol is not user friendly if several rooms are used during the session. It becomes difficult and time consuming to synchronise and analyse all the different recordings. It is therefore suggested that the protocol is limited to be used in situations where only one or a maximum of two rooms are used during the session.

- **The protocol shall be easy to update**

  The questionnaires can easily be adjusted to fit different situations by changing the time periods for which the questions shall be answered. It is also easy to add or remove questions from the questionnaire. The observation analysis can also be adjusted easily by changing the time interval for which the recording is to be analysed and parameters can easily be added or removed. The number of video cameras and sound recorders can also be adjusted to fit the session to be analysed. No modification of the protocol is needed for this criterion.

- **The protocol shall give comparable results**

  The results from the pilot study were compared both within each group (Group 1 Scenarios A and B, Group 2 Scenarios A and B) and between the groups.

  The results show that the first performance of Group 1 (Scenario A) fluctuates around the opportunistic control mode with four changes in control mode during the session. The second performance (Scenario B) fluctuates around the tactical control mode with two changes in control mode during the session. The conclusion is that the control mode is generally higher in the second performance than in the first and that fluctuations are less frequent in Scenario B than in Scenario A.

  The results from the first performance of Group 2 (Scenario A) show a static tactical control mode. No fluctuations are identified. The second performance (Scenario B) is rather similar to the first performance with the tactical control mode being dominant. However, the difference between the two performances is that the team manages to reach a level between tactical and strategic control modes in the Scenario B.

  When comparing the first performances (Scenario A) between the two groups the conclusion becomes that for Group 1 the performance fluctuates around opportunistic control mode whereas for Group 2 the performance is steady at the tactical control mode. Thus, the control mode is generally higher for Group 2 than for Group 1.

  For the second performances (Scenario B) both teams were working around the tactical control mode. Group 1 had two fluctuations towards opportunistic control mode and Group 2 had one fluctuation towards the strategic control mode. Thus, the performance of Group 2 was at moments in a higher control mode that the performance of Group 1.

  According to the teams themselves they performed better in the second session that in the first. This was also the opinion of the instructors who also found that Group 2 generally performed better than

Group 1.

> When comparing the results from the team performance assessment with the opinions of the team members themselves and the instructors it seems as if the result given by the protocol reflects reality. There is an indication, at least for this type of sessions, that the protocol gives comparable results. The protocol does not have to be modified regarding this design criterion for the moment. Further research, including the aspect of inter-rater reliability should be undertaken to thoroughly verify this finding.

The protocol has not been tested in such extent that it now can be used to assess team performance in terms of control. However, when the protocol has been further validated, through studies of more teams in different contexts and including aspects of inter-rater reliability, the goal is that the protocol shall be used to assess team performance in various fields, such as aviation, in fire services and in health care.

In order to validate the protocol and to fulfil the design criteria the protocol has to be further tested, also in other domains than fire services. The question to be answered is: Is the protocol generic?

5   Conclusions

In order to answer the research question *How can team performance be assessed in terms of control?* the literature surrounding cognitive system coordination and control was reviewed. Taking off from the literature, a protocol for assessing team performance in terms of control was developed. This protocol was then tested in a pilot study. The main points of the work are summarised below.

- It is possible to assess team performance in terms of control. A method for doing this was developed by reviewing the definition of control and performance from CSE and by incorporating a language for capturing the team's work and performance into a team performance assessment protocol.
- The developed protocol changes the focus of team performance assessment from good and poor behaviours toward the team's activity.
- The pilot study indicates that it is possible to identify differences in performance by using the protocol to assess team performance.

There are several potential implications of a team performance assessment protocol focused on team level control rather than individual motivational and cognitive factors. Being consistent with the JCS theory stressing cognition as distributed in the work process the protocol can be used to guide design of human-machine environments (in which cognition is, according to JCS distributed between the human as well as the technological artefacts). In training environments the protocol can help guiding a discussion about the impact of increased complexity in terms of changed management strategies, in situations when the team experience changes of control modes, as well as the (potentially) positive impact of training. In short there is a need for team performance assessments that reflect the characteristics of the work process and there team performance assessment based on control seems to hold the potential of filling an important gap.

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