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Development of a Self-Rating instrument to Measure Team Situation Awareness

Topics: Information Sharing and Collaboration Processes and behaviors, C2 Assessment Metrics and Tools

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ABSTRACT

The goal of this paper is to describe the development of an instrument to measure team situation awareness (TSA). Individual team member SA may or may not be shared through communication processes with other team members. Most existing instruments do not measure these processes but measure TSA as a product. Because team members have access to the quality of their communication processes, we developed a self-rating instrument. Advantages, compared to existing TSA instruments, are that it is non-obtrusive with the task and easy to use. Based on a literature review, we selected conditions, processes and outcomes that had to meet three criteria. They had to be relevant for achieving and maintaining TSA, easy to measure, and offer opportunities for team leaders to improve TSA. We administered the instrument in two military and one civilian crisis management exercise. On the basis of these results, we determined psychometric properties such as validity and reliability of the items constituting the instrument. The results of these case studies show that the instrument provides valuable insight to the team leader. The questionnaire will be further improved by developing an automatic tool that identifies and visualizes the feedback on TSA to the team.

Key words: measurement instruments; field studies; questionnaire; team situation awareness

INTRODUCTION

Team Situation Awareness (TSA) is important for effective decision making and team results. Without TSA, teams lack common ground on which to base their decisions, and the result may be flawed decision making due to different perceptions of the situation, the current task, the responsibilities involved, or other factors. TSA is often a problem because team members do not always understand which information is needed by other team members, because they lack the proper devices to share information, because they lack shared mental models, or because they lack the communication skills for sharing relevant information. Measuring TSA will give insight in what hampers acquiring and maintaining TSA and how this can be improved. The goal of this paper is to describe the development of an instrument to measure TSA.

In a recent review of situation awareness models for individuals and teams, Salmon et al. (2008) distinguish between team situation awareness models, shared situation awareness models, and distributed situation awareness models. In their view, team situation awareness models comprise individual team member SA, SA of other team members, and SA of the overall team. Shared SA refers to the level of overlap in common SA elements between team members. Distributed situation awareness views SA as an entity that is separate from team members and is in fact a characteristic of the system, the ensemble of humans and machines, itself (Artman & Garbis, 1998). Salmon et al. (2008) argue that the team SA perspective may be sufficient for simple, small-scale collaborative scenarios, but that the distributed SA approaches are the most suited to describing and assessing SA in real world, collaborative environments, such as in military network enabled capability scenarios. Even though we focus on measuring team SA in a complex environment, C4I, our measurement is developed from the team SA perspective.

The difference among the use of these concepts, according to Salmon et al. (2008), seems to evolve around the necessity of sharing everything with everyone. In this respect, there is a parallel with the ambiguous concept of 'shared' as in 'shared mental models.' 'Shared' can either mean 'to have in common', as in shared beliefs, or 'to distribute', as in sharing a dessert (Cooke & Gorman, 2007). However, in our opinion, the concept of team SA is not limited to the notion of 'to have in common.' Team-level properties are in large part the result of team-member interactions (Hackman, 1987). Therefore, SA of the overall team is constituted by team-member interactions (Salas, Prince, Baker, & Shrestha, 1995). Individual team member SA may or may not be shared through communication processes with other team members. Hence, the communication processes are what matters in teams, not the amount of knowledge shared. TSA, by focusing on team processes, does not assume complete overlap in knowledge, and is therefore just as applicable in C4I environments, where there is obviously no complete overlap, as in small, simple-scale scenarios.

Because achieving and maintaining TSA in C4I environments seems a continuous, complex and dynamic team process (Bezooijen & Essens, 2007) that changes constantly, we focus on the processes of acquiring and maintaining TSA. Furthermore, the definition of a team as "a distinguishable set of two or more people who interact dynamically, interdependently, and adaptively towards a common and valued goal/object/mission, who have been assigned specific roles or functions to perform, and who have a limited life span of membership" (Salas, Dickinson, Converse, & Tannenbaum, 1992) already implies that TSA cannot be seen as a state at a certain point in time but refers to a continuous, complex and dynamic team process.

Most existing measurements do not measure processes but measure TSA as a product, for example tools such as the situation awareness global assessment technique (SAGAT). Content

methods and flow methods, on the other hand, can be used to gain insight in processes by observing team member interactions. Content methods focus on an analysis of the meaning of communication. Flow methods tend to focus on the sequencing and timing of communicative interactions among team members. Although these methods are useful in laboratory settings, they are too time-consuming and expensive to be useful in field settings. They also require extensive instrumentation and the presence of expert observers and analysts. In practice, this is frequently impossible.

We hypothesize that self-rating techniques may well be applied to measure TSA in C4I environments. The first reason for this hypothesis is because team processes are observable. Team members have access to, and can form judgments on, the quality of communication processes involved in the sharing of information. The second reason for our hypothesis is that self-rating techniques do not interfere with task performance because they are completed post-trial. Thirdly, self- rating questionnaires are very quick and easy to use because they require very little training, accompanied by very little cost. A fourth advantage is that self-ratings of TSA can be obtained from different team members (Endsley et al., 2000b), thereby offering a first step into the assessment of team SA. One aspect that needs to be taken into account when using self-rating techniques in C4I environments is that they need to be adjusted to suit the dynamic, complex, and collaborative nature of such environments. A C4I-specific self-rating technique thus needs to be developed.

The instrument to be described below was developed for use by military commanders and their staff and commanders and sub commanders on different levels (for example battalion level and brigade level, ships). With some adjustments the instrument can also be used for civilian teams, such as emergency management teams.

METHOD

Development of the self-rating questionnaire

A condition-process-output model was used as a framework to develop the questionnaire. We adopted the following approach: based on overview chapters and articles, we first identified conditions that influence acquiring and maintaining TSA. Next, we selected critical processes for both individual sensemaking (building up a picture of the situation) and shared sensemaking (sharing a picture of the situation) and finally we identified outcomes. We used these conditions, processes and outcomes to develop items for the questionnaire. These steps are described in more detail below.

Conditions. Three components that influence the processes of acquiring and maintaining TSA can be distinguished: environmental component, team component and individual component (Bolstad, Cuevas, Gonzales, & Schneider, 2005). Based on team research (e.g. Essens et al., 2005) a fourth component should be distinguished: the task that has to be performed by the team. These four components consist of multiple factors that are believed to influence achieving and maintaining TSA, as depicted in Figure 1.

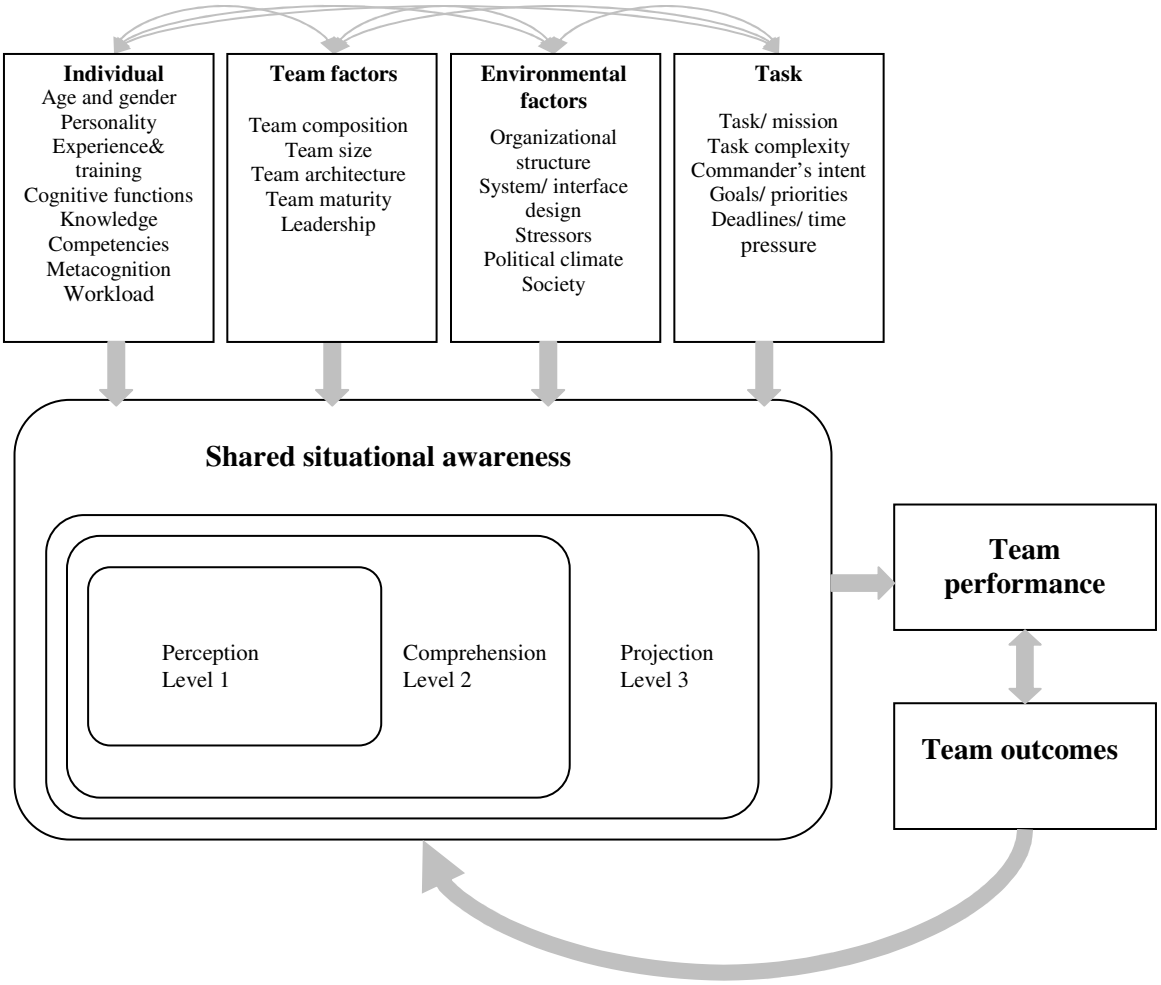

Figure 1. Theoretical framework of TSA (Van Bemmel, Langelaan, de Koning, Van Hattem, 2008)

We selected, based on literature and practical implications, the most relevant factors of these components to serve as input for the questionnaire. Personality, for example, may influence acquiring and maintaining TSA, but measuring this factor would require an extensive set of questions. Workload, on the other hand, is a relevant and easy to measure construct that affects TSA. At high levels of workload, (shared) situational awareness declines, because not all information can be attended to (Endsley & Jones, 1997). Therefore, we consider workload to be a factor that should be represented in the questionnaire. Another individual factor that can increase TSA is shared experience (e.g. working or training together as a team; similar

experiences that may occur either together or individually) (Endsley & Jones, 1997). This factor is also easy to measure and offers team leaders possibilities to intervene, and is thus selected for the questionnaire.

We used the same procedure to select relevant factors of the task, team and environmental components to be included in the questionnaire. Next, we grouped the selected factors into two main categories: team-related conditions and task-related conditions. The team-related conditions concern factors related to awareness of other team members' information needs, tasks and responsibilities. Task-related conditions are factors related to the task itself, such as workload and task complexity. A selection of these team-related and task-related factors and corresponding items is shown in Table 1.

Table 1. *A Selection of the Conditions and Corresponding Items in the Questionnaire*

Conditions	Factor	Item
Team factors	Insight in each other's information needs	What was the insight of the team members in the information needs of other team members?
Task factors	Workload	What was the level of workload?

Processes. Given the typical heterogeneous team structure that we encounter in command and control teams, interactions among team members are crucial for arriving at TSA. This implies that assessment of TSA should focus on communication processes, or, more generally, on the quality of interactions. Quality of interactions is determined by quality of individual sensemaking and leads to a certain degree of shared sensemaking (Salmon et al., 2008). The following sources were in particular useful for selecting relevant, easy to measure factors to serve as input for the questionnaire: Hackman (1987); McGrath (1984); Wilson, Salas, Priest, &

Andrews (2007); Endsley (2006); Klein, Philips, Rall, & Peluso (2006); and the evaluation of crisis management team processes during a large crisis management exercise in The Netherlands (Van de Ven, Frinking, Van Rijk, & Essens, 2008). The individual sensemaking processes concern behaviors related to achieving an accurate picture of the situation (for example, searching for more information). Shared sensemaking processes are behaviors related to sharing this picture with other team members (for example, sharing information about the situation). A selection of these factors and corresponding items is shown in Table 2.

Table 2. *A Selection of the Processes and Corresponding Items in the Questionnaire*

Processes	Factor	Item
Individual sensemaking	Information exchange	How well did your team actively seek further information to extend and elaborate their picture of the situation?
Shared sensemaking	Closed-loop communication	How well did your team members verify that information sent was interpreted as intended?

Outcomes. Positive scores on team and task factors as well as on individual and shared sensemaking processes are expected to correspond positively to a higher level of TSA and better team results in terms of perceived quality of plan, decisions and actions taken. A selection of these factors and corresponding items is shown in Table 3.

Table 3.
A Selection *of the Outcomes and Corresponding Items in the Questionnaire*

Outcomes	Factor	Item
Shared awareness	Shared awareness of goals	To what the degree did the team have shared awareness of the goals to be achieved?
Team results	Quality of decision making	What was the quality of the decisions that were taken?

Application of the self-rating questionnaire

To investigate the practical applicability of the TSA questionnaire, we applied the instrument in practice to teams participating in a civil flood control training, a military preparation exercise for Afghanistan, and a Joint Air Defense exercise.

Civil flood control training. The civil flood control training was part of a flood control training that takes place twice a year in the Netherlands. Multiple organizations were involved in this training, namely officers of first responders (police, fire department and paramedics), liaisons of the department of defense, districts water board and the Ministry of Waterways and Public Works. All persons within these organizations have their own tasks and responsibilities. The operational team that was assessed consisted of 16 members. Nine team members had little experience with being a member of an operational team (0-5 times) and seven members had a lot of experience with being a member of an operational team (6 or more times). The TSA-questionnaire was distributed on the second day of the training.

Military preparation exercise for Afghanistan. The military preparation exercise for Afghanistan took place in the Netherlands. The staff that was assessed consisted of 15 staff

members. Eleven team members filled out the questionnaire. The tasks that were trained were planning and decision making.

Joint Air Defense exercise. The joint air defense exercise served as a platform to evaluate a new doctrine. The team that was assessed was composed of officers from the navy, air force and the army. The questionnaire was distributed twice; after the planning process and after the plans were executed.

RESULTS

We will describe the most important results of the cases in which we used the questionnaire. After the results were analyzed, these were discussed with an observer of the exercise and with a team member who took part in the training. The description of these cases will give insight in the usefulness of the instrument.

Civil flood control training

The results show that team members knew what the roles and tasks of the other team members were, but didn't know what information was needed by other team members. Team members also didn't determine well enough for whom information might be relevant. Consequently, passing information to other team members was insufficient. Sharing information was difficult because there was no shared information system and organizations were located in different parts of the building. Sharing information with other team members is easier if everybody has access to the same information and if people are located close to each other. Even though not all conditions and processes for achieving and maintaining TSA were judged as positive, team members rated their overall TSA as good. This may either be explained by a demand characteristic or by compensatory processes taken during the exercise. The first explanation is unlikely, given that team members were more negative about another outcome

variable, TSA of actions taken, than about TSA of the situation or the goal state. TSA of actions taken was judged as relatively poor, as the actions were not actually taken during the exercise and team members did not receive feedback on the quality of their actions. Evidence for compensatory proceses comes from an interaction with level of experience with exercises such as this one. On several questions (looking ahead; quality of decision making process; asking clarifying questions), the more experienced team members scored significantly higher than the less experienced team members. Debriefs afterwards showed that experienced team members used more opportunities for clarification, compensating for less optimal sharing of information and use of different terminology.

A military preparation exercise for Afghanistan

The team members judged the conditions concerning the team as positive. The members of the battle group staff that participated in this military exercise knew each other very well. Most of the team members had often worked with all other staff members. The battle group staff participated in five previous exercises in which most of the same staff members were present. Roles and tasks were therefore clear and the staff was trained well to perform the tasks. The conditions concerning the tasks were less positively rated. Complexity and workload of the training were rated as high. The processes concerning building and sharing a picture of the situation were rated positively by the largest part of the team. Team members remarked that information was shared regularly, team members listened to each other and interpretations of the situations were compared. As a result, all team members were positive about the shared awareness of the situation and goals to be achieved.

Joint Air Defense exercise

The questionnaire was distributed twice during this exercise. The fist measure was taken after the planning process and the second measure after the plans were executed. The results show that most conditions and processes improved during training. After the first measurement, team members' insight in each other's information needs and insight in different roles and tasks was rated as insufficient. After the second measurement, the team members had worked together for a while and the insight in each other's tasks and roles and information needs was improved. The use of a common terminology was a problem during the whole exercise. The first measurement showed that half of the team members were of the opinion that the use of (a common) terminology needed improvement. After the second measurement still one third of the team members was dissatisfied with the lack of a common terminology. This lack of a common terminology is a big problem because it causes confusion between team members and has a negative impact on achieving TSA. In general, team members were satisfied with processes. After the first measures, some processes concerning building and sharing TSA needed improvement, for example 'checking if factual information is correct' and 'noticing differences in interpretations about the tasks and roles'. However after the second measure team members judged the different processes positively. Remarks were made that they had to get used to share the picture of the situation with team members. To do this properly a lot of (useful) discussions were needed. TSA about the plans and the goals also improved during the training. At first, about one third of the team members rated TSA about plans and goals as insufficient. After the second measurement, most of the team members rated TSA about plan and goals as sufficient.

Conclusion practical applications

The questionnaire was distributed in several exercises. For each of these exercises insight was gained in what conditions, processes and outcomes were rated positively and what aspects needed improvement. The results of these practical applications show that this was different for each team. For example, the results of the flood control training show that the processes concerning sharing the picture of the situation didn't go well. This was mainly caused by the structure of the building, the lack of a shared system and the insufficient insight in each other's information needs. Besides, most of the team members had only worked together one or two times before this exercise. The results of the military training for Afghanistan show that the different processes and outcomes were sufficient even though the workload was very high. The battle group staff had participated together in several exercises before this exercise and therefore they knew each other's tasks and roles very well and knew also what information was needed by other team members. This might explain why the different processes concerning building and sharing a picture of the situation went well, even though the tasks were complex. The results of the Joint Air Defense exercise show that repeated administration of the questionnaire gives insight in what effect the exercise has on the different conditions and processes. The second measurement showed for example that insight in each other's tasks, roles and information needs improved compared to the first measure. The dissatisfaction with terminology, however, remained. The questionnaire was adjusted based on the feedback we received from the practitioners. We also conducted a factor analysis to improve the validity of the instrument.

Validation of questionnaire

The questionnaire is based on a conditions-process-output model. To test whether this structure is appropriate we conducted a factor analysis. This analysis was conducted on a different data set as discussed above. The questionnaire was distributed in a military exercise where a new structure of the staff was evaluated. Fifty-three officers filled in the questionnaire. We used these results to conduct a factor analysis. Overall, 7 factors can be extracted. These are shown in table 4. We had to delete questions about task complexity and workload (task factor), probably due to the formulation of these questions. It might be better to use existing scales such as the NASA-TLX. Furthermore, we had to delete the question 'how well does the team leader check whether goals are clear'. Probably, because all questions are asked on a team level, except for this question. The question about checking goals was also asked on a team level (did team members ask questions to clarify the goal) and therefore the question 'how well does the team leader check whether goals are clear' can de deleted. The results of the factor analysis show that all other items of the questionnaire were part of a factor. The results of the factor analysis are shown in table 4. The adjusted and final questionnaire is shown in appendix A.

Table 4. *Factor analysis and cronbach's alpha of questionnaire.*

	Name of factor	Eigen value	% of variance explained
Conditions	Team factors (2 items)	1,9	27,3 %
Processes	Building a picture of the situation, Level 1 Endsley (2 items)	1,3	21,1 %
	Building a picture of the situation, Level 2 and 3 Endsley (3 items)	2,1	35,6 %
	Sharing a picture of the situation (2 items)	1,2	19,4 %
	Heedful interrelating (noticing different interpretations) (4 items)	3	50,1 %
Output	Team situation awareness (4 items)	2,8	55,7 %
	Team results (4 items)	3,5	43,3 %

DISCUSSION

Measuring team situation awareness in large-scale life exercises has proven to be a daunting challenge (Salmon et al., 2008). The sheer number of participants, the lack of control over the measurement process, and a host of practical constraints (time, cost, effort) rule out a large number of available measurement tools. For instance, tools that require a scenario to be frozen in order to assess team members' individual SA are not likely to be applicable in these large-scale life exercises. Similarly, tools that demand heavy involvement from expert observers may not be feasible when teams are distributed and/or observers are not allowed to carry out observations. Other constraints that apply to situation awareness measurement tools are: validity, reliability, sensitivity, lack of interference with the primary task, and the ability to measure team SA as well as individual SA.

We have found that self-rating questionnaires, although not perfect, are able to meet a lot of the constraints mentioned above: they are simple to administer, require little cost and time, can be filled in without the presence of expert observers, by large numbers of participants, do not interfere with primary task performance, and are able to measure team SA as well as individual SA in a valid, reliable and sensitive manner, although these latter methodological issues need further corroboration. As far as validity is concerned, we have attempted to ground our questions in the available literature. Although we could have included many more questions in our questionnaire, filling out the resulting all-encompassing questionnaire would have become too time-consuming for participants. Based on the available literature, we believe we have included the most relevant questions. As far as reliability is concerned, this may be less of an issue in field settings than in laboratory settings, where the goal is theory development. Our aim with the questionnaire is not primarily to advance theory, but rather to provide commanders with insight into their teams' information gathering and communication processes. Whether these teams would fill in the questionnaire in the same way, under identical circumstances, is largely a theoretical question that does not arise in practice. We have had our Joint Air Defense teams fill out their questionnaires at two occasions separated in time, and we found interpretable differences, due to the team's development in TSA. Finally, as far as sensitivity is concerned, the question may be asked whether a questionnaire is able to record small differences in TSA. Again, this is more of a theoretical than a practical concern. In practice, commanders are more interested in the number of participants scoring a particular dimension in a negative or positive way, rather than in subtle differences in means. We have therefore adopted pragmatic criteria such as when 30% of the participants score below the midpoint of an item, that item demands attention, given that most participants have a bias to respond positively.

Apart from these practical concerns, have our field studies yielded novel insights in cooperation and coordination processes? Generally, we have seen that there is a lot of improvement on gaining accurate and correct situation awareness. Actively seeking information, assessing factual correctness, asking critical questions, checking clarity of goals are all processes that demanded attention. Lack of common terminology and not knowing the information requirements of other team members are also frequently occurring issues. This may hamper coordination and cooperation in teams, particularly when teams consist of diverse units that do not share a common language, as is frequently the case in joint and combined exercises. In contrast, relatively stable units such as our battle group preparing for Afghanistan reported far less communication and coordination issues.

Not only was there room for improvement in gaining situation awareness, there was even greater room for improvement in sharing situation awareness. Sharing of information is difficult if one does not know who needs what information when. This is exacerbated if there are no common information systems and people are dispersed physically, as in the flood control exercise. In military exercises, common information systems are available, but lack of common terminology between forces may hamper achievement of TSA.

There also remains the issue of the relation between TSA and outcome measures. We have circumvented this issue by asking respondents directly about their opinion on various outcome measures (quality of decision making; quality of plans; quality of SA). This is justifiable given that our focus was on team processes rather than outcomes. We have noted occasional discrepancies between TSA and outcome measures, in that respondents were generally more negative about team processes than about team outcomes. As noted above, one possibility is that team members compensate for defective team processes and in the end achieve satisfactory team

outcomes. However, another interpretation could be that team members have a different view on the relation between processes and outcomes than we as researchers have. In their view, proper team outcomes may well be achieved by processes other than the ones we have asked them about. In that case, our questionnaire lacks completeness. Theoretically, it is well-known that individual taskwork determines team outcomes to at least the same extent as teamwork (Mathieu et al., 2000), albeit indirectly through its impact on team processes. Our questionnaire, by focusing on team processes, may therefore still capture individual taskwork factors as well. Yet another interpretation is that team members only become aware of team processes when they need to respond to the questionnaire for the first time. This could evoke a somewhat less biased response than when they have to answer questions on team outcomes, with which team members are frequently more familiar. Finally, it may be likely that team members do not have a proper understanding of the outcomes of the team as a whole, which implies that we should attach less weight to their response to these items than to the team process items.

We are currently validating our questionnaire with larger sample sizes. We have recently administered the questionnaire during a large-scale NATO Response Force (NRF) exercise, with units distributed across three countries. Approximately 80 respondents have filled out the questionnaire, which allows us to calculate internal consistency. Another area for improvement is more rapid data collection and reporting of results to commanders. We are working on automating data collection and analysis, so as to be able to present results to commanders during the exercise, instead of a few hours or days afterwards. This should enable commanders to get a quick overview of their team's SA. As a next and logical step, we will focus on interventions that commanders can employ to enhance TSA.

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Apendix A
The TSA-Questionnaire

Component	Item
Team factors	1. What was the level of skills and knowledge of your team members to perform the task?
	2. What was the insight of the team members in the information needs of other team members?
	3. What was the insight of the team members in the roles, tasks and responsibilities of team members?
Building a picture of the situation: level 1	4. How well did your team actively seek further information to extend and elaborate their picture of the situation?
	5. How well did your team assess whether information was factually correct?
Building a picture of the situation: level 2 and 3	6. How well did your team understand what the information meant for their own task?
	7. How well did your team form an impression of how the situation will develop?
	8. How well did your team pose critical questions to clarify the goal and the tasks to be accomplished?
Sharing the picture of the situation	9. How well did your team members pass relevant information to other team members within a timely manner before being asked?
	10. How well did your team members verify that information sent was interpreted as intended?
Heedful interrelating (noticing different interpretations)	11. How well did your team members notice different interpretations of the important factors?

Component	Item
	12. How well did your team members notice different interpretations of the situation?
	13. How well did your team members notice different interpretations of the goal and corresponding tasks to be accomplished?
	14. How well did your team members notice different interpretations of the roles, tasks and responsibilities?
Team Situation Awareness	15. To what the degree did the team have shared awareness of the situation?
	16. To what the degree did the team have shared awareness of the goals to be achieved?
	17. To what the degree did the team have shared awareness of the tasks that have to be performed?
	18. To what the degree did the team have shared awareness of the factors that influence task performance?
Team results	19. What was the quality of the planning process?
	20. What was the quality of the plan?
	21. What was the quality of the actions that were performed?
	22. What was the quality of the decisions that were taken?