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# Analysing team processes of operator teams working in high risk environment

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## Introduction

More and more organisations prefer to restructure the workflow around teams. The technological developments, the increased complexity of operations, the high variety of the systems that needs to be controlled underlines the demand of discipline specialisation, the justness of expert or professional teams, especially in ***high reliability organisation*** or ***high risk environment.*** High risk environments are environments in which there is a more than normal chance of damaging one's own life, the life of others or material property (Dietrich & Childress, 2004). The ***professional or expert teams*** are highly differentiated from other teams by the exclusive membership of experts, where the team members represent different areas of speciality and they have to integrate their specific knowledge in order to operate the technologically complex system on team level. Cockpit crew, air traffic controllers, medical teams, operator teams in different power plants can be considered as professional teams.

To run a complex system the individual knowledge structures including the specific long term professional knowledge and the information about the current situation must be integrated into the team knowledge. The interaction of team members during task accomplishment is remarkably important, since individual knowledge is transferred to team knowledge through ***team processes***. In spite of the fact that the individual knowledge is clear and accurate, the inefficient team processes may impede the integration of these knowledge structures, leading to inaccurate team knowledge and inappropriate team action (Cooke et al., 2000). There is a substantial body of conceptual work, as well as empirical research that focus on the effects of team knowledge on team performance; nevertheless the picture is less clear if we want to identify what kind of team processes may help the integration of individual knowledge.

In high risk environment there have been strong efforts to minimize unsafe acts, to make the system more predictable and controllable, through a high level standardization. The high degree of standardisation led to a work environment where the majority of actions are covered with standardized procedures. Due to strong standardisation the teams mainly work under low or moderate level of task load. Task load can be considered as an objective difficulty connected to the properties of a task and of the environment (Grote, Zala-Mezö, 2004). Despite the high standardisation, as the task environment is complex there is always a chance for unexpected, novel events that can have a strong effect on the team members' behaviour. The constant alertness intensively loads the team members' capacity, as they have to provide a quick and immediate response to the emergence of unexpected event that disrupts the normal procedures of task accomplishment. Under these circumstances any errors, omissions made by the team members may hay have serious material and (life) consequences. Although the appropriate adaptation to high level of task load periods is crucial, it is still under question how the team should efficiently adapt with the team processes to high task load periods.

One of the main questions of studying expert teamwork is how the team members having specific knowledge are able to integrate their knowledge in order to operate and manage a technically complex system. Furthermore the other question that needs to be addressed is how the team should adapt with team processes to different levels of task load.

## Research aim

The central question of my research is how the team members are able to integrate their individual professional knowledge during task accomplishment to run complex systems. The present research studies key team processes that help the appropriate joint assessment and management of the current situation, thus leads to high team performance. The first part of the study aims to identify specific team processes that guide team performance through the integration of individual knowledge creating and shaping team knowledge. After exploring key team processes the research goals are:

1. to analyse the relationship between team processes and ***team performance***, in order to distinguish/differentiate between excellent and poor performing teams' team processes;
2. to analyse the relationship between team processes and ***task load***, to identify how the team processes change under different levels of task load, and to understand how teams adapt to high task load situations with team processes;
3. to analyse the combined effect of ***team performance and task load*** on team processes, to explore how the excellent performing teams adapt to the emergence of unexpected event (high task load).

## Team processes and team performance

The team knowledge frameworks emphasize that team cognition may be captured through two different cognitive constructs. On one side through ***team mental model***, referring to the collective task and team relevant knowledge (roles and responsibilities, knowledge of team mates, skills, abilities, beliefs) that supports the joint, collective interpretation of the task and team actions. On the other side through ***team situation model***, describing collective understanding of the specific situation, team situation awareness that guides the team in assessing and interpreting cues and patterns of the current situation (Cooke et al., 2000; 2001; 2004). Team cognition guides the team in assessing the cues of situation, determining strategies, taking appropriate actions. Team performance will be maximized to the extent that team knowledge is accurate, appropriately apportioned among members, structured in a way that supports the development of effective strategies (Cooke et al., 2000). In this way team performance is shaped by those team processes – such as communication, cooperation and coordination- that help to integrate, share individual knowledge, to create and continuously update team knowledge about the team, task, and the current situation.

In the following section the hypothesis will be presented along with the literature review.

**Hypothesis 1: Excellent performing teams are more efficient in their information flow, information collection and distribution behaviour than poor performing teams**

### COHERENCE OF INFORMATION FLOW

The primary task of communication is to foster the establishment, maintenance and modification of team knowledge. The complete information flow between team members is particularly important in the joint establishment and fine tuning of this shared knowledge. A

coherent information flow helps the team to transfer, distribute and assimilate the relevant information related to the task and the team, establishing the coherence of the joint actions.

The coherent conversation can be viewed as continuum. There is a strong semantic connection, relation between the talk and the parts of a text, such as cause, condition, affirmation and summary. In other words, the text is hierarchically structured, each part is semantically related to other parts (Krifka, 2004).

Grommes and Dietrich (2002) analysed the coherence of cockpit crews' and medical teams' conversation. Data were taken from cockpit voice recorder and the video tape transcripts of the team members' communication. As a result of their study the researchers emphasize that the coherent information flow may be described by *quaestio maintenance* (where the team members sustain the information flow, though they do not add new information), or by *qaestio shift* where the team members add new information to the conversation. Both quaestio maintenance and quaestio shift necessitates high level of common ground between team members. Analysing the coherence of information flow Grommes (2007) stated that the operating room team members share a broad common professional knowledge, which constitutes the basis to be engaged in a coherent conversation. The coherent flow of information facilitates the creation of shared knowledge, common ground, which is essential for efficient joint activities.

### COLLECTING AND SHARING INFORMATION

It is often claimed that team members collect and share information in order to identify the necessary information about tasks they need to perform, receiving, collecting, screening information about these tasks. Appropriate information collection allows the team to better understand the situation, the system, which will help to build a shared conceptualization of the faced problems, leading to the effective establishment of team knowledge. (Waller et al., 2004). Analysing medical teams', cockpit crews' and nuclear power plant operator teams' communicative behaviour, the results revealed that the teams where they strive to share information with each other, will collect more useful information about the system and the task. It leads to a more clear and appropriately apportioned team knowledge, in this way they will be more efficient in their task accomplishment. While in low performing teams the members do not aim to acquire information, they reduce their ability to perceive the relevant environmental cues and act accordingly (Waller et al., 1999; 2005; Krifka, 2004; Krifka et al., 2004; Johannsen, 2008).

In order to collect the information needed to accomplish the task is important to form the questions in an appropriate way. Some studies claim that the use of more complex questions loaded the working memory, which in turn increased the risk of sending and receiving erroneous messages (Sexton J. Bryan, 2004). The closed, yes/no questions are verifications, they are easy and quick to answer, in contrast with open questions ("what, why, how") that are incomplete and force the addressee to use the cognitive resources, to think and reflect.

### ACKNOWLEDGING THE RECEIVED INFORMATION

In the process of the formation of common knowledge it is not sufficient only to gather and share the information, but it is also necessary to confirm the received information. It is not

only the information sharing and information collection activity that counts, but also the acknowledgement of the received information.

To acknowledgement of the received information is essentially important in a technologically complex environment, where the team members have to process information simultaneously from more sources, in addition the team members have to face several communication noise (in particular given the background noise of the control room for ex. control room indicators and alarms). All these factors may lead to the loss of relevant information, which in high risk environment could have some serious consequences. The lack of verbal feedback may suggest that the addressee overlooked the information (that may be relevant), in this way the speaker does not know whether the information has been perceived or not that entails the risk of interrupting the communication. The importance of affirmation, acknowledgments has been confirmed by previous researches, the frequent use of affirmation has been shown to be indicative of high performing teams/cockpit crews (Krifka, 2004; Krifka, et al., 2004).

**Hypothesis 2: Excellent performing teams' team processes include more coordination supporting behaviours compared to poor performing teams .**

### COORDINATING THE ACTIONS

Several researches have been demonstrated the constructive effect of coordination on team performance. Detailed behavioural analyses of naval tactical teams revealed that the effective teams demonstrated higher frequencies of behaviours involving coordination (Oser et al., 1989). These results are in line with other previous researches. Siskel and Flexman (1962, In: Oser et al., 1989) emphasize the importance of coordination, orientation, organisation and motivation as important aspects of efficient team functioning.

The aim of coordination is to integrate, synchronise individual actions, to continuously compare the actual results with the goals, material, time and other types of resource constraints. Coordination is the team process of orchestrating the sequence and timing of team members' actions. For a synchronized action it is important for all team members share the same idea about the goal, task and the process toward the goals. In order to establish the shared vision about the goal and tasks it is important to identify and divide the main task, to specify the goals and responsibilities, to develop shared mental model of the task accomplishment. Having the same goal in mind, team members tend to focus their attention on behaviours leading to goal attainment and ignore activities irrelevant to the goal (Rousseau, 2006). Teams with poor strategy, goal and mission development risk misguiding their attention, not to be able to focus their energy at the same direction (Marks at el, 2001).

In order to develop the shared vision about the goals and task accomplishment it is also important to prioritize the course of actions, to identify the primary and secondary tasks. Synchronising the tasks of all the different professional fields may be accomplished only if the team members compare their actual task to the assigned goals, situational and time constraints. Tasks executed in a timely manner ensure goal accomplishment without resource losses (Rousseau, 2006). Comparing cockpit crew's behaviour with two behavioural marker system (NOTECH, LOSA) the analyses revealed that the excellent performing teams showed planning and briefing more frequently in their behaviour (Hausler et al., 2004).

**Hypothesis 3: Excellent performing teams' team processes include more heedful interrelating behaviour, more signs of joint and anticipated actions compared to poor performing teams.**

When the team members act heedfully, their attention is focused on the joint situation, they endeavour to have a detailed representation of others' actions, to support each other to accomplish a successful join action, the contributions are shaped by anticipated responses, they strive to understand the consequences of the unfolding events.

### FOLLOW AND CONTROL THE PROCESS, SYSTEM AND ACTIVITY

Following and controlling the progress toward goal accomplishment, the team members' activity, the changes in the system are all behaviours that serve the successful goal attainment (Oser et al., 1989; Dickinson, McIntyre, 1997; Marks et al., 2001). The efficiently performing teams follow and control system information, team members' actions in terms of what needs to be accomplished for goal attainment and in this way the team is able to determine the likelihood of success. Following the progress toward the goals enables them to recognize when they have a discrepancy between the current state of task accomplishment and the desired, expected goal. This helps the team members to correct, regulate their behaviour and to adapt team resources to the environmental requirements (Rousseau, 2006). Effective teams that work in a dynamic environment continually follows with team processes the progress toward the goal, system status and the team activity. Following the team members' activity along with the system, environmental information helps the team to synchronize the sequence and the timing of team members' action in regard to the goals thus supports team coordination. Tracking the process, the system as well as the team actions may also support team members' heedful interrelating. Heedful interrelating is present in the team, when the team members mobilize deliberate effort to constantly reconsider effects of their own actions in relation to the goals and of others (Weick, Roberts, 1993).Tracking the system, the environmental conditions and the team actions along with the effective communication of this information, support the establishment of team situational awareness (Marks, et al., 2001). Furthermore the summary of all the steps that are taking or have taken, along with the information that has been mentioned may also help the team members to establish and maintain their situational awareness. This behaviour supports to conduct situational planning/contingency planning; helps to determine what steps need to be done to achieve the team's goals. In this way this team process promotes, fosters team coordination too (Crichton, Flin, 2004; Grote, Zala-Mezö, 2004; Groete et al., 2004).

### ANTICIPATE THE PROCESSES

In a dynamic environment the key element of successful mission accomplishment is the efficient adaptation to the unexpected events. Anticipating the consequences of the actual events, anticipating the potential problems lead to deliberate actions, where the team members interrelate their actions with the goals (actions will be subordinated to the team goals). The team behaviour when the members think deliberately about the consequences of their acts, of the situation is considered a sign of a heedful interrelating (Grote, Zala-Mezö, 2004; Groete et al., 2004). Weick and Roberts (1992) emphasize that efficient team cooperation, heedful interrelating requires from the team members to subordinate themselves to the requirements

of the joint action as well as to the team goal, and to continuously be aware of the consequences of their actions.

#### SUPPORT AND CORRECT THE ACTION OF TEAM MEMBERS

Studying navy team cooperation the analyses revealed that excellent performing teams made more often positive statements to motivate each other, they were open to call each other's attention to a mistake. The excellent performing teams motivated to correct each other's behaviour, thanked another members for catching their mistakes. Teams that were successful in training praised each other for doing well on a task, made positive statements to motivate each other, and thanked another member for catching errors (Oser et al., 1989). These results were in line with previous findings, well performing teams were oriented to identify acknowledgement and correct mistakes (Siskel, Flexman, 1962, IN: Oser et al., 1989).The positive reinforcement of the behaviour beside the mistake orientation and correction also includes motivational and reinforcing statements between the team members. Correcting team member's behaviour may be considered as a sign of coordination (Dickinson, McIntyre, 1997), cooperation (Goeters et al., 1998; Yule et al., 2006) or heedful interrelating (Groete, Zala-Mezö, 2004). Team members point out each other's mistake, in this way they reaffirm the right course of actions. Teams act heedfully when their behaviour is characterised by deliberateness, attention, support, awareness provision, watchfulness and vigilance (Weick, Roberts, 1993).

Another manifestation of the supporting behaviour is when the team members ask and offer assistance to each other. If there is trust within the team, team members / do not hesitate /are not afraid to ask help from each other, because they do not fear to exploit their vulnerabilities, by asking help from another team member (as long as they trust in each other the team member will have no fear of being vulnerable by asking help, because they believe that they will not seem incompetent by asking help) (Tarnai, 2003). The presence of trust will lead to team perspective where the team members show willingness to help each other. In teams with high levels of trust, the individual easily overcome obstacles, difficulties, as the team members direct their effort toward the team goals, while near a low level of trust the individuals are less likely to direct their efforts toward common goals, individual action will take the place of joint actions (Dirks, 1999). The absence of trust among team members will easily lead to conflict, the team members will have the tendency to apply a faulty attribution style, instead of focusing on the task, they orient the attention to each other, and any negative statement will be taken as a personal attack that calls for defensiveness.

## Team processes and task load

During low task load the team members monitor the system, environment, routinely scan the particular parameters, and detect any changes in specified signals. During moderate level of task load the team members have to respond to the system information, by following the standardized procedures, they have to maintain and improve the function of the system. Despite the high level of standardization the team has to be continuously on alert as there is always a chance for the emergence of high task load situation where the team has to manage unexpected events, unfamiliar problems.

Previous literatures have already emphasized the negative effects of high task load on the attentional focus, working memory, information processing (Mumaw, 1994; Driskell et al., 2006; Kontogiannis, Kossiaveou, 1999; Dietrich et al., 2004). Most of the previous literature summarizes the task load effects on performance based on laboratory researches, focusing more on the individual and less on team level consequences of high task load. The present research aims to determine in a realistic environment how team processes change under different levels of task load, focusing on the high level of task load.

**Hypothesis 4: During high task load the narrowing and shift in the attentional focus, the narrowing of team perspective and the impaired information processing will have manifestations in team processes.**

One of the most commonly mentioned effect of high task load is the narrowing and a shift in the attentional focus. During high task load due to the increased level of arousal the individuals' attention becomes more narrowly focused on the central cues. As the attention narrows, firstly the peripheral cues are ignored; later the task relevant ones may be neglected too. The narrowed attention that occurred during high task load will have an effect on the information receptiveness (Mumaw, 1999; Driskell et al., 1999; Dietrich et al., 2004). During task accomplishment the expert teams have to integrate information from more sources. As the attention becomes focused and selective the team members will process information from less channels, in the optimal case they will focus on the channels that are crucial in the current situation (Fukuda, Sträter, 2004). The information process capacity is limited, the activated selective filters serve to cope with the overwhelming amount of information, but it might happen that due to the same selective filter crucial stimuli will be filtered out and lost. In emergency situation the language processing is not just focused, but becomes intensively selective or reduced inhibiting the necessary communication, cooperation with the environment.

Driskell (et al., 1999) concluded that the narrowing of attention that occurs under high task load may be applied to the social cues as well, resulting in a restriction of social cues and a narrowing of team perspective. The team perspective means the perception of the interrelations of actions in a team. The individuals perceive the dynamic interdependence of group members. It implies a mutual awareness of the tasks as a collective, joint act. The signs of the narrowed team perspective may be captured by the shift from a broad team perspective to a narrow individualistic focus. Under high task load, team members adopt a narrower, more individual perspective of task activity, the social cues are neglected, the individuals become less socially cognizant, and they will be less sensitive to the need of others. High task load results in a shift of individual attention from external cues to a more internal self-focus. The increased self-focus may be adaptive till a certain degree as it increases self-awareness, at the same time diverts the attention from external task-relevant information, inhibits the efficient information processing. Although, the efficient team functioning requires common perspective about the team's goal, resources, and performance strategies.

The increased arousal level may inhibit the efficient functioning of working memory. The reduced working memory capacity could have a negative effect on tasks that require information processing, such as deductive reasoning, arithmetic computations, and spatial

manipulations. High arousal is better for speeded processing of information which in turn will lead to increased quality in the storage of information (Mumaw, 1999). In sum we may conclude that the capacity of working memory is severely reduced under high task load which will impair all communicative tasks that need information processing.

**Hypothesis 5: During high task load even though the cognitive resources are overloaded, the frequency of team processes oriented toward the management of technical problem will be increased.**

According to some approaches during high task load the increased arousal level will result in narrowed attention focus. This explanation suggests that under high task load the majority of cognitive resources are focused on the threats, on the most critical elements of the environment. Under these circumstances there is a high need to reduce the perceptual field to the potential threats, the technical problem, in order to help the individuals to cope with them (Mumaw, 1999). In this way, even though during high task load the cognitive resources are overloaded, as the attention is focused on the technical problem the frequency of communicative behaviours that address to focus on the unexpected event and on the management of the technical problem may be increased.

## The effect of team performance and task load on team processes

**Hypothesis 6. Excellent performing teams adapt their team processes to the requirement of the environment: adapt more efficiently to high level of task load than low performing teams.**

Several researchers indicate the importance of adaptive coordination. Different types of tasks, situations requires different coordination mechanisms, moreover different phases of the same task necessitates different types of coordination and cooperation (Espinosa et al., 2002; Groete, Zala-Mezö, 2004; Groete et al., 2004). During goal attainment different coordination, cooperation, communication mechanisms are appropriate for different situations, as the degree of standardisation and the level of task load changes. According to some researchers the high task load situation requires intensive explicit coordination, as the coordination through standardisation of behaviour is not enough to orient, integrate and synchronize the individual actions (Xiaou, 2001, IN: Manser et al., 2008; Kolbe et al., 2009; Schraagen, 2011). Contrary to this view other researchers argue that implicit coordination is more efficient in high task load situations, where resources for explicit coordination may be limited (Manser et al., 2008). Compared to explicit coordination, implicit coordination requires less time and energy, it is an economic way of coordination.

In a technically complex environment – such as a control room – there is a strong need for understanding, knowing the potential threats and possible contingencies (Antalovits, Izsó, 2003; Izsó, Antalovits, 2006; Sexton et al., 2004). Briefings at the beginning and at the end (before and after crew session) of task accomplishment have been demonstrated to be an efficient mean to reduce the uncertainty and the level of perceived workload (Krifka, 2004; Krikfa et al., 2004; Dietrich, 2004).

High task load situations can increase communication density, as the team members need to create a new common ground about the situation. During high task load, the team members' cognitive capacity is overloaded; under these circumstances the intensive communication may further increase the load of cognitive capacity. The shift from explicit to implicit communication could be one of the efficient strategies to adapt to high task load situations (Serfaty et al., 1993, IN: Kontogiannis, Kossiaveou, 1999). One manifestation of implicit communication is when the team members anticipate the needs of others, share information with each other without explicit request. Implicit communication relies on shared picture about the task and the team (team mental model), as well as on a common ground, collective understanding of the current situation (team situation model, team situation awareness) (Kontogiannis, Kossiaveou, 1999).

High task load will result a greater the degree of interdependence among team members which requires the presence of a strong team perspective (Driskell et al., 1999). The previous researches claim that team members respond to high task load with increased self-focus, narrowed focus of attention and decreased information receptiveness (Mumaw, 1994; Driskell et al., 1999; Dietrich et al., 2004). According to some studies higher level of interdependence leads to a broader team perspective, however high task load results in a narrowed team perspective. The results further indicated that the narrowing of team perspective that occurred under high task load leads to impaired team performance. High task load, emergency situation requires several tasks to perform in parallel which increases the demand for synchronising activities (Kontogiannis, Kossiaveou, 1999).

## Research method

The data collection was based on operator team interactions observation in the Simulator Centre of a Hungarian power plant. Since team processes are the central factor of my research, the empirical studies of a "lively" interaction can best be carried out by analyses of carefully chosen simulator sessions. The Simulator Centre may be considered as a realistic, high-fidelity tool that is widely used in training and examinations creating the required level of face-validity to be relevant for real life situations. Data from 16 operator teams' interaction have been collected. Each team had to follow the same scenario. Choosing the simulation, we took into consideration that the scenario had to be oriented toward communication, in this way, all team members had to be involved in problem solving. Possessing complementary knowledge they had to share information with each other to manage the problems occurred during the simulated malfunctions. Video records of operators' activity during the selected scenario have been also used for collecting and analysing data. In order to keep the operators' real life behaviour the instructor informed them at the beginning of the simulator study about video recordings during the on-going training session, but they did not know exactly which of the programmed scenarios would be videotaped. The mean duration of scenario is about 35 minutes. All the recorded conversation of the operators was transcribed in chronological order.

**OPERATOR TEAM:** Control room operators are responsible for maintaining safe and correct running of plant operations and optimising all of its parameters. Primary task is to monitor

important plant parameters. The Power Plant's operator teams consist of 5 operators and a Shift Leader.

**TASK LOAD EVALUATION**: The instructors had to divide individually the scenario into different parts according to the level of task load. The level of task load was analysed on a 3 point Likert scale (1- low, 2 moderate, 3 –high). After the individual task load evaluation, the instructors had to reach consensus on their evaluation. Finally, the scenario was divided into 3 phases by the instructors: (1) ***moderate***, (2) ***high,*** (3) ***moderate*** level of task load.

**PERFORMANCE EVALUATION**: The performance scores were made by the instructors' evaluation, both at individual and collective levels. The individual performance was based on the evaluation how the role related tasks were accomplished, using the 3-point Likert scale (1 – ***poor,*** 2 – ***medium,*** 3 - ***excellent***). The team performance was assessed by the instructors' impression about the teams' efficiency (based on the number of detected errors by the team, if the tasks were accomplished in a timely manner; following the rules, standard operation procedures) using the same 3-point Likert scale. Based on the assessments of expert instructors the data can be considered reliable. The analysed 16 teams contained 4 poor, 8 medium, 4 excellent performing teams.

## Team processes analyses

The team processes analyses were based on the ***transcribed conversations, communication*** and the ***video recordings***.

The team process analyses were focusing on two aspects of team processes: on one side to the processes ("how") on the other side on the content ("what"). The team process analyses aimed to answer two questions: (1) what team members communicate and (2) how team members communicate during task accomplishment (*Table 1.*).

| The focus of research methodology | TEAM PROCESSES | | |
|---|---|---|---|
| | PROCESS ("HOW") | CONTENT ("WHAT") | |
| Levels of analyses | Coherence | Sentence level | Event level |
| Sources of analyses | Transcribed communication | Transcribed communication | Transcribed communication and video recordings |
| Units of analyses | Communicative behaviour | Sentence | Communicative behaviour |

*Table 1. The focus of research methodology and the levels of analyses*

Process based ("how") team process analyses focused on the coherence of information flow. The communication, information flow is coherent when there is a semantic connection between the verbal utterances.

The other, content focus ("what") had two different levels of analyses:

- ***Sentence level***: the communication between team members has been analysed at sentence level, classifying the sentences in predefined categories that covers the team processes.

- ***Event level***: the team members' communicative behaviour has been analysed based on the video recordings and on transcribed conversation.

The process ("how") based team process analyses oriented toward the sequencing of communicative behaviour among team members , take into consideration the on-going stream of information exchange, information flow (sequential analyses).

Content ("what") analyses apply static measurements, where specific coding schemes were developed, the communicative behaviours were coded into these categories, aiming to capture the most relevant part of the team processes. The analyses consider the team's communicative behaviour as an aggregate of the information flow during the complete task accomplishment.

## Process („how") based team process analyses

One of the most important questions that needs to be answered by communication analyses is how coherent is the information flow, discourse between team members. The communication is coherent when there is an explicit semantic relationship between the elements of discourse (Krifka, 2004).

The categories measuring the coherence of information flow were based on the work of Grommes and Dietrich (2002; Grote et al., 2004), the Quaestio theory and methodology (new quaestio, shift quaestio, back shift, restoration, maintenance categories). The units of analyses were parts/segments of communicative behaviour, thoughts, communication utterances (by one member of a team limited by a longer pause) that describe a new thought in the discourse. These units of communicative behaviour were coded into one of the following categories:

- ***Thoughts with turn taking***: taking up an initiated thought, the interlocutor develops a new thought related to the previous one, adding new information or just maintaining the conversation.
- ***Thoughts without turn taking***: an initiated thought is not taken up by any of the team members. Thoughts without turn taking were coded when two or more new thoughts were expressed after each and none of the team members reacted on these.

## Content („what") based team process analyses

### Sentence based analyses

Categories for sentence based content coding analyses were based on two team work methodologies and researches made in high risk environment: (1) Speech Act Type-inventory for the Analyses of Cockpit Communication STACK (Krifka, 2004), (2) GIHRE (Group Interaction under High Risk Environment) - Linguistic Factor Project (Krifka et al., 2004).

Developing the categories two other widely used methodology were taken into account, though these were not aiming to categorize team work in high risk environment: (1) LIWC (Linguistic Inquiry and Word Count) (Pennebaker et al., 1997, 1999) (2) Interaction Process Analysis, IPA (Bales, 1950).

The second step after the literature research and review was the semi-structured analyses of transcribed communication. These analyses revealed that the sentences can be categorized

into four distinct categories: ***questions, commands, information providing and affirmations***. The categories described by the previous methodologies and studies were classified into these four categories, dividing the main categories into more subcategories. The final categories were mutually exclusive: each sentence can be categorized into only one of the main categories.

In order to ensure the reliability of analyses, the interobserver agreement indicator, the Kappa statistics, Cohen's kappa coefficient were calculated, analysing the agreement between two independent observers' analyses. The inter-rater reliability $r_k$ varied between 0.056 – 0.088 among the categories. The list of final categories is presented in the *Chart 1*.

### Event based analyses

The sentence based content analyses of team processes created the need to analyse the team processes at higher level, taking into account wider units of communicative behaviour than the sentences. The essence of team processes often goes beyond the sentence, requiring a wider measurement. In order to capture the team processes in a realistic and comprehensive way the analyses should take into account (beyond the sentence) some relevant events. The unit of analyses were events, communicative behaviours that include one or more utterances describing a predefined team process category. The analyses were based on both transcribed communication and on video recordings, taking into consideration the non-verbal communication as well. The background noise and the varied sound quality made difficult to rely only on the video recordings. The coding was made on the transcribed conversation using Atlas Ti. qualitative data analysis software.

The literature research and review regarding the development of team process categories at event level focused on theoretical and empirical frameworks of team processes mainly made in high risk environment (*Table 2*.).

| | |
|---|---|
| Theoretical frameworks about team processes | •Interaction Process Analysis, IPA (Bales, 1950)<br>•Conceptual framework for teamwork measurement (Dickinson, McIntyre, 1997)<br>•Temporally based framework and taxonomy of team processes (Marks et al., 2001)<br>•Hierarchical Conceptual Structure of Teamwork Behaviors (Rousseau et al., 2006)<br>•Adaptive group responses to non-routine events (Waller, 1999) |
| Empirical frameworks about team processes | •An analysis of critical team behavior (Oser et al., 1989)<br>•MedTeams teamwork behaviour matrix (Risser et al., 1991)<br>•Non-Technical Skills (NOTECH, Flin et al., 1998)<br>•Line Operation Safety Audit (LOSA, Klinect et al., 2003)<br>•Non-technical skills of Surgeons (NOTSS, Yule et al., 2006)<br>•Observational teamwork assessment for surgery (OTAS, Healey et al., 2004)<br>•Anaesthetists' Non-Technical Skills (ANTS, Fletcher et al., 2003)<br>•Behavioral Markers for Neonatal Resuscitation (Thomas et al., 2004)<br>•Non-technical skills of nuclear emergency response teams (Crichton, Flin, 2004) |

*Table 2. Theoretical and empirical frameworks about team processes*

In order to ensure the reliability of analyses, the same statistics were calculated as at sentence level. The inter-rater reliability $r_k$ varied between .585 – .938 among the categories.

The list of final content based team process categories (including the sentence and event based categories) is presented in the following *Chart 1*.

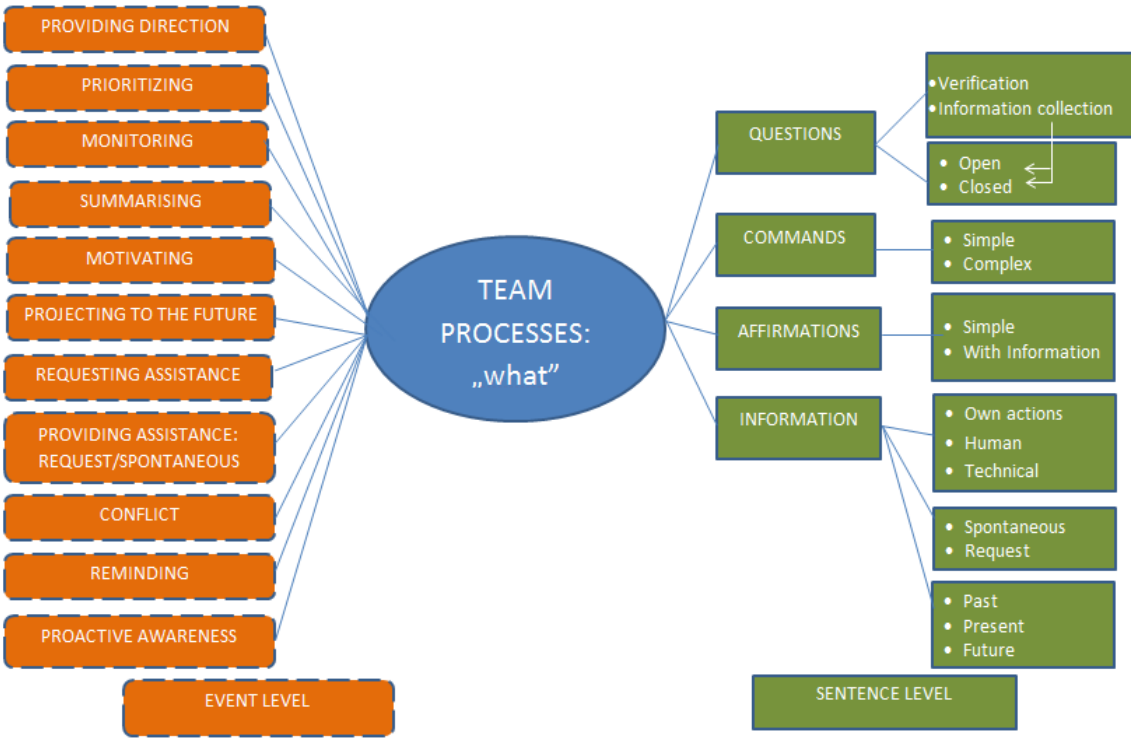


*Chart 1. Content based team process categories at event and sentence level*

## Results: team processes and team performance

In the following section differences between good and poor performing teams' team processes are described. Presenting the significant differences the levels of analyses are also marked in the tables.

**Hypothesis 1: Excellent performing teams are more efficient in their information flow, information collection and distribution behaviour than poor performing teams**

| EXCELLENT PERFORMING TEAMS' TEAM PROCESSES | Level of analyses |
|---|---|
| Coherent information: more thoughts with turn taking, fewer thoughts without turn taking | Coherence |
| Fewer Open Information Collecting Question | Sentence based analyses |
| More Simple Affirmation | |
| More Human Information; Fewer Technical Information, Information on Request; | |
| Fewer Reminder | Event based analyses |

*Table 3. Significant results related to the Hypothesis 1.*

Comparing the coherence indicators of good and poor performing teams' information flow it has been explored that the poor teams' conversations include more ***thoughts without turn-taking*** and fewer thoughts with turn-taking. These results indicate an incomplete flow of information and less common ground between the poor team members. The excellent teams' dialogical conversations can be smoothly and tightly integrated, indicating coherence.

Coherent communication means that the team members are aware of the information distributed by others, and react to the received information creating a semantic connection in the information sharing activity. In this way coherent communication is one of the key elements of the effective establishment or modification, fine tuning of accurate and complete team knowledge (Krifka, 2004). The conceptual chain in the conversation helps the team to focus and maintain the attention on the exchange of information, avoiding the loss of relevant information. These results are in line with other previous researches made in high risk environment, with medical teams (Grommes, Dietrich, 2002; Grommes, 2007) and cockpit crew (Krifka et al., 2004; Krifka, 2004).

According to the results good performing teams use more often simple ***affirmation*** compared to poor performing teams, they acknowledge more frequently that the message has been properly perceived, understood. The frequent affirmation of the received message is more important in an environment where the tasks are allocated to several team members and the individuals have to simultaneously receive, process information from different sources (Sträter, 2002; Fukuda, Sträter, 2004). The background noise can easily hamper, inhibit the simultaneous information processing. The lack of affirmation can increase the risk that the relevant information will not be integrated into the team knowledge (Krifka, 2004).

The ***human information***, information about the status, resources, actions of team members are more frequent at excellent performing teams, compared to poor performing teams. This result suggests that high performing teams strive more intensively for sharing information about the team actions. The information about the team members' action, status helps to establish and maintain an accurate shared knowledge, team mental model about the team including the team members' characteristics and interactions. This common knowledge helps members to anticipate each other's' needs, to better tailor their behaviour to the team, to predict the nature of team interactions. Other researches with medical teams have also revealed the importance of this kind of information (Krifka, 2004; Krifka et al, 2004). This research demonstrated two important functions of information proving behaviours. Information about the action, status of team members has an informative function, helps to create shared knowledge about the team members and the team interaction. Beside the informative function these information providing behaviour has a corrective, validate function too. Informing each other about the action of team members provides the opportunity to validate the action, to point out possible mistakes, errors, or to suggest another course of action (Johannesen, 2008).

Contrary to previous researches (Waller, 1999; Waller et al., 2004) and to our hypothesis, the results of the present study show that lower performing teams were engaged in more ***information collection*** activities used more frequently ***open questions***. To explain the surprising result we have to emphasize that the previous studies did not measure the type of information collection (nor the information providing) behaviour. The frequent use of open questions suggests that when lower performing teams form their questions they have less information, knowledge about the environmental cues, so they formulate the question in a less complete form to develop a clear picture of the situations, or about the task. This type of question makes the other person think more elaborately, forcing to give a longer answer.

Conceivably the good performing teams do not need to use often open questions, as they hold more stable (established) professional knowledge about the on-going events, tasks, being able to face the challenge of the situation. Questions that need to be completed by the addressee (like open questions) require more cognitive resources and in this way they may increase the risk of incomplete, erroneous information flow (Sexton, 2004).

The results have revealed that the poor performing teams use more technical information in their information flow, contrary to our expectations based on the previous literature (Waller, 1999; Waller et al., 2004). The ***technical information*** about certain indicators, technical events helps to establish and update the common picture (team mental model) about system, about the task. The frequent use of technical information suggests that the poor performing teams have less information, knowledge about the environmental cues, the situation and the task. The lack of professional knowledge about the actual technical events creates the need to share more often information related to these events.

In the poor performing teams' information flow there is a higher need to ***remind*** each other more frequently. Team members draw each other's attention more often to an action, information, rule that previously has been told or done. This result suggests that at low performing teams there is a higher risk to lose the transferred information which indicates a deficient, erroneous information flow, lack of team knowledge maintenance.

**Hypothesis 2: Excellent performing teams' team processes include more coordination supporting behaviours compared to poor performing teams.**

| EXCELLENT PERFORMING TEAMS' TEAM PROCESSES | Level of analyses |
|---|---|
| More Complex Commands | Sentence based analyses |
| More Providing Direction | Event based analyses |

*Table 4. Significant results related to the Hypothesis 2*

The excellent performing teams are more efficient in coordinating their actions, they provide more often ***commands*** in ***complex*** way, do not give simple and quickly performed tasks, but rather assign long term tasks or allocate tasks to more than one member. Furthermore the excellent performing teams are more efficient in the integration, synchronisation of individual actions, they ***provide directions*** more often, communicates plan, provide standards to the relevant staff, and consider the requirements. They plan more frequently creating big picture that include several steps of the future work process. The importance of these behaviours has been demonstrated by previous researches, the good performing teams are more efficient in the coordination of their action and information flow (Oser et al., 1989; Marks et al., 2001; Rousseau, 2006; Waller, 1999; Waller et al., 2004; Crichton Flin, 2004). Planning together the steps, strategies to accomplish the task ensures the integration of team members' actions, supports the team to act and behave as a coherent whole. This process helps the development of team mental model of the task accomplishment (Rousseau, 2006). Furthermore this team process ensures that all members have a shared vision of the team's purpose and objectives during the individual as well as the joint actions. For the coherent, synchronised joint action it is important that all team members share the same vision about the goals and tasks, in this

way the task execution will be focused, the tasks are completed without wasting individual efforts.

**Hypothesis 3: Excellent performing teams' team processes include more heedful interrelating behaviour, more signs of joint and anticipated actions compared to poor performing teams.**

| EXCELLENT PERFORMING TEAMS' TEAM PROCESSES | Level of analyses |
|---|---|
| More Summarising, Monitoring, Projecting to the Future | Event based analyses |
| Fewer Motivating, Requesting Assistance | |

*Table 5. Significant results related to the Hypothesis 3*

According to my results the excellent performing teams ***summarize*** more frequently the steps that are taking or have taken, along with the information that has been mentioned. This team process helps the team to maintain situational awareness at team level. The complete picture established with the help of joint summary of the current situation and information constitutes the ground of subordinating the individual steps to the requirements of the joint action as well as to the team goal in this sense it is an important indicator of heedful interrelating. Rousseau (2006) emphasized that the active contribution to the teams' goals could be achieved only if the team members have a complete picture about the events going on around them. According to some researches summarizing is one of the indicators of explicit coordination, helps to develop contingency plans (Groete, Zala-Mezö, 2004; Groete et al., 2004).

Excellent performing teams ***project*** their actions to the ***future*** more often, they think ahead about potential outcomes, consequences of actions, interventions, anticipate potential outcomes and consequences of actions. Projecting to the future can be conceptualized as an element of situation awareness (Endsley, 1995). Thinking ahead about potential outcomes, developing alternative steps, actions, strategies helps to establish the continuous alertness. Anticipating the future and verbalizing this information helps the members to become aware of the consequences of individual acts, to interrelate these acts with the team goals. Anticipating potential consequences, problems help to subordinate the individual actions to the goals of the team of the envisaged system, which is one of the important markers of headful interrelating. At the same time an important element of coordination is to anticipate the consequences of actions to the future (Groete, Zala-Mezö, 2004).

In order to create heedful interrelating, team members need to monitor and report the changes in the environment, in the system. As hypothesised, excellent performing teams ***monitor*** and verbalize the progress toward the goal, team members' activity and the changes in the system more often than low performing teams. The more frequent monitoring and reporting of the process does not mean necessarily that excellent performing teams follow and control the progress more often than low performing teams do; it rather means that they share more often this information with each other. Providing information about monitoring, following and controlling the environment, team members helps to establish the team knowledge, mental model about the team and task. This team process can be more important when the team members do not share the same visual information and when team members accomplish simultaneous tasks. If the team fails to follow and communicate their actual, current progress toward goals they cannot provide themselves self-regulation feedback. Monitoring can be

conceptualized as an indicator of heedful interrelating, when the team members strive for having a detailed representation of others and their attention is focused on the joint situation (Groete, Zala-Mezö, 2004).

Counter to the predictions and to the previous literature (Oser et al., 1989; Marks et al., 2001; Lepine et al, 2008 IN: Forsyth, 2009) the poor performing teams ***motivate*** each other, ***request assistance*** more often than high performing teams. Motivating includes providing reassurance, encouragement (encouraging members for active task accomplishment), providing constructive feedback, correcting the behaviours of others (pointing out the mistakes made by others), managing emotions. One explanation of this surprising result may be that during poor performing teams' task accomplishment the tension occurs more often, requiring a more intensive emotion management. This explanation is supported by the fact that poor performing teams' team processes included more conflict (even though statistical analyses were not reasonable due to the relatively low occurrence of conflict). Another interpretation of this unexpected result is that low performing teams' task accomplishment required more often corrective behaviours (to reaffirm the right course of action). At the background of frequent assistance request beyond the high level of trust there is often uncertainty of the procedure, task accomplishment that suggest an incomplete professional knowledge, skills and abilities. The supporting behaviour will manifest in assistance request when the team face the uncertainty of members. Moreover, the low performing teams' team processes contained more ***assistance request without answer***, members were asking more often help and more of these requests remained unanswered. Near a high level of interdependence, if the teammates are not willing to help each other, the team will fail, when any of the team members fails (Rousseau, 2006). This result may also suggest the poor performing teams' erroneous information flow. The assistance requests were not answered because the member are not willing or cannot help each other, or because the help requests were not received by the addressee due to the inappropriate, incomplete information flow.

## Results: team processes and task load

The present research studied how the team processes change according to the different levels of task load, aiming to understand teams' adaptation strategies to high task load situations.

**Hypothesis 4: During high task load the narrowing and shift in the attentional focus, the narrowing of team perspective and the impaired information processing will have manifestations in team processes.**

| DURING HIGH TASK LOAD: | Level of analyses |
|---|---|
| Decreased coherence of information flow | Coherence |
| Decreased Affirmation, Commands | Sentence based analyses |
| Decreased Providing Directions, Summarising, Projecting to the Future | Event based analyses |
| Increased Reminding, Proactively Raising Awareness | Event based analyses |

*Table 6. Significant results related to the Hypothesis 4*

As the task load increases the occurrence of ***thoughts without turn taking*** becomes more frequent, the coherence of information flow decreases, along with the frequency of

***affirmations***. During high task load the team members have to ***remind*** each other about the task that has been accomplished, information that has been told. Furthermore they endeavour to prevent the loss of information using more often ***proactive awareness***, proactively draw each other's attention to the relevant aspects of the information flow, and ask if the other team member understood the information. During high task load the communication is severely impeded, which can be explained by the operators' overloaded cognitive resources (due to the activated selective filters the attentional focus becomes narrowed, language processing becomes focused and selective) (Mumaw, 1994; Dietrich et al, 2004). The unexpected technical problems intensively load the team members' cognitive capacity, being unable to share their attention between the accomplishment of the task and communication, there is a higher risk that some parts of the information flow will mislay.

The ***complex commands*** and ***direction providing*** actions are those indicators of coordination that are useful at the beginning of task accomplishment (before high task load), when the team assigns long term tasks, goals and allocates, divides the tasks to the members. One efficient way to prepare for high task load phases is to establish a common ground about the task, procedure which will implicitly lead the team actions during high task load.

***Summarizing***, reviewing the situation, interpreting the information received, ***projecting to the future*** the actions, potential problems help to establish the contingency planning (set expectations and plan for contingencies) as well the state of continuous alertness. The need for all these team processes are the highest before the task load, when the members have the necessary resources to set expectations and plan for contingencies, prepare for the high task load situation.

**Hypothesis 5: During high task load even though the cognitive resources are overloaded, the frequency of team processes oriented toward the management of technical problem will be increased.**

| DURING HIGH TASK LOAD: | Level of analyses |
|---|---|
| Increased Information Collecting Questions, Spontaneous, Requested, Technical Information | Sentence based analyses |
| Increased Monitoring, Requesting and Providing Assistance | Event based analyses |

*Table 7. Significant results related to the Hypothesis 5*

The high frequency of information providing (***technical information, requested information***) and collecting (***information collecting question***) activity may serve the role to explore the causes and the consequences of technical problem occurred/emerged during high task load. If the team members are able to establish a common ground about the task(s) and the team activity at the beginning of the task accomplishment, this knowledge serves the basis to anticipate the course of action, entailing the opportunity to share information without request (spontaneous information). The increase of ***spontaneous information*** during high task load may also be due to the emergence of new events, creating the need to share information about events that were not previously mentioned in the conversation.

The technical problem emerged during high task load necessitates the increase in the alertness, vigilance of team members leading to more frequent ***monitoring*** activity. During high task load facing the technical problem give rise to professional uncertainty which in turn leads to more frequent ***requests of assistance***. The increased assistance request entails more frequent ***assistance providing*** actions.

## Results: the effect of team performance and task load on team processes

To manage high task load situations successfully, teams have to be prepared to adapt with their team processes to different levels of task load. The periods with high task load necessitates flexible adaptation from the team. The present research aims to explore how the excellent performing teams adapt to the emergence of unexpected event, to high level of task load.

**Hypothesis 6. Excellent performing teams adapt with their team processes to the requirement of the environment: adapt more efficiently to high level of task load than low performing teams.**

| BEFORE HIGH TASK LOAD EXCELLENT PERFORMING TEAMS' TEAM PROCESSES: | LEVEL OF ANALYSES |
|---|---|
| More Complex Commands, Spontaneous Information | Sentence based analyses |
| More Providing Direction, Prioritizing Projecting to the Future | Event based analyses |
| **DURING HIGH TASK LOAD EXCELLENT PERFORMING TEAMS' TEAM PROCESSES:** | **LEVEL OF ANALYSES** |
| Fewer thoughts without turn taking | Coherence |
| More Simple Affirmation, Human Information, Verification Question | Sentence based analyses |
| More Monitoring, Proactive Awareness | Event based analyses |
| Fewer Assistance Request, Assistance Request without Answer | Event based analyses |

*Table 8: Significant results related to the Hypothesis 5*

The frequency of ***complex commands*** decreases during high task load at excellent performing teams, contrary to poor performing teams. Furthermore excellent performing teams use more ***prioritization*** and ***providing directions*** at the beginning of the task accomplishment, before the high task load period. These elements of explicit coordination establish the common ground, team mental model about the task accomplishment that helps to synchronise and integrate the individual acts. It is important to establish this shared vision about the goal attainment before the high task load because this joint vision leads the team actions during high task load periods, when the resources for explicit coordination may be limited. To provide information, details about the task accomplishment, the implications of the unfolding events (***project to future***) at the beginning of the mission helps to reduce uncertainty, provides the formal opportunity to build the team, while at the end of the task fosters the development of strategy planning (what needs to be improved in the future) (Krifka, 2004; Krikfa et al., 2004; Dietrich, 2004).

According to the literature in a technically complex environment there is a strong need for setting expectations and planning for contingencies (Antalovits, Izsó, 2003; Izsó, Antalovits, 2006; Sexton et al., 2004). The results show that teams performed at higher level used

***projection to the future*** more often before the high task load period. Efficient teams discuss how to deal with potential problems, adverse events before the problems could arise. This activity is also known as *mental simulation*, the process of understanding how events may escalate, imagining action consequences and how to deal with these events (Kontogiannis, Kossiaveou, 1999). Creating contingency plans help the team members to anticipate events that might happen in the future, consequences of their actions, errors they may face during task accomplishment. Analysing operator teams' communicative behaviour this behaviour was called by Johannesen (2008) the *Joint Assessment of the State of Management*.

The frequency of ***spontaneous information*** is higher at the beginning of the task accomplishment at excellent performing teams, although this ratio remains the same during high task load, the difference between excellent and poor performing team is higher before than during high task load. The use of information without request necessitates the presence of shared knowledge about the task, team (team mental model), collective understanding of the specific situation (team situational model) (Kontogiannis, Kossiaveou, 1999; Kolbe et al., 2009; Rico et al., 2008). According to some researches the use of spontaneous information is an indicator of heedful interrelating (Grote and Zala-Mezö, 2004), the role of this team behaviour becomes more crucial during high task load, preventing team members from potential overload.

The results demonstrate that excellent performing teams' information flow contains less ***thoughts without turn taking*** during high task load compared to low performing teams, suggesting that the manifestation of the consequences of high task load on the cognitive resources (narrowing the attention, information processing, team perspective) is smaller at excellent performing teams. This is also supported by the more frequent use of ***affirmation*** by high performing teams during all the phases of the scenario (including high task load phase).

As the attentional focus is narrowed during high task load the risk of incomplete information flow is higher. Excellent performing teams endeavour to prevent the loss of information using more often ***proactive awareness*** during high task load.

The frequent use of ***human information*** during high task load was associated with high performance. This result shows that, even though the team perspective becomes narrowed during high task load (Driskel et al., 1999), excellent performing teams do not miss to inform each other about the actions and status of team members, they prove to be socially cognizant even during high task load. In this period it is important to have a complete picture about the team, to focus the attention to the joint situation (Kontogiannis, Kossiaveou, 1999).

Another important strategy to adapt to high level of task load is to actively ***monitor*** the progress toward the goals, as the higher performing teams do according to the results. Monitoring the progress toward the goal and the team members' activity entails several team activities such as controlling, verifying task progress, tracking, noticing/detecting in time potential errors (Kontogiannis, Kossiaveou, 1999). The importance of these activities becomes more crucial during high task load.

During high task load due to the overloaded cognitive resources it is more efficient to form the questions in a closed way (Sexton, 2004). This statement was confirmed by the frequent

use of ***verification questions*** (short question that aims to seek reinforcement, to make sure about some information) during high task load. The high performing teams use the economic advantage of this type of question during high task load.

## Discussion

The present research aimed to identify team processes that support the integration of individual knowledge, the establishment and maintenance of team knowledge. Furthermore to analyse the revealed team processes in relation to team performance and task load.

According to the results the excellent performing teams are more efficient in their information flow, information collection and distribution (more coherent information flow, used more frequent affirmation, information about team members activity), coordination supporting (used more complex command, providing direction) behaviour. Furthermore team processes of teams performed at higher level included more indicators of heedful interrelating (used more often monitoring, projection to the future and summarising actions) compared to poor performing teams.

Comparing team processes during different levels of task load the results show that the effects of high task load (e.g. narrowed attentional focus, impaired information processing) have manifestations in the team processes, there is a higher risk of erroneous and incomplete information flow. Analysing the combined effect of high task load and team performance on team processes the results demonstrated that excellent performing teams use more explicit team processes before the high task load in order to prepare for it. During high task load higher performing teams use more economic team processes to prevent the teams from the information overload.

Exploring and analysing team processes in relation with team performance and task load may support high reliability organisations to improve the selection, performance appraisal and training systems or tailor these systems to some of the results.

We should also note some of limitations of the present study. First, my study focused on team processes that support the establishment and modification of team knowledge thus lead to high team performance, though the analyses did not aim to measure directly team knowledge. Second, the research has some methodological limitations too, such as the different teams' scenarios and the performance evaluations were conducted by different instructors, this might have led to some differences in the progress of the scenario as well as in the evaluations.

Future research on one side should more thoroughly compare those teams' team processes where the average of individual performance is above or below the team performance. On the other side future work should go also beyond analysing frequencies of team process categories, focusing on hidden patterns between these categories.

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