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Human Aspects of NPP Operator Teamwork

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1. Introduction

The aim of this Chapter is to describe several important human aspects of NPP operator teams that have significant effect on safe and efficient operations. The first part of the Chapter provides an overview about the concept of high reliability organisations, safety culture, focusing on the question how to conceptualise and measure safety culture, presenting two distinct perspectives about background of human unsafe acts. Based on theoretical and empirical works made in high reliability organisations, the second part of the Chapter aims to detail the paradox of human factors, describing the main task, job and teamwork characteristics of first line personnel.

The first line personnel in the NPP control room works in team. There have been several attempts to describe the characteristics of efficient teamwork, although little is known about the antecedents of efficient teamwork in high reliability organisation. Based on the *Input-Process-Output* model the empirical works aim to understand those inputs and processes that determine safe and efficient operator teamwork.

After the theoretical considerations, the chapter synthesise different empirical works made in NPP control room analysing operator teamwork from different perspectives. Based on the theoretical works about specific task loads, the goal of Case study is to identify particular sources of task load, as *inputs* that influence operators well being. The revealed list of task load offers a practical guidance how to enhance operators' well-being, safe and efficient work performance. Another important input of operator teamwork is the team members' personality. Even though the NPP environment is strongly standardised, providing little room for individuals' personality, team members' characteristics influence how they behave and perform in this restricted environment. Based on Five Factor Model of personality the goal of Research 1 is to determine those personality traits that count for efficient teamwork, relating personality to team communication, to behavioural markers of team members, and performance. Operator team is a professional work team, requiring the interaction of team members representing different areas of speciality. It is important to understand how the operator team members having specific technical and professional knowledge are able to operate and manage jointly the plant system. *Communication as a key process* is used to share specific technical and human aspects of the plant parameters, operations, establishing the shared knowledge about the plant, environment, task and team members. This shared knowledge helps the operator team to develop joint strategies in order to manage the plant and to share different levels of task load during their operation. Research 2 aims to describe

characteristics of efficient team communication, to relate operator team communication to performance and to different levels of task load. The *output* of teamwork communication manifests in shared knowledge, the output of effective balance between demands created by high level of task load and operators resources is shown in the team well being. The most important output of teamwork is the team performance. In order to enhance team performance those input and process factors should be considered that determine efficient and effective performance. In sum, the present Chapter aims to provide theoretical background to understand the human factors of operator teamwork, and through the empirical works aims to reveal those factors that influence team performance.
All the presented empirical works were made in Hungarian NPP. The Hungarian NPP located in Paks, along river Danube, houses four nuclear reactor units, and covers more than 40% of national energy production.

2. Safe and efficient operations

Advances in technology have remarkably improved an organisation's ability to build and manage hazardous technologies. Although, hazardous technologies are not maintained for their own sake, but to improve the quality of life of human beings. Since the complexity of hazardous technologies has extensively spread, the balance between safe and efficient actions has been widely acknowledged. It is often claimed that the management should endeavour to find the right balance between safe and financially, economically efficient operations (Reason, 1997). This equilibrium becomes crucial in the case of high reliability organisations that can be described as organisations that are faced with high hazard situations, and for this reason they try to achieve and maintain high reliability, safe and efficient performance, while managing complex systems.
First in the 1960s, three organisations were considered as high reliability organisations: the US air traffic control system, organisations operating at nuclear power stations, and the US Navy nuclear aircraft carrier operations. The initial definitions were less precise saying that hazardous systems are organisations that should function almost without errors, accidents. This broad definition raises the question how to interpret "almost without" or "near error-accident free function". This unclear definition has been changed to a more precise interpretation, which instead of error, accident rate emphasises the effective management of inherently risky technologies or environment. Another expression, describing organisations in which there is more than normal chance for damage one's own life, the life of others or to material property is called high risk environments (Dietrich & Childress, 2004). The latter concept focuses on the inner characteristics of these organisations, high risk, hazards, while the former emphasizes the efficient management of high-hazard situations.
In the present work *high reliability organisation* and *high risk environment* concepts are used interchangeably to describe organisations such as a Nuclear Power Plant (NPP) where the idea of safety is not just a theoretical concept, but an eternal, conscious endeavour to maintain safety in the nature of the high hazard operation, environment.

2.1 Differences and similarities between high reliability organisations

Recent researches on high reliability organisations deal with domains in health, safety and environmental issues, including studies about the personnel of aircraft, air traffic control, nuclear power stations, operating rooms, medical team, intensive care units, fire service (Reason, 1997). Even though these organisations have some strong common characteristic in

their function, it is necessary to consider the differences between local features, such as the output of erroneous actions, types of damages stemmed from inefficient work, the degree of standardisation of action and of communication, the size and structure of team. In the case of a NPP the output of erroneous action is the most severe, demanding high number of fatalities, or worst case environmental catastrophe, while in medical field a committed error leads to relatively low number of fatalities. Despite these specific features, there is a list of joint characteristics of these organisations stemming from the duty of efficiently and reliably managing high reliability situations. One of the main characteristics of high-reliability organisations may be described by the eternal endeavour to collect, analyse information about errors, incidents, near misses, sources of potential accidents, such as mistakes, lapses, slips. The aim of *information collection* and analyses is to enhance the safety of the system. For example, in an NPP data and information gathered from reports about unsafe acts are used in order to improve the training procedures, or to refine rules, procedures that govern safe operations.

The process of establishing technical standards, norms, and procedures to implement guidelines for safe actions has led to a high level of standardisation. *Standardization* can be regarded as the key element in minimizing unsafe acts. The efficient and reliable management of high-hazard situations necessitates highly level of training, to have the fundamental professional knowledge about the function of the systems, about events, and about the correct actions. In NPP, the simulation centres provides the opportunity to establish, update and practice professional knowledge, at the same time to drill compliance with rules, procedures.

The obligation to manage efficiently and safely an innately hazard environment implies a *strong pressure* on the first line personnel to provide high-level performance under all possible circumstances. This high pressure is indispensable to maintain safe acts; however, it can have its own adverse effects. As a response to this strong pressure, the highly trained first line personnel have developed a strong sense of *invulnerability*. The recognition of effects of stress or the acknowledgement of vulnerability to error is an indispensable part of efficient stress and error management strategy. This does not imply that the organisations should decrease the pressure to high-level of performance, but rather to underline the importance of performing efficiently and reliably, without the pressure to cover up, or to hide the errors, and vulnerability. The personnel should be given more information about the effects of stress with guidance on how to manage stressful situations, such as the reallocation of human resources between team members.

Due to high-level standardisation the first line personnel need to work mainly under a low or moderate *level of task load*. The vast majority of operations in a NPP are highly automated, in this situation the personnel need to monitor, follow the processes and to react on the specific events. The personnel need to be aware of the eternal presence of external factors that threaten the safety and effectiveness of operations. This awareness of new unfamiliar event emergence causes continuous alertness, one of the main sources of high task load in a high- risk environment (Mumaw, 1994).

3. The paradox of human factors in NPP operations

3.1 Autonomy vs. control

High reliability organisations strive for minimizing hazardous, unsafe actions while improving operational efficiency by keeping maximum control and implementing strict

procedures that prescribe how to act, interact, and communicate under certain conditions (Gudela & Zala-Mező, 2004). On the other hand, the first line personnel is composed of individuals with high professional knowledge, highly skilled and experienced persons, with the strong need to manipulate and control their environment, striving for autonomy. *Autonomy* is a self determination regarding which goals, rule, and procedures to follow. Hackman and Oldham (1975, as cited in Byrne & Davis, 2006) defined job autonomy as the degree of freedom that employees have in order to schedule, choose and determine the method how to accomplish his/her tasks, responsibilities and work. *Control* is an influence to guide or regulate the activities or operation of a person, system or machine. In work-related settings, the constellation when a person has little autonomy and strong centrally determined control is called strong situation (Barrick & Mount, 1993). In high risk environment the management is committed to minimize uncertainty with strong centralized control; this in turn will not allow the local actors to be engaged in situations where they have the opportunity to use their professional knowledge. In strong situations, individual differences in knowledge, skills, abilities, experience, and personality has little opportunity to be manifested, because individual's actions are constrained by a variety of external factors including detailed rules, standard operation procedures, and supervision. In contrast, high degree of autonomy and low control situations, so called weak situations, permit or even elicit individual differences, where individual characteristics would play a major role in behaviour, actions to accomplish assigned tasks.
The paradox between the centralised control and the need for local autonomy could be dissolved by the implementation of right balance between centrally defined rules procedures and opportunities to use expert knowledge.

3.2 "The golden rule is that there are no golden rules" (George Bernard Shaw)

The need to reduce uncertainty is manifested by the need to foresee all the possible events, including normal situations and operations deviating from normal events. Uncertainty reduction is achieved by developing standardized procedures, rules for all the potential cases. In this sense standardization proves to be the key element of coping with uncertainty at organizational level. The paradox is caused by the fact that overregulated behaviour guided by strict rules may impede local actors to adapt to and manage situations when the rules are incomplete or inappropriate. During these uncertain events, especially during abnormal operations the appropriate action depends on *reasonable flexibility* between the use of procedures and professional knowledge (Gudela & Zala-Mező, 2004). In NPP industry 60% of human performance problems are associated with wrong or inapplicable rules, procedures (Reason, 1997). In sum, harmful effects of high standardisation could be demonstrated by the incapability of reaction to those uncertain situation which lack adequate rules, and by an over-reliance on inappropriate rules. The detrimental effects of high standardisation can be avoided by the use of deep professional knowledge and experience.

3.3 Certainty of uncertainty

Due to strong standardisation the work of first line personnel mainly consists of periods of low and moderate levels of workload. During a low workload period, the personnel need to monitor and detect different sources of information, or to scan and follow particular parameters. During a period of moderate workload, the personnel need to react on certain parameters, information from different sources of the control panel, based on

predefined rules, procedures. This period of the work is described by routine operations. During a period of low and moderate workload the aim is to keep the system in equilibrium, to sustain or to improve the function of the complex system (Waller et al., 2004). The task accomplishment is described by foreseeable actions and the steps, the decisions are mainly based on the application of prescribed rules, procedures. Even though, the "sharp end" personnel are exposed to the emergence of *unexpected events* (Mumaw, 1994). This constant alertness *evokes high workload on the personnel's capacity* to adapt from the routine to non-routine actions, where the appropriate reaction relies, not just on rules-based behaviour, but more on expert knowledge to manage the unfamiliar and uncertain problems. The occurrence of uncertain situations can hardly be predicted, thus the adaptability to dynamic task load, flexible change from predictable to unpredictable situations is considered to be the key characteristics of managing complex system functioning.

3.4 Centralisation vs. decentralisation

The management of complex technologies necessitates the implementation of a conventional hierarchy, where the *hierarchical structure of information and interaction flow*, chain of actions is kept under control by centralised persons. The effective handling of an unexpected, uncertain event, where the rules do not cover the situation or they are not appropriate for the tasks in hand, the reliance on decentralised actions of the professional experts can be the crucial aspect of reliable and efficient performance. In this way it could be stated that in efficient high reliable organisations a decentralised hierarchy should coexist with a centralised hierarchy, in the form of adaptability from a hierarchical centralisation structure to a decentralised professional mode. This flexibility is an important way of achieving common, joint awareness of the situation, and to share the high task load between the team members, increasing the teams' capacity to face high task demands (Reason, 1997).

3.5 Individual- vs. teamwork

Work teams consist of highly trained individuals with special expert knowledge. Each person is responsible for one specific area of the complex system. The intensive and constant pressure to perform efficiently and reliably, the high expectations from the organisation as well as from the society, stress out the importance of well established professional knowledge that guides the behaviour of these personnel under any circumstances. In this way the training of first line personnel is mainly focused on practicing professional technical knowledge, such as the management of the complex system. On the other hand, researches about safety functioning show that one of the major contributing factors of accidents, unsafe acts are not linked to the lack of professional knowledge related to technical aspects of the complex system, but rather to the *failures of efficient teamwork*, such as inappropriate *communication, coordination* (Flin et al., 2002). The duality lies in the fact that even though these operators are highly trained and strive for independence, the efficient system functioning depends on teamwork. The central point of this paradox is caused by the fact that the variety of the systems exceeds the variety of the persons who control them (Reason, 1997). In this way the nature of these systems requires cooperation between the first line personnel. Since the cooperation, communication and coordination within the team is efficient, the end of these processes could exceed the variability of individuals, which in turn could minimize the unbalance between the variability of the system and the variability of

the human controllers. All work teams can include team members who prefer to work alone, rather than to work in group, to share information, cooperate with other team members. Also demands of the tasks can influence the level of the necessity of cooperation in teamwork (Thompson 1967 as cited in Blyton et al., 1989; Gudela & Zala-Mező, 2004; Hellriegel & Slocum, 2007).

4. The relevance of teamwork in NPP

More and more organisations prefer to restructure the workflow around teams. This is particularly true in the case of high reliability organisations, where the actions are based on technically complex operations. The increased complexity of operations requires the knowledge, experience, skills and abilities of more than one person, as the management of complex problems is too demanding for one individual. Furthermore, technological developments have led to a high variety of the system. As mentioned above this system variety exceeds the variety of the human controller's characteristics. No wonder that professional work teams have started to play a crucial role in the management of complex operations, where the team members need to interact and integrate their individual capabilities to efficiently cope with the variety in the system they coordinate. Even though the education, training of individuals become more specialised, the problems that the teams need to face turns out to be more complex, requiring an inter- and multidisciplinary contribution. This line of reasoning underlines the demand of discipline specialisation, the justness of heterogeneous teams, where the team members posses specific roles knowledge, expertise (Ballard et al., 2008; Barry & Stewart, 1997; Cooke et al., 2001; Kiekel, & Cooke, 2004; Mathieu et al., 2000; Cannon-Bowers et al., 1993).

4.1 NPP control room operator teams

NPP control room is the central point for safe and reliable plant system coordination. Control room operators are responsible for maintaining safe and correct running of plant operations and optimising all of its parameters. The operators' primary task is to monitor important plant parameters and to coordinate the efficient functioning of the reactor and its support system. The operators also direct activities of the personnel in the outer fields of the plant (for example maintenance staff). For safe and reliable plant operations the synchronisation of different support systems is needed. The control room operator team requires the interaction of six members: Unit Shift Supervisor, Reactor Operator, Turbine Operator, Turbine Chief Mechanician, Unit Electrician, and Shift Leader. The professional supervisor of the operator team is the Engineer in Duty.

When taking into account the group's definition (Cooke & Gorman, 2006) saying that a group consists of two or more individuals assembled together for a special common purpose, operator teams can be considered as a group. Furthermore, the operators in the control room can be considered as a team, because they exceed the characteristics of the group, consisting of members with specific and varied roles and with some degree of interdependence among the members. A team is "a distinguishable set of two or more people who interact, dynamically, interdependently an adaptively toward a common and valued goal, each of whom has been assigned specific roles or functions to perform, and who has a limited life-span of membership" (Salas et al, 1992 as cited in Salas & Fiore, 2002). The assemble of the operators in the control room is considered to be a team, inasmuch as they all need to follow and achieve a common goal: to obtain and maintain the optimal plant parameters and to detect and react on

incidents deviating from the normal conditions. The output of efficient coordination manifests in the „syntonization" with the entire plant. A control room operator team is a heterogeneous professional work team. Heterogeneous because the roles, responsibilities, tasks within the team are distributed heterogeneously between the team members. Moreover, the operator team is distinguished from other types of teams falling into the category of work teams. Work teams are relatively stable in terms of time, team objectives, goals and team members, where the individuals have stable work roles (Cohen & Bailey, 1997). An operator team can be considered as a professional work team highly differentiated from other teams by means of the exclusive membership of experts, where the team members represent different areas of speciality. The teams execute operations under technologically complex conditions, which require extended training and preparation from the organization as well as from the individuals focused on the development of both professional and social skills (Dietrich & Childress, 2004; Cooke et al., 2000).

4.2 Team Input-Process-Output model

Despite the renaissance of teamwork, relatively little is known about how the individual contributes to the team processes and outcomes. The dominant way of thinking about the team is the Input-Process-Output (IPO) model. The model posits that a variety of inputs are combined to influence processes, which in turn affect team outputs. This model has a powerful influence on recent empirical research on team effectiveness, and on theories studying the influencing factors of team performance (Salas et al., 1992; Barrick et al., 1998; Essens et al., 2005). Hackman (1987) divided the inputs into three categories: 1) individual-level factors (team member attributes, personality, knowledge and skills), 2) team-level factors (structure and size) and 3) environmental-level factors (task characteristics, level of the autonomy). Intragroup processes refers to interactions that take place among the team members and include interaction patters such as conflict, efforts toward leadership and those communication patters that differentiate teams from each other. Each team has its own communication style depending on the environment they are working in. Team output refers to team outcomes associated with productivity, performance, as well as capability of team members to continue the work cooperatively.

Based on the IPO model we would like to present those inputs-process-output variables that could count as important factors in NPP.

Team inputs could be distinguished in three categories:

- Team members' characteristics, such as team members' knowledge, ability, skills, personality. In case of NPP operator teams, the emphasis is on the team members' professional knowledge, although the team members need to posses social skills and abilities for teamwork.
- Tasks characteristics: level of autonomy and control; level of task interdependence; different level of task load, task complexity, uncertainty. The control room operator team needs to face different levels of task load, necessitating a continuous behavioural adaptation from the team members.
- Organisational process: organisational culture employee selection, training, performance appraisal, reward system. In a NPP environment safety is the central key concept that appears in the practice of each organisational process.

Process variables include all the written and unspoken rules, norms, beliefs, and team processes such as communication, information exchange, coordination, cooperation, leadership, and stress management.

Output variables include the quantitative and qualitative aspects of team performance, effectiveness, efficiency, productivity, team members' satisfaction, well being, and commitment. The current and the future performance predict the capability whether the team continue to work together as a unit or not. The most important measure of team effectiveness is the current performance assessment of the team, which is based on either supervisor ratings of team productivity or objective indicators of team quantity and quality of productivity. Another critical measure of team effectiveness is the assessment of the team's capability to continue functioning as a unit.

5. Inputs of operator teamwork

5.1 Task load and workload

For those working in the control room of a NPP the level of task load continuously changes. In the work setting *task load* can be considered as an objective difficulty connected to the properties of a task and the term *workload*, is used when referring to how a situation is perceived by the people facing the task (Gudela et al., 2004). In our concept task load is considered as the sources of stressor that are related to the task environment and task fulfilment. Task load as a demand is inherent in the objective circumstances of the task and of the environment.

5.1.1 Sources of task load in a NPP

NPP operator teams need to work under various levels of task load, during normal operations there is always a chance for an unexpected, novel event that can have a strong effect on the team members' behaviour. High level of task load may be a consequence of sudden and unexpected high demands that disrupt the normal procedures of task accomplishment. Task environments are complex and often unpredictable; the causes of the events are sometimes unclear, even though they demand a quick and immediate response. The personnel must perform multiple tasks under high time pressure, noise, heat or other type of stressors. The consequences of poor performance are immediate and severe (Driskell et al, 2006).

Early stress approaches focus on the environment characteristics that have a direct impact on the operators. With the introduction of new technology the focus has shifted to task demands that operators are faced with. In the process of individual performance gradually increased the task complexity and the necessity of internal resource. In a NPP surrounding the following distinct categories as sources of task load can be distinguished:

- **Environmental factors**

The activity of control room operators and technical personnel are severely monitored by the management, the state, local government, the media and the citizens, causing a high pressure to perform without unsafe acts. Any slips, lapses, mistakes, delays, near misses or accidents should be analysed later and the operators, staff members are aware of their responsibilities in line with this. In a workplace such as a NPP the licensed operators need to be highly qualified persons who are requested to periodically renew their licences taking simulator-based requalification exams. Continuous professional trainings, exams can extensively load the personnel causing *performance anxiety*, which has been shown to be associated with performance decrements during trainings and exams.

The operator teams are exposed to facing several external and internal environmental task load factors which may have significant effects on their operations. Hockey (1986, as cited in Mumaw, 1994) classifies *external* environmental factors in two categories: *a)* The physical

environment includes high heat, poor lightening, protective clothing, noise, and vibration. The control room operators' concentrated activity may be disturbed by a high number of activated alarms. *b)* The social environment includes cooperation with each other, managing conflicts between operators, communication, increased demands of coordination with the personnel, and the requirement of keeping each other informed of event progress. The next three environmental stressors are considered as *internal* determinant of physiological state such as *c)* drug use such as caffeine, nicotine, depressants, alcohol. Under certain conditions some of these can facilitate task performance while others may impede it. *d)* Fatigue states caused by prolonged work, sleep deprivation or disruption and *e)* cyclical changes-regular, periodic changes in hormonal levels, alertness, body temperature due to sudden changes in work shift.

In general, in a NPP environment, control room personnel and support staff are well protected from the environmental changes mentioned above because the back-up system is well functioning and highly reliable.

- **Factors related to the characteristics of the task**

An occurrence of novel and uncertain event such as loss of critical information, failed implementation of a plan is a serious phenomenon that should be considered. *Novelty* refers to events that have not been experienced before and are perceived as a potential risk. *Uncertainty* generally refers to an inability to know how an event will progress or be resolved or the lack of exact information how to act properly. The role of technology as a source of stress such as unfriendly interfaces can increase information uncertainty. Novelty can be tied to uncertainty when a situation is novel, as there is no expectation about the outcomes. Both novelty and uncertainty are significant sources of task load for control room operators. To reduce the effects of these types of task load more information should be provided to the operators, which could make events more predictable, getting back the control over the event's outcomes.

In NPP settings the task demands are very high and the increased occurrence of unsafe acts is likely to occur due to greater requirements in task demands. Time pressure, increased monitoring of plant state and increased job complexity due to multiple task accomplishment are additional sources of task load contributing to higher level perceived stress, workload. Stress may be defined as a state of imbalance between environmental demands and the human's resources for dealing with the demands. The effects of *time pressure* impede the task performance in two ways. On one hand, under high time pressure people may perform the task more quickly at the expense of accuracy. On the other hand, performers may give an incomplete performance and the decision-making process can potentially produce significant errors. *Multiple task accomplishment* may have a negative effect when multiple sources of information need to be monitored or consulted simultaneously. Under these circumstances the shift in the focus of attention is needed for an effective task performance, although, this fast change, adaptation is impaired by the narrowed, focused attention. Complex multiple task environments strain the performer's cognitive resources. *Cognitive load* is provoked by stressful conditions where the performer's attention becomes more and more narrowly focused on cues of tasks and less sensitive to the more peripheral cues. Conditions described by a huge amount of information activate certain attention filters causing an increased selectivity of attention during perception of the tasks components. The filters serve as a protection from cognitive overload. A high amount of information process loads the working memory capacity that requires storing temporally relevant environmental cues, rules, procedures related to task accomplishment.

5.1.2 Reactions to task load

It is not enough to measure the task characteristics causing demands independently of individuals' ability because the difficulty in a stress situation is due to the degree of mismatch between task demands and human resources. A well-experienced operator possesses more abilities, skills, resources helping to cope with high demands in an overwhelming situation. For this reason, confronting with the same task a very experienced operator perceives less workload compared to an inexperienced one. Workload for individuals depends on the relationship between the cognitive resources of the individual and the demands of the situation. Experience is positively related to decision quality under high stress. Well established professional knowledge stimulates the person to analyse systematically the situation, to seek optimal solution, loading the cognitive resources (Fiedler, 1995). During high task load and under time pressure there is no room for systematic elaboration, in this way professional knowledge may impede a fast and efficient reaction. Professional knowledge by itself, without experience may impede the optimal contribution during high task load situations, due to the strong need to seek rational solutions which may not be available. Although, experience enriches the person with higher perceived control in the vast majority of the situations, and provide the feeling of comfort and stability during managing events. Experience enables the operators to react in an appropriate way without the need to think systematically.

All the stress theories emphasise the interaction between a person and the environment, looking at stress as a misfit between them. Cooper (1998) provides an approach to describe why one person seems to flourish while another suffers in the same situation. Individuals try to maintain *equilibrium* between environmental demands and their own resources. The person's physical and emotional state has a "range of stability" in other words "*comfort zone*" in which the individual feels stable, comfortably maintaining the control over the situation. The individual strives to cope with the external and internal sources of task load in order to restore the feeling of control and comfort. The balance between demands and resources should be kept by the persons' endeavour to mobilize his/her own resources. The level of stress depends on the individual perception of the mismatch that can be considered as workload.

Resources play an important role in the stress process. Skills, knowledge and ability are important resources to manage the task in hand and to cooperate with the team members. In a control room the operator team members can share the high level of workload by exchanging information via communication and asking each other to provide direct support. In order to support operators in keeping the balance between task demands and their resources, information should be provided to personnel about different sources of task load and potential limits and strength in resources, enlightening the personnel about the certain effects of task loads.

5.1.3 Consequences of task and workload

While there are some positive effects associated with high level of task load, such as the increased level of arousal, the high level of vigilance, wide range of cognitive skills may be affected at individual and team level, leading to various psychological, physical, behavioural problems.

What price do we pay for imbalance between resources and demands? Scientifics have identified the physical and behavioural symptoms of stress that affect individuals' well being. *Physical symptoms of stress include:* insomnia, constant tiredness, headaches, cramps and muscle

spasms, high blood pressure. *Behavioural symptoms of stress include* counterproductive behaviour such as absenteeism, aggressive behaviour, swear words, frequent drug use, smoking, loss of interest in other people, loss of sense of humour, difficulty in concentrating. *Psychological* problems: include constant irritability with people, feeling unable to cope with stress, lack of interest in life, feeling of ugliness. All these symptoms cause not only human suffering but they also imply economical costs.

In order to avoid the negative consequences of uncertainty, task load, there have been strong efforts to foresee as many non routine situations as possible deviating from normal operations and to develop standardized procedures. High level of standardisation has been developed in order to reduce the influence of individual differences in the perception of imbalance between demands and resources.

5.1.4 Case study

Some years ago in the Hungarian Nuclear Power Plant a new model for monitoring and assessing the psychological state of the front line employees was worked out. A new model, called **P**sychological **S**tate **A**ssessment (PSA) was developed in order to capture whether adaptation to the task load endangers employees' health and safe, effective work. The model is based on previously revealed sources of task load relevant in the work of first line personnel. The goal of the model is to provide guidance to assess employees' psychological state, and identify symptoms that could endanger safe work behaviour. The application of the model during several years promoted the establishment of preventive attitude in the organisation, providing counselling and training system, and various health promotion programs for employees.

First of all, job analysis was carried out to identify the sources of the main task load for the first line personnel. Based on these results a 41-item questionnaire was compiled and sent to 380 employees. 61% of the persons sent back the questionnaire so our sample consists of 231 workers' answers.

Analysing the fulfilled questionnaires by means of factor analyses the sources of task load were categorised in three groups: 1) Task, 2) Environment and 3) Organisation.

1. **Task**: *Complexity of job* (high amount of information to be provided and to be received, high level of attention and concentration, great amount of cooperation); Constant *alertness, readiness, decision* (decision making and working under time pressure, unexpected events, continuous alertness, responsibility for decisions consequences); *Work shift* (multi-shifts, overtime); *Continuous learning* (requalification exams, following technological developments).
2. **Environment**: *Working conditions* (working equipments and devices, the materials, the equipments, the protective outfits, hygienic conditions, changing room, restroom, dining room); *Physical environment* (climate control, noise, lighting, potentially dangerous circumstances).
3. **Organization:** *Organizational operation* (roles and responsibilities, over-regulated work process, information flow in the organisation); *Atmosphere at work* (work climate, work conflicts); *Organizational instability* (organizational changes influencing the work, employment uncertainty).

In the following, factors are summarised that decrease or increase employees' well being:

Factor influencing well being negatively: shift work, overregulatedness, responsibility and decision making, increased attention and concentration, work overload, time pressure, permanent learning, and exams.

Factor influencing well being positively: experience of success, problem-solving, good community and atmosphere at work, opportunity to develop, wider knowledge, interesting, various exercises, human relation, communication, professional challenges, which require creativity, "correct" salary.

5.2 Team members' personality

The job characteristics of the operator teams of a Nuclear Power Plant are complex and highly controlled in which there are considerable demands and pressures to behaviour conformity and a person is restricted in the range of his/her own behaviour. Thus, individual differences in personality characteristics are more likely to influence the specific behaviour a person adopts. This type of environment determines and regulates the team members' communication flow that consists of team and task-oriented utterances. The role of personality in team process and team performance is unarguable. All these circumstances lead our focus on analysing the relationship between the employees' communication and observable behaviour and their personality traits.

Personality is an important factor in accounting for how employees behave in teams and in the organisation. The interest in identifying personality predictors of job performance has led researchers to use the Five Factor Personality Model as an important conceptual framework. The development of the Five-Factor Model (FFM) is an important event in the history of personality psychology because provides taxonomy for measuring personality traits. It describes personality traits based on five basic dimensions (Costa & McCrae, 1992).

i. **Neuroticism (N):** The tendency to experience nervousness, tension, anxiety, emotional instability, hostility and sadness.
ii. **Extraversion (E):** An energetic approach to the external world, including sociability, assertiveness and positive emotionality.
iii. **Openness to experience (O):** Describes the breadth, depth, originality and complexity of an individual's mental and experiential life.
iv. **Agreeableness (A):** The quality of one's interpersonal interactions along a continuum from compassion and altruism to antagonism.
v. **Conscientiousness (C):** Persistence, organization, and motivation in goal-directed behaviours, and socially prescribed impulse control.

The predictive power of the model within the employment context has often been demonstrated (Barrick & Mount, 1991; Tett et al., 1991; Piedmont & Weinstein, 1994; Salgado, 2001; Gellatly & Irving, 2001). In a review of Moynihan (2004) three basic theoretical perspectives explain the nature of personality effects on team performance. *Universal* approach: certain traits always predict teamwork process and team performance. *Contingent* approach: certain traits predict team performance depending on the task and organisational culture. *Configurational* approach: the mix of traits within a team and the fit of individual members with each other predict team performance.

Universal approach: Conscientiousness (C) has been examined in team performance because it is a reliable predictor of individual and team performance in field and laboratory settings (Neuman & Wright, 1999; Lepine et al., 1997; Barry & Stewart, 1997; Waung & Brice, 1998). Conscientiousness has consistently been found to be positively related to task focus and team performance, but only when both the team level and the leaders' conscientiousness are high. But it seems that in creative tasks, for example, a brainstorming study found that when team members are allowed to discuss strategies, teams composed of highly conscientious people produce better-quality performance (in terms of feasibility), whereas teams composed of low-

conscientiousness members produce a greater quantity of potential solutions. Tasks that require creativity may moderate the relationship between team conscientiousness and task performance. Therefore, Conscientiousness may be broadly applicable across numerous types of tasks, but may not predict specific types of tasks that require a high degree of creativity. The level of Conscientiousness in a team influences team functioning and outcomes. High level of Conscientiousness facilitates cooperation and creates an atmosphere in which individual team members are willing to learn from each other resulting in satisfied team-mates. If the level of Conscientiousness is low, no one feels responsible for a task, and team members do not stick to agreements or decision. All this can cause intragroup conflicts, stress and thus dissatisfaction. Conscientiousness relates to satisfaction and learning if the team is autonomous. A high level of autonomy is necessary to make decisions concerning any kind of work issues increasingly intensive intra-team communication and the mutual adjustment of efforts. If the team members are conscientious, they actively participate in decision making, and there is an opportunity to learn. So by sharing work-related attitudes and cooperating with each other, teamwork improves, contributes to satisfaction (Molleman et al., 2004).

The trait of Extraversion (E) has been shown to have positive effects on individual job performance for jobs requiring a high degree of social interaction (Barrick & Mount, 1991; Mount & Barrick, 1995; Littlepage et al., 1995). Teams higher in mean levels of Extraversion receive higher supervisor ratings of team performance than teams low on Extraversion. Teams with more extraverted members tend to be more socially cohesive and more highly evaluated by their supervisors. The degree of variance of Extraversion has a curvilinear relationship to task performance suggesting that too many or too few extraverts in a team can be inefficient. In general, Extraversion appears to facilitate cohesive team process, but only at moderate levels.

Teams with high mean levels of Agreeableness (A) have higher team viability, because Agreeableness is characterized by the concern for the team over desires and interests. In teams of management students working on a case study analysis and presentation task, individuals high on Agreeableness were more likely to be rated as cooperative team members by their peers. Low levels of Agreeableness (high individualism) are associated with reduced individual effort or social loafing in teams. Individuals low on Agreeableness tended to be unresponsive to teammates and tended to focus on their own task performance (Wagner, 1995; Comer, 1995).

Neuroticism (N) has been identified as a detrimental variable for team performance, and productivity. Teams with negative affective tone (negative affectivity or neuroticism) experienced higher rates of absenteeism. In sum Neuroticism is negatively associated with cohesive team process and effective decision making.

Contingent approach: According to this perspective the optimal team performance depends on the nature of the work, task and the organizational culture. These situational variables have moderating effects on the relationship between personality and team process or performance. Some studies consider the role of moderators in the relationship between personality traits and job performance (Barrick & Mount, 1993; Gellatly & Irving, 2001; Bono & Vey, 2007). The most important moderator is the situation in which the job performance takes place. The level of *task autonomy* moderates the relationship between personality and job performance: personality-performance correlations are founded to be higher in highly autonomous work situation than in less autonomous work situations (Beaty et al., 2001). The Agreeableness and performance relation is positive when the autonomy is low. When the autonomy is low, high level of agreeableness can helps the team member to achieve a higher

level of performance, while in high autonomy situations agreeableness can impede a high level of performance. This result indicates that personality-contextual performance correlations vary across situations with different expectations for performance. Personality and contextual performance behaviour is most strongly correlated when there are only weak cues and less correlated when there are strong cues.

Configurational approach: Certain personality traits may interact with others to result in desirable, as well as undesirable workplace behaviours depending on the pattern and interactions of other traits. Studies on team composition attributes have highlighted the relationship between team composition characteristics and team outcomes, but the results are inconsistent. Most of researchers have found a positive relationship between the mean level of Conscientiousness in a team and performance (Barrick & Mount, 1991; Hogan & Ones, 1997). Using the supervisory rating as a reliable measurement of workplace behaviour and performance, the evaluations show that highly conscientiousness workers (C) being low in Agreeableness received lower ratings of job performance than highly conscientiousness workers being high on Agreeableness. Highly conscientious workers who lack interpersonal sensitivity may be ineffective, particularly in jobs requiring cooperative interchange with others (Witt et al., 2002; Barrick & Mount, 1993; Molleman, 2004). If all team members are highly conscientious, each member contributes to the team task, and this will lead to many opportunities of learning from each others, facilitating cooperation. However, if the level of Conscientiousness is low, no one will feel responsible for a task, and team members will not stick to agreements or decisions resulting an atmosphere in which members are blaming each other for social loafing. This will cause intragroup conflicts, stress, and thus dissatisfaction.

A team that consists of stable members (N) is more effective. Stable individuals are more confident and less insecure while collaborating with others, and therefore they will more easily bring in their own knowledge and opinions and be more receptive to the inputs of others. This will enhance the opportunities of learning and lead to a more relaxed atmosphere. As Barrick (1998) argued, teams with unstable people tend to demonstrate more anxiety and negative feelings, which lessen the satisfaction of the individual team members.

Individuals who are open to experience (O) will prefer tasks that demand creativity, and they will enjoy experimenting with new problem-solving strategies; hence, they will be motivated to learn. They will prefer work that challenges them to utilize and develop their cognitive abilities. Persons low in Openness to experience will easily bear a cognitive overload and avoid new and ambiguous situations that demand creativity and offer opportunities of learning (Molleman, 2004).

5.2.1 Research 1

Our research aim was to focus on NPP operator team members' personality traits and to relate personality traits to communication patterns, to behavioural markers of non-technical skills, and to teams' performance.

5.2.1.1 Methods

The data collection was based on 16 operator teams' (N=96) interactions analysis in the Simulator Centre of the Hungarian Nuclear Power Plant (NPP). The NPP Simulator Centre is a realistic, high-fidelity tool that is widely used in training and exams creating the required level of face-validity to be relevant for real life situations.

Each of the 16 operator teams had to follow the same scenario. In order to provide a complete picture of simulation the scenario "*Failure of one turbine unit*" will be described

briefly: according to the annual schedule used by instructors, a live Switchover Test needs to be performed, while an unjustified operation of the turbine protection occurs resulting in the failure of one turbine unit. The failure of the equipment is followed by the malfunction of the primary circuit pressure control, creating a condition that also needs to be managed. The mean duration of the scenario is about 35 minutes.

Video records of operators' activity during the selected scenario have been used for collecting and analyzing data. In order to keep the operators' real life behaviour at the beginning of the simulator study they were informed about video recordings during the ongoing training session, but they did not know exactly which of the programmed scenarios would be videotaped. Video recordings were made with the operators' joint consent.

The operator team consists of the following team members: 1) Unit Shift Supervisor (USS), 2) Reactor Operator (ROP), 3) Turbine Operator (TOP), 4) Turbine Chief Mechanician (TCH), 5) Unit Electrician (UE), and 6) Shift Leader (SL).

- **Personality measurement**

Each team member (N=96) was asked to fill in the NEO-PI-R personality questionnaire. The NEO-PI-R focuses on five major domains of personality, as well as the six traits or facets that define each domain (Costa & McCrae, 1992). (Table 1.)

Neuroticism **N**	Anxiety **NAN**; Angry hostility **NAH**; Depression **NDE**; Self consciousness **NSC**; Impulsiveness **NIM**; Vulnerability NVU.
Extroversion **E**	Warmth **EWA;** Gregariousness **EGR;** Assertiveness **EAS;** Activity **EAC;** Excitement seeking **EEX;** Positive emotions **EPE**
Openness to experience **O**	Fantasy **OFA;** Aesthetics **OAE;** Feeling **OFE;** Actions **OAC;** Ideas **OID;** Values **OVA.**
Agreeableness **A**	Trust **ATR;** Straightforwardness **AST;** Altruism **AAL;** Compliance **ACO;** Modesty **AMO;** Tender mindedness **ATM.**
Conscientiousness **C**	Competence **CCO;** Order **COR;** Dutifulness **CDU;** Striving for achievement **CAS;** Self discipline **CSD;** Deliberation **CDL.**

Table 1. NEO-PI-R factors and scales

- **Communication measurement: team-oriented utterances**

All the video recorded conversation during the selected scenario was transcribed word by word, identifying the operators' verbal utterances by two independent expert evaluators. Difficulties occurred in transcribing videotapes due to communication density during some periods of the interaction, much simultaneous conversation flow between members, additionally we were faced with a noisy control room environment. For all these reasons we have few blind points in the transcribed videotapes, where the speaker of some utterances cannot be identified properly.

Our aim was to capture some relevant *team and task-oriented communication utterances.* Research 1 focuses exclusively on team-oriented communication utterances that are likely to be related to team processes, on the team atmosphere stemmed from the individuals' personality. Team-oriented communication refers to the activities required to coordinate the workflow among team members. Task-oriented communication utterances and their analyses will be described in Research 2. During the task accomplishment specific team-oriented communication utterances were identified that were not strongly related to task accomplishment but rather to team process and interactions during the operation. **Communication utterances: *R****elation* (R) - Relation-related utterances, maintenance of contact, relationship, and vigilance in sentences ("*Hold the line please!*", naming the addressee). ***P****oliteness* (P) - The speaker gives a command,

information, question or affirmation formulated politely. The speaker determines the team atmosphere, and indicates the mutual respect among team members ("*Thank you", "Would you be so kind…", "Do it, please"*). ***M**otivation* (M) - Encouragement, formulated as reinforcement, completed with motivation, stimulation ("*It's perfect, just go on like this!"*). *First person plural (**We**)* - The speaker uses first person plural ("*We, our, us, let's"*). ***A**ffection* (A) - Words describing emotions, someone's emotional status, indicating astonishment, exasperation, frustration, excitement, relieve happiness or contentment ("*I regret it*", "*I'm quite happy*" or laughing). ***T**hinking, cognitive* (T) - Words indicating cognitive process. It may suggest a problem-solving mechanism and can increase especially in facing with technical problems (*„I think…", „Attention!", „If… than…", "Check it!"*).

- **Team performance measurement**

The team performance was assessed by the instructors' impression about the teams' efficiency using a 3-point Likert scale (1: poor, 2: medium, 3: excellent) according to how fast and punctual they accomplished the task and in what degree they distorted from the optimal solution. 17% of the examined 16 teams were assessed as poor, 40 % as a medium and 35 % as an excellent performance teams.

- **Non-technical skills measurement**

Non-technical skills are defined as the cognitive, "hard" and social "soft" skills of team members (Flin et al., 2003). The cognitive so called "**hard**" **skills** are related to task-solving processes: *Professional knowledge* (appropriate knowledge about technology, equipment, environment, and ability to transfer and use this knowledge during operations); *Problem solving* (the skill to recognize and define the sources of task difficulties, and to be active in providing and implementing solutions); *Standard compliance* (following technical norms, rules, procedures, and stimulating other team members to comply with standards).

The social "**soft**" **skills** are team relevant skills: *Task load management* (efficient coping mechanism with unexpected and novel events and with difficulties during team processes); *Cooperation* (the ability to work effectively in team, to consider and support other team members' needs); *Communication* (the ability to exchange information briefly and clearly, acknowledging the received information). After each scenario accomplishment the instructors were asked to evaluate each nontechnical skill using a 4-point Likert scale (1: weak, 2: acceptable, 3: good, 4: excellent).

5.2.1.2 Results

- **Team-oriented communication utterances**

Analysing team-oriented communication utterances, the results reveal that the most frequently used communication utterances are *Thinking (T),* indicating the team members' cognitive, mental effort during the scenario. In the case of work teams, such as the operator team where the team's goal is mainly task-oriented, the frequent use of cognition related utterances is inevitable, although these elements of the communication contribute to the establishment and maintenance of team processes. The second most frequently used communication utterance is the *first person plural pronoun (We)* that indicates that the team members apply team perspectives in their point of view, emphasizing a high level of identification with the team. *Motivation,* as a communication utterance is relatively rarely used by the team.

Analysing the occurrence of communication utterances among different roles, the findings suggest that the Unit Shift Supervisor (USS) is the most active member in the communication process, often using team-oriented communication utterances such as Relation (R), the first person plural pronoun (We), Thinking (T). (Figure 1.)

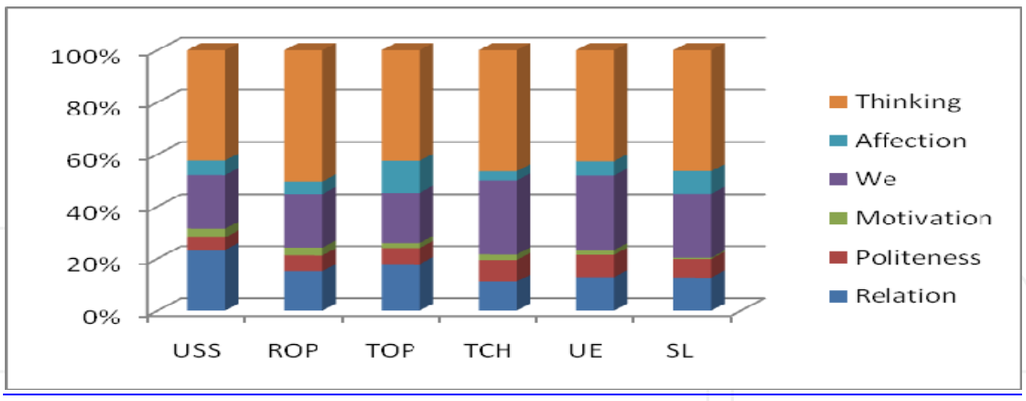

Fig. 1. Descriptive statistic of the non-technical-related communication utterances according to observed teams' roles

- **Relationship between team-oriented communication and personality**

The significant correlations between the frequency of different types of communication utterances and the NEO-PI-R factors and scales are presented. Correlation coefficients between personality and communication utterances organize around the Extroversion, Agreeableness, and Openness to experience personality factors and their scales. (*p<0,05; **p<0,00)

These analysed operator teams' communication refers to maintain relationship (*Relationship*) shows a significant correlation with Assertiveness (EAS) personality scale (,23**). The Extraversion personality factor and their scales such as Activity, Excitement seeking have significant correlations with *Politeness* communication style (E, EAC, EEX – Politeness: ,34**; 32**; 34**). The polite and acceptable communication style also has significant correlations with Openness personality factor and openness to fantasy and feeling scales (O, OFA, PFE – Politeness: ,26*; 32**; 32**) and Achievement striving scale (CAS – Politeness: ,27*). Behind a polite communication there is a positive and open personality, who is able to create an open and sincere relationship with other people and has the power to form acceptable team ambience in which everybody respects and tolerates each other without exaggeration.

To our surprise the Agreeableness personality factor and their scales indicate negative correlations with most of these team-oriented communication utterances (A, AAL, AMO, AST - Relation: -,40**; -,29*; -,40**; -,38**; A, AMO, AST, ACO – Politeness: -,31**;-,27*;-,40**;-,35**; AST – We: -,24*; A, AMO, AST, ACO – *Thinking*: -,31**; -,26*; -,29*; -,27*. It seems that the higher score on the Agreeable factor and its diverse scales, the lower is the possibility of using communication utterances related to maintaining interaction in this highly task-oriented team. For maintaining good relationship and a strong cohesion in these types of work teams for the team members it is important to be assertive (EAS) and it seems to be less agreeable (A) or compliant (ACO). An agreeable character is less fitting to teams operating in a high risk and strongly standardised environment. Highly modest (AMO), altruist (AAL), compliant (ACO) operators are less willing to initiate a new social action and easily become pressed by others in the team. Less agreeable people (A) more frequently apply expressions related to problem-solving procedures like 'think', 'attention', 'if…than' than those high score on Agreeableness.

- **Team performance and personality**

The results of regression analysis are presented in Table 2. As shown, the relevant personality traits are significantly related to team performance as a dependent variable:

Extraversion (E) and Conscientiousness (C). The standardized Beta Coefficients give a measure of the contribution of each variable to the model. ΔR^2 value tells that the Order scale (COR) model accounts for 9,8% of variance in the scores. Seeing that *t* value in this case is almost 3, it suggests that the Order scale as a predictor variable has a moderate impact on the criterion variable, on team performance. These findings underline and reinforce the relevant role of Conscientiousness (C) in the wok-setting performance.

	Team performance rating (as dependent, criterion variables)			
Personality factors and scales (as predictor variables)	**ΔR^2**	**ß**	**t**	**p**
Extraversion: Assertiveness (EAS)	.048*	.248	2,156	.035
Extraversion: Activity (EAC)	.050*	.252	2,190	.032
C_Conscientiousness	.071*	.290	2,552	.013
CCO_Competence	.050*	.252	2,195	.031
COR_Order	.098**	.332	2,966	.004
CAS_Achievement striving	.076*	.298	2,633	.010
CSD_Self discipline	.036*	.223	1,923	.058

Table 2. Regression results for testing Team performance and various personality factors and scales. Note: *p<0,05; **p<0,00 (one-tailed), for *t* values (for unstandardized regression coefficients) or *F* values (for overall model). *ß* = Standardized Coefficients.

Furthermore, it has also been analyzed how the homogeneity and heterogeneity of a certain personality factor alter team performance. The previously used Levene test rejects the homogeneity of variances, the Welsch D test on Agreeableness shows a significant main effect on standard deviation (SD) (d2=6,218; p<0,05). So, highly performing teams have a greater standard deviation of Agreeableness than poor or average performing teams. (Figure 2.)

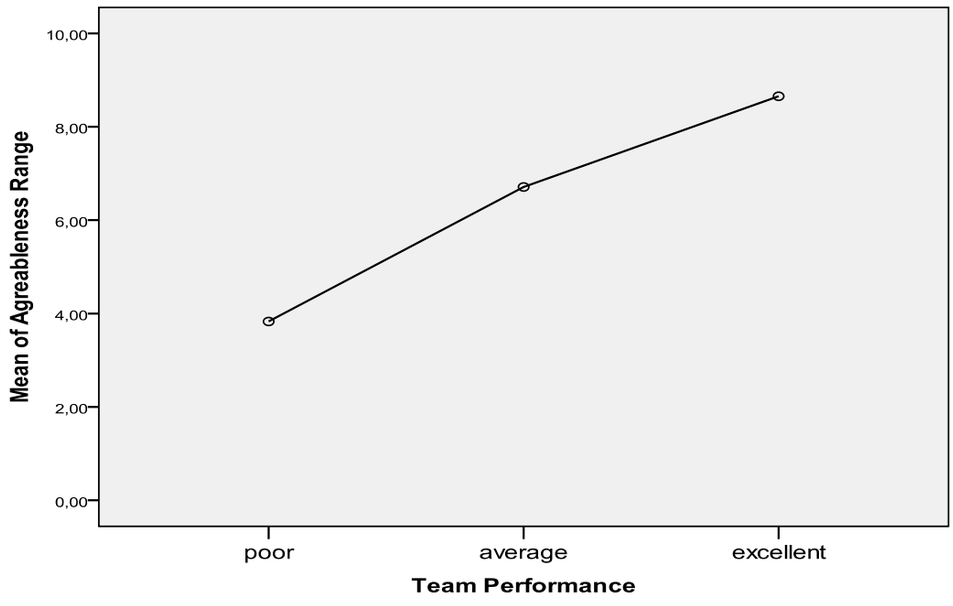

Fig. 2. Team performance and Standard Deviance of Agreeableness

- **Non-technical skills measurements and personality**

Using the stepwise linear regression analysis from all the predictors only the Anxiety (NAN) personality trait predicts significantly *Professional knowledge* as a dependent variable (*ß*=0,34; t=3,07; p<0,00) along the supervisor ratings. The NAN has been left in the model even if the dependent variable has been changed: *Comply with standard* (keeping rules) (*ß*=0,3; t=2,59; p<0,05), *Communication* (*ß*=0,38; t=3,38; p<0,00) or *Cooperation* (*ß*=0,37; t=3,24; p<0,00).

The other determinative personality trait that plays an important role in the instructors' judgment is Conscientiousness (C) factor, precisely Dutifulness (CDU) and the Order (COR) scales. When the *Comply with standard* factor has been evaluated the Dutifulness (CDU) factor has emerged from all personality traits (*ß*=0,251; t=2,16; p<0,05), and when the *Cooperation* factor is the dependent variable the Order (COR) personality trait (*ß*=0,31; t=2,78; p<0,00) influences mostly the instructors' rating. Furthermore, from the instructors' point of view an operator's *communication* skills mainly depend on his/her Assertively personality (EAS) type (*ß*=0,30; t=2,62; p<0,05).

Whilst the communication utterances have a strong relationship with the Extraversion, the Openness to experience and the Agreeableness factors, the "soft" and "hard" skills only show a significant correlation with the Anxiety scale (NAN) and the Order and Dutifulness (COR, CDU) scales.

Regarding our findings the Neuroticism factor associated with the Consciousness factor and their scales indicate their beneficial impact on the *Professional knowledge, Comply with standard* and on the interactive behaviour forms such as *Communication* and *Cooperation*. A moderate level of anxiety interacting with Conscientiousness can help persons to form a good impression about their own skills and behaviour. These persons endeavour to be accepted by others and strive to mark out from their environment with their remarkable performance. These people adapt to the changing environment in a very sensitive way.

5.2.2 Discussion

The extent to which the external environment constrains the individuals' personality varies in weak or strong situation. In strong situations, the organization exerts considerable pressure or demands to induce conformity. These controlling forces press the individual to behave in a specific way or exhibit a very narrow range of behaviours. Controversially, in weak situations the individual determines which behaviours to display, leaving bigger space for personality. In a NPP environment the individuals are placed in strong situations due to the high level of standardisation. In spite of this fact, personality has a key role in coping with these constrains.

The role of team members' personality in team communication has been analysed, in occurrence of observable non-technical skills and in team performance during specific task accomplishment. Our study reveals that team-oriented communication utterances highly correlate with Extroversion and Openness to experience personality traits, and to our surprise, in a negative direction with Agreeableness. Similar findings have been found in the Barrick & Mount (1993) study, in which the predictive validity of Agreeableness is investigated introducing autonomy as a moderator variable. The validity of Agreeableness is also higher in high-autonomy jobs compared with low-autonomy ones, but the correlation is negative. These findings suggest that the degree of the job autonomy influences the validity of personality dimensions. It means that in NPP operator teams when the members

work in a high autonomy, so-called strong situation the Agreeableness softly impedes the effective team functioning.
During the team-process the operators' "soft" and "hard" skills have a remarkable relationship with personality traits. First of all, Professional knowledge and Coordination behaviour markers show significant correlations with the Neuroticism and the Conscientiousness personality factors. The stable role of Conscientiousness has been reinforced, precisely Dutifulness and Order that mainly influence the operators' *Keeping rules* and *Cooperation* skills that largely determine their behaviour in this type of work settings. It seems that *Team-performance* as a team process output is directly influenced by the Conscientiousness and the Extraversion personality factors based on the instructors' evaluations.

6. Process of operator teamwork

The main question of studying teamwork in high risk environments is how the team members having specific knowledge, cognition and representing different fields are able to operate and manage a technically complex system. Cooke et al. (2004) emphasize that team cognition emerges from the interplay of the individual cognition of each team member and team process behaviour, thus team cognition is more than the sum of the individual team members' cognition. According to theoretical approaches of team cognition each individual has two different models: an *individual mental model*, which is long term knowledge (professional knowledge related to task, and team members) and an *individual situation model* describing a momentary, transient understanding of the current situation. In order to run a complex system it is needed to integrate the information and knowledge of the individual team members. The integration of long term knowledge, as well as the harmonisation of all the continuously changing environmental technical information may be attained through *team process* behaviour such as communication, coordination, cooperation and decision making, etc. The interaction of team members is remarkably important, since individual knowledge is transferred to team knowledge through these team processes. The output of this process will be two kinds of team level cognitive constructs: the *team mental model*, referring to the collective task and team knowledge (roles and responsibilities, knowledge of team mates, skills, abilities, beliefs), and the *team situation model*, describing collective team understanding of the specific situation. This team situation model guides the team in assessing and interpreting cues and patterns of the current situation (Cooke et al., 2000). In our view *shared knowledge* includes two of the above mentioned knowledge: team situation and mental model.
When analysing deeper the current literature of team cognition, two different complementary views of this construct can be found. The collective view of team cognition approaches this cognitive construct as aggregated individual knowledge. According to the other view the team knowledge may be assessed at a holistic level too, by focusing on the individuals' actions, and behaviour, not only on their knowledge. Team knowledge at a holistic level is the team members' knowledge that has been processed or integrated through team behaviours such as communication, coordination or cooperation (Cooke et al., 2004). On one hand, the collective view proved to be useful when knowledge is distributed homogenously among individuals, on the other hand, the holistic view is more appropriate when knowledge is distributed heterogeneously among team members (Kiekel & Cooke, 2004).

In spite of the fact that the individual knowledge is clear and accurate, the inefficient team processes (such as communication, coordination) may impede the integration of these knowledge structures, leading to inaccurate team knowledge, and inappropriate team action. This line of reasoning points out the importance of a holistic approach of team cognition. Thus, our view of team cognition describes this construct as the collection of individual situation and mental models, as well as those team processes that help the establishment and modification of team situation and mental models.

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 turn, team performance may influence team process. An unsuccessful performance may urge the team to change their communication, coordination or decision strategies.

Team cognition is shaped by those team processes -such as interaction of the team members, communication - that helps integrate the team members' knowledge creating and continuously sustaining shared knowledge. In this way one of the critical aspects of team cognition is the team process that helps team members to create and share their individual knowledge.

Another question raised by researchers and practitioners is whether team knowledge exists, since team knowledge cannot be captured in one members' mind, brain. It exists within the context of team actions, interactions and within dynamic environment.

6.1 Communication as a crucial means to establish shared knowledge

Communication as a key team process is used in the team to share information, individual knowledge, to establish and to maintain current shared knowledge. Communication defines the way how team members execute complex tasks, and the way how a team handles and manages difficulties, and high task load situations.

There have been several attempts to help team communication in order to create and sustain shared knowledge under different circumstances. Waller et al. (2004) aimed to identify the adaptive communicative behaviours that help the NPP operator team to flexibly adapt to a dynamic task load environment. According to their studies adaptive behaviour such as information collection, task prioritization, and task distribution helps the team to create shared knowledge, which in turn helps the team to describe, explain, and make predictions and decide which action to be taken in a dynamically changing environment. It is also stated that information is collected and shared by the team members in order to identify tasks they need to perform, and receive, collect and screen 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 cognition (Waller et al., 2004). All these results suggest that teams attempting to collect more information will have an opportunity to gain, analyse, and understand the relevant cues from the environment resulting in higher level performance. While in low performing teams the members do not aim to acquire information reducing their ability to perceive the relevant environmental cues and act accordingly. Furthermore it has been also found that the use of long words is negatively related to performance and positively related to rates of errors. Similarly, 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 & Helmreich, 2000). 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. It has been found in the existing literature that the increases in communication volume, in particular communication about coordination (number of coordination requests), are inversely correlated with team performance, (Diedrich et al., 2005). However, it may be concluded that it is not just the communication quantity that affects team performance but also the characteristics of communication such as stability, focus, object of communication and timing. For the sake of an efficient information flow between team members it is also important to answer the question, to provide the information in timely manner. We tend to assume that team communication, has to be focused on the task itself trying to catch the relevant environmental cues from the present, and use this information to project future situations in accordance with the team's goals in order to facilitate the establishment of shared knowledge and performance. Furthermore, if the team's communication is consistently engaged in the past, they may fail to perceive and share relevant environmental cues from the present moment.

In the process of the formation of shared knowledge it is not sufficient to gather and to share the information, but it is also necessary to confirm the received information. It is not only the information collection behaviour that counts, but also the acknowledgement of the received information. Besides shared knowledge, the importance of its accuracy is also emphasized, since creating a shared cognition by itself does not lead to high performance only if the shared knowledge is accurate (Mathieu et al., 2000; Mohammed et al., 2000; Banks & Millward, 2007). In NPP operation, the tasks are allocated to several operators, and what is even more important is that each operator has a different information source. Communication is the only way of sharing information with each other, in this way it is crucial to clearly perceive the information and develop shared knowledge. One of the major characteristics of effective communication is verbal reaction, affirmation signing that the addressee perceived the information (Sträter & Fokuda, 2004). The lack of verbal feedback may suggest that the recipient overlooked the information (that may be relevant), in this way the speaker does not know whether the information has been perceived or not. At the same time the verbal reaffirmation of information may have some important side effects, the repetition of information may increase redundancy and what is even more important it strains the linguistic and cognitive resources of team members (Krifka, 2004). Individuals who expand their cognitive resources to speak more elaborately, to acknowledge the received information in detailed manner do so at the expense of decreased situational awareness (Sexton & Helmreich, 2000). Krifka (2004) advises "Make your contribution as informative as is required, BUT do not make your contribution more informative than required". The use of simple affirmation will help the team to clarify and acknowledge the received information, in this way to establish an accurate shared understanding of the situation. Conversely the affirmation with information will overload the cognitive resources of both the information provider and receiver, creating interference, impeding the team in creating a clear shared picture of the relevant aspect of situation. This criteria of efficient communication is in line with the Grice maxims, namely with the maxim of quantity prescribing that during efficient information transfer the speaker needs to give as much information as necessary but not more and with the maxim of manner describing the need to be brief and clear and avoiding long-winded information transfer (1957, as cited in Pléh, 1997).

The complete information flow between team members is particularly important in the joint establishment and fine tuning of shared knowledge. Coherent communication can be viewed as communication that responds to a previously initiated thought. These thoughts must be recognized, responded and new thoughts related to the previous one must be developed by the speakers, interlocutors. This goal can be achieved only if the members of the conversation are aware of each other's needs. The coherent conversation can be viewed as a continuum, as there is a strong semantic connection, relation between the parts of conversation, such as cause, condition, affirmation, and summary. In other words, the conversation is hierarchically structured, each part is semantically related to other parts (Krifka, 2004). Analyzing the coherence of conversation, Grommes (2007) states that coherence can be connected to mental processes. The operating room team members share broad common professional knowledge which constitutes the basis to be engaged in a coherent conversation. In turn, the coherent flow of information facilitates the creation of shared knowledge, common ground, which is essential for efficient joint activities (Grommes, 2007).

Communication is the most appropriate means of preparing for a coordinated action during routine operations and becomes more emphasised during non-routine situations, when the shared knowledge of the current situation is the key factor of efficient team actions. Shared knowledge can constitute the basis of an economical form of communication, namely implicit communication. Implicit communication is based on the knowledge of each others' personality, competencies, needs, task and responsibilities allowing voluntary task relevant information exchange, listening and offering assistance, unsolicited help. This form of communication allows team members to reduce the costs of explicit communication. Explicit communication includes information exchange as a response to a specific request verifying and acknowledging information, giving orders and assigning tasks (Swain & Mills, 2003; Gudela et al., 2004). During high task load the individuals' cognitive resources are overwhelmed with the management of a novel and complex situation, therefore it is important to save resources by means of implicit communication.

6.1.1 Research 2

The present paper aims to describe data from empirical researches about Nuclear Power Plant (NPP) operator team's communication, and its application to efficient teamwork. The research aims to analyse and describe team communication, to identify those specific communication dimensions that help to create shared knowledge, supporting the joint assessment of the current situation and developing adequate team strategies to face it.

The study focused on the NPP operator teams' communication, firstly in order to identify and understand those key communicative utterances that could be linked to higher team performance, secondly to identify how the teams adapt to high task load situations.

6.1.1.1 Methods

The data collection was based on the analysis of 16 operator team interactions in the Simulator Centre of the Hungarian Nuclear Power Plant. Since communication is the central factor of our research, the empirical studies of a "lively" interaction can best be carried out by analysing carefully chosen simulator sessions.

Each team had to follow the same scenario "Failure of one turbine unit" described under Research 1. Choosing the simulation, it was taken into consideration that the scenario had to

be oriented toward communication and in this way all team members had to be involved in solving the control task. Possessing complementary knowledge they had to share information with each other to manage the problems occurring during the simulated malfunctions.

As described under Research 1, Methods, video recordings of operators' activity during the selected scenario have been used for collecting and analyzing data. All the 16 teams' conversation has been transcribed in order to analyse team communication utterances.

- **Task load evaluation**

The scenario was divided into 3 phases by the instructors, according to the level of task load.

1. Phase of scenario *Moderate* level of task load: Executing a live switchover test
2. Phase of scenario *High* level of task load: Identifying, announcing and managing sudden, unjustified turbine operation
3. Phase of scenario *Moderate* level of task load: Indicating pressure control failure as well as the drop of one safety shutdown, requesting support service, resolving the situation.

- **Team performance measurement**

The performance scores were made by the instructors' evaluation, based on their impression about the teams' efficiency under the different phases of the scenario using the same 3-point Likert scale (1 – poor, 2 – medium, 3 - excellent).

By eliciting data from performance assessments four team performance categories were developed:

1. Excellent team: the whole team performance is evaluated excellent, through all the phases of the scenario (No. = 4 teams).
2. Average team: the team performance is medium continuously through all the phases of the scenario (No. = 5 teams).
3. Unbalanced team: the team performance varies from excellent to poor through the scenario (No. = 3 teams).
4. Poor team: the team performance is evaluated steadily poor through the complete scenario (No. = 4 teams).

- **Communication measurement: task-oriented utterances**

In Research 2 our aim was to capture some relevant task specific static and sequential analyses of the operator team's communication. Static measurements consider the team's communication only at a given point of time (e.g. every 10 seconds), or as an aggregate of the information flow over a period of time (e.g. during a complete task accomplishment). Sequential analyses take into consideration the ongoing stream of information exchange, interaction (Kiekel et al., 2001; Kiekel et al., 2002; Cooke & Gorman, 2006).

In order to capture the most relevant content static aspect of team communication *task-oriented communication utterances* have been developed expanding and specifying the communication dimensions used in similar environments (Conversation Analysis by Sacks, 1992; Speech Act Type-inventory for the Analyses of Cockpit Communication, STACK by Diegritz & Fürst, 1999; Krifka, 2004).

Task-oriented communication refers to the activities strongly linked to task strategies, task accomplishment, and it refers to the technical aspects of a task that must be performed.

Categories of communication (static measurements):

- *Information collecting question:* The aim of the question is information acquisition, for example asking about certain indicators or resources.
- *Open Question Information*: The question is addressed in order to complete the proposition with certain information, therefore, it is likely to receive a long answer (Questions that usually starts with words like *what, when, who*, etc.).
- *Closed Question Information*: The aim of this question is verification, to judge the truth of a position; therefore, the answer is either a single word (yes, or no) or a short phrase ("*Can we start the program*?").
- *Information Providing:* The team members inform each other about some relevant aspect of the mission related to human or technical indicators.
- *Information Providing Past*: The speaker informs the addressee about technological information, certain indicators that happened in the past, or about the crew's past status, personnel resources in the past ("*The error sign was caused by the failure of the pressure regulator.*").
- *Information Providing Present*: The speaker informs the addressee about some actual, present technological information, certain indicators, or about the crew's present status, personnel resources ("*I am preparing the necessary condition for the switchover test.*").
- *Information Providing Future*: The speaker informs the addressee about some technological information that may change in the future, foretells about certain indicators, or about his intentions and future actions ("*We will continue the test as soon as we have managed this unjustified reaction.*").
- *Affirmation:* It is the manifestation of two-way communications.
- *Simple Affirmation*: Answers to closed questions or commands, acknowledges the received information (Affirmations, acknowledgements, acceptances, answer: *'yes', 'no', 'ok', 'good'*).
- *Affirmation with Information*: A feedback, reinforcement on a status report or information, or command completed with additional information ("*Please switch on the 1 cb001 circuit breaker!" "1cb001 circuit breaker is on, we have the necessary differential current.*").

The team communication sequential analyses focused on the coherence of conversations. The anchored point of the *coherence analyses* was the new thought (that can be a question, information, etc.) initiated by one of the team members. The main condition of the coherent conversation is *turn-taking*, following this thought; the interlocutor develops a new question, information or command related to the previous information. Otherwise, if an initiated thought is not followed by any of the team members, it will be considered as a *thought without turn taking*.

6.1.1.2 Results

- **Open information question and performance**

Appropriate information collection and distribution allows the team to better understand the situation helping to build a shared conceptualization of the faced problems. According to our analyses, several specific communication utterances were related to performance. Particular forms of questions proved to be the best way to dispel uncertainties and to realize efficient communication. The results revealed that fewer open information collecting questions are used by the excellent performing teams than the lower performing teams ($F= 4{,}690$, $p<0{,}05$). (Figure 3.)

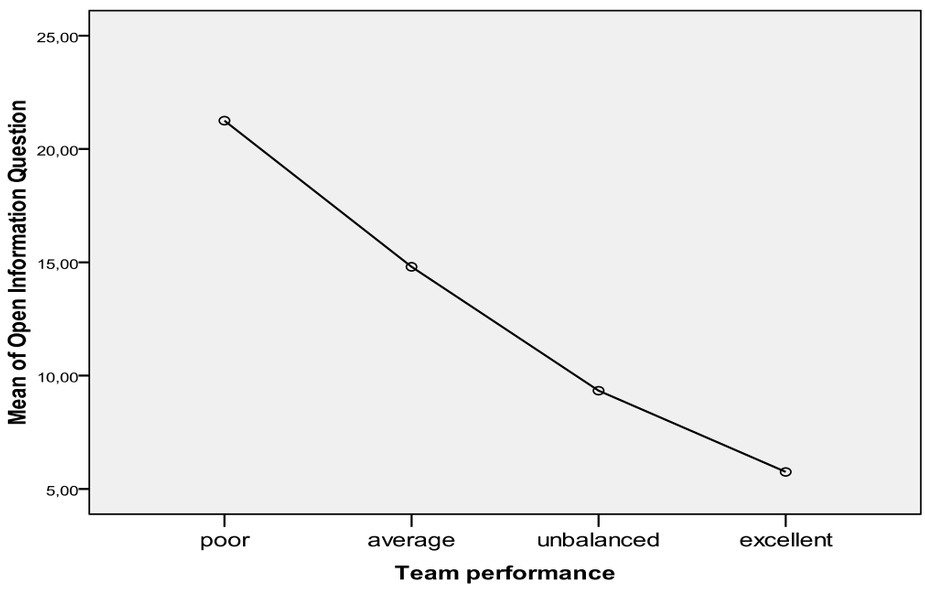

Fig. 3. The mean frequency of Open Information Question according to the team performance

The frequent use of open information collecting questions suggests that when lower performing teams formulate their questions, they have less information, knowledge about the environmental cues, so they formulate the questions in a less complete form. In turn, the excellent performing teams do not use open information questions so frequently, since they have more stable professional knowledge about the ongoing events being able to face the challenge of the situation. The open questions are incomplete and force the addressee to use the cognitive resources to complete the proposition. However, it is necessary to emphasize the usefulness of open questions in establishing team knowledge, but only during low task load, when the cognitive resources are not overloaded, so postulating an open question will not lead to any negative consequences. In this way effective communication that helps to establish team knowledge, and improve performance implies the ability of applying a simple and succinct vocabulary.

- **Affirmation and performance**

For the efficient information flow between team members it is also important to answer the formulated question, to acknowledge the received information. Although the differences are not statistically significant, the results can be regarded as a tendency that describes excellent performing teams using more simple affirmations and fewer affirmations with information, conversely with the low performing teams, where team members exchange more affirmations with information (Figure 4.). The result indicates the need for a clear information exchange that helps to establish accurate team knowledge, instead of creating an interference with additional, not so relevant, information. This result is line with Krifka's advice (2004) and Gricean quantity and manner maxim (1957, as cited in Pléh, 1997) to apply a simple brief vocabulary and to avoid providing information that is above the needed quantity.

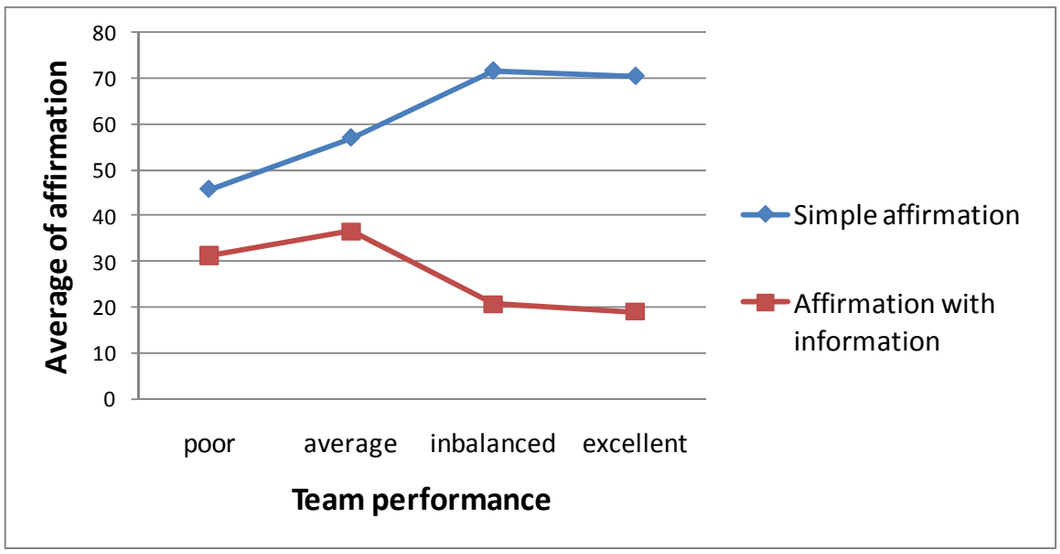

Fig. 4. The mean frequency of affirmation according to team performance

- **Information providing activity and performance**

Focusing closely on teams' information providing activity (Figure 5.) it is possible to describe the team's general tendency of focusing on the present, and less orientating about the past and future; at the same time there is a significant difference between the use of these communication utterances among excellent and poor performing teams. The poor teams' information flow contains more information about the past events ($p<0,05$), less information about the presently ongoing events ($p=0,005$) and about the future than the excellent performing teams' communication. The results suggest that excellent teams succeed to perceive the environmental elements in the present, to project the elements of the present status to the future, and focus less on the past.

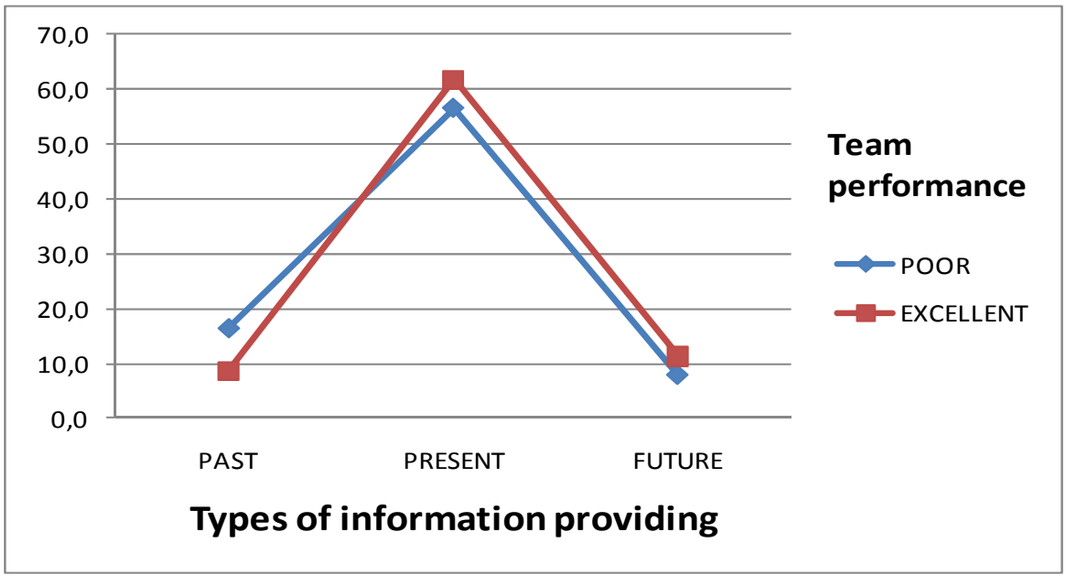

Fig. 5. The frequency of providing information about past, present, future according to team performance

- **Coherence of information flow and performance**

The coherent information flow between team members proved to be an efficient communication strategy to attain high performance. Comparing the coherence indicators of the excellent and the poor performing teams' conversations, the results show that the poor teams' conversations include more often thoughts without turn-taking (t=5,506, p<0,05) and fewer thoughts with turn taking (t=4,069, p=0,05) indicating an incomplete flow of information. Coherent communication means that the team members are aware of the information distributed by others, and react to the received information (either with a simple affirmation, or with a question, or providing additional information), creating a semantic connection in the information sharing activity. In this way coherent communication is one of the key elements of effective establishment or modification, fine tuning of accurate and complete team knowledge. 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. (Figure 6.)

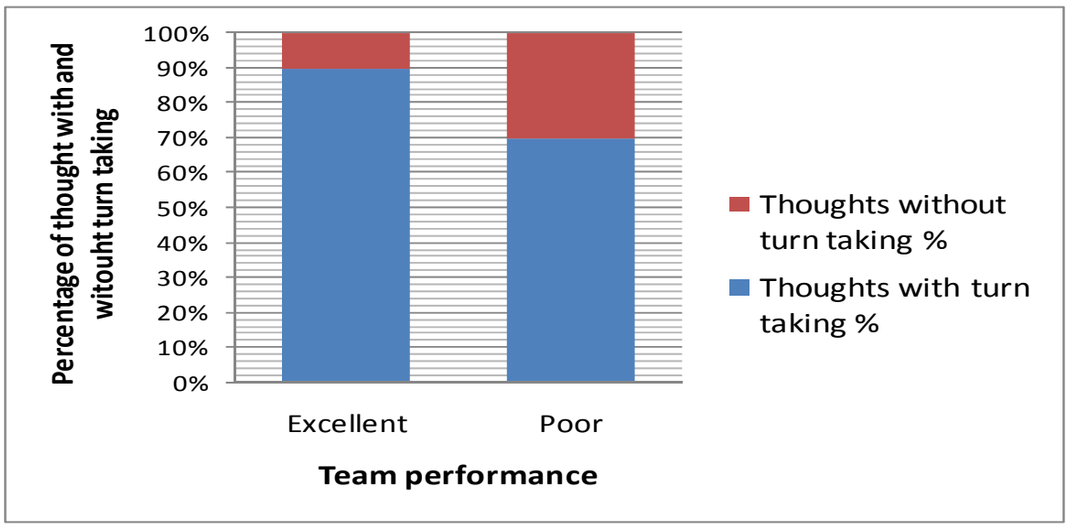

Fig. 6. The percentage of thoughts with and without turn-taking according to team performance

- **Communication under different level of task load**

Generally it can be concluded that as the task load increases, the frequency of communication utterances decreases. During high task load the communication is severely impeded, which can be explained by the operators' overloaded cognitive resources. The unexpected problems, failures intensively load the team members' cognitive capacity being unable to share their attention between the accomplishment of the task and communication. Furthermore, as the allocated resources disengage the collective need to process the causes and the consequences of unexpected event results in more frequent communication. (Figure 7)

6.1.2 Discussion

Some specific task-oriented communicative utterances prove to be crucial factors in the team processes that create and modify shared knowledge. Research 2 considers some specific aspects of communication that could be linked to establishing shared knowledge, such as using open information questions, affirmations, information providing activity, and

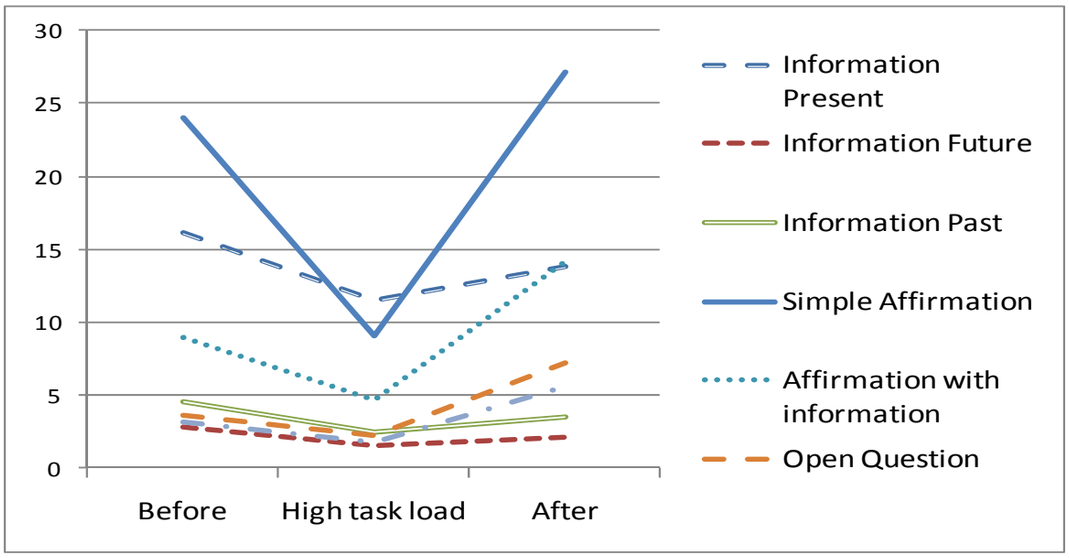

Fig. 7. The mean frequency of task-oriented communication utterances according to different levels of task load

coherence of information flow in a NPP environment. The use of effectively formulated information collection questions, the development of a well established effective communication strategy that focuses on the ongoing events and projecting the environmental cues to the future, affirming the received information could all help the team to build, and modify accurate shared knowledge and to improve team performance. The coherent information flow between team members proves to be an efficient communication strategy to attain high performance. Coherent communication means that the team members are aware of the information distributed by others, and react to the received information (either by means of a simple affirmation, or by means of a question, or providing additional information), creating a semantic connection in the information sharing activity.

Finally, at the beginning of the scenario, moderate task load necessitates less mental effort leaving more room for communication, although during simulation scenarios operators have some anticipation regarding unexpected events causing high task load (Antalovits & Izsó, 2003, Izsó, 2001). Under high task load the personnel's and the operators' cognitive resources are overloaded paying attention to the occurring problems, failures, and are unable to share their cognitive resources between problem management and communication. The communication density increases significantly in the third phase, under moderate task load as the cognitive resources disengage a collective need of elaborating the sources and consequences of high task load.

7. Output of operator teamwork

Taking into account that team performance is a multidimensional construct, measurements of team performance should focus not just on team efficiency but also on team effectiveness, because teams can be effective but inefficient at the same time. *Team effectiveness* measures the team output focusing on whether the team has reached all the specified goals, produced the intended results or not. While *team efficiency* refers to the way, how the team has reached the intended goals. The efficiency measures if the team was able to accomplish all of the

necessary tasks for a job in the appropriate amount of time, with the appropriate level of efforts or not. The aim is not just to reach the specified goals, but also get the maximum output for a long term, without consuming all the accessible resources. Effectiveness focuses on the end of the activity, efficiency focuses on the process or "means", if the team has reached the desired goals in an economical manner (Robbins, 1998 as cited in Horrowitz, 2005).

Measuring team performance two types of indicators should be considered:-*quantitative* and *qualitative* aspects of performance. In NPP control room the quantitative aspects of operator team performance includes incident, error, and accident data obtained from official reports, results of requalification exams. Qualitative aspects of performance consists of peer and supervisor ratings (Shift Leader) evaluating specific professional knowledge as well as cognitive and social skills required for safe and efficient plant functioning.

In order to improve team performance, the measurements and development efforts should focus near the outputs, on processes as well. Firstly, because the team performance output could be often influenced by external factors, on which the team has little impact, in this way, focusing on the output may be incomplete and misleading for developmental guidelines. Moreover, team improvement recommendations based only on outputs may lack some substantial information, since the output measures do not specify what aspects of performance are insufficient, deficient. Thirdly, the exclusive focus on team output may be misleading for team training recommendations, because in practice we can easily meet cases when team outputs has reached the specified level, even though the processes were impaired. In this case if we base our team training principles on these scenarios we could erroneously reinforce some defective processes (Cannon-Bowers & Salas, 2000).

Processes are regarded as a window to those strategies, knowledge, skills application that are used to accomplish specified goals, aims. Team processes refers to the application of team members' cognitive and social skills during task accomplishment. In NPP environment simulation training programs aim to develop and maintain these cognitive and social skills. During the program instructors evaluate and provide continuous feedback about task and team-oriented skills. Task-oriented skills are described as skills strongly required for task accomplishment such as decision making, problem solving, situation awareness. Task-oriented skills and knowledge are not sufficient when accomplishing tasks in a teamwork setting. Interpersonal, self-management skills and knowledge are regarded to be essential for performing well in teamwork setting. Team-oriented skills contains skills oriented toward team interaction, information exchange, those processes that help to maintain team as a whole unit, including cooperation, coordination, and communication between team members. The goal of training programs - besides developing professional, technical knowledge - is to reinforce efficient team interaction processes, to work better as a team. As a result shared knowledge will be formed, shaped about team including each other's characteristics, roles, needs, and about task referring to equipment, environment, rules and procedures. This shared knowledge serves as crucial aspect of the adjustment to novel and complex, dynamic task environment.

In recent years, the NPP industry has recognized besides the technical training the importance of team and task-oriented skill training, namely team interaction training. The concept of team interaction training stemmed from Crew Resource Management (CRM) training that has been developed as a special training in order to reduce error and increase the effectiveness of flight crew. This program focus on team and task-oriented skills critical for operational performance such as leadership, coordination, situation awareness, decision-

making, teamwork and communication. CRM in NPP field consists of the following topics: operational conduct, health at work, decision taking, situation awareness, choosing behaviour, feedback, communication, and team skills (Flin et al., 2002).
Training programs attempts to achieve change and development in different level: team members' attitude, skills, behaviour, knowledge, and finally to improve safety functioning at organizational level. To measure training efficiency accurately is a difficult task. Objective, direct measurements such as accident rates are incomplete, not always reliable indicator of training efficiency, especially as the high reliability organizations tend to have low accident rates. Subjective, indirect measurements including expert evaluators determine whether there has been any improvement in operators' knowledge, skill, behaviour, and attitude. For this evaluation experienced and trained observers use specially developed behavioral marker system such as in aviation Line/LOSA checklist (Line Operations Safety Audit, Klinect et al., 2003), NOTECHS (NOn-TECHnical Skills category, Flin et al., 1998), in medical field the behavioural marker system based on ANTS (Anaesthetists' Non-Technical Skills, Fletcher et al., 2003), NOTSS (Non-Technical Skills for Surgeons, Yule et al., 2006).

8. Conclusion

To conclude the results of the case studied and researches presented above, specific *sources of task load* were identified *related to the task* such as complexity of the task, constant alertness, continuous learning, and *related to the environment*, such as working conditions, *related to the organisation*, such as the amount of rules, responsibilities, the overregulated work process.
Analysing team members' personality based on Five Factor models and identifying the relationship between individual traits and performance, Extraversion and Conscientiousness were proved to be important characteristics influencing positively team members' behaviour and performance, while Agreeableness had a negative relationship with behaviour and performance.
Separating characteristics of team communication in two categories, the frequent use of *team-oriented communication* utterances were linked to Extroversion positively and Agreeableness negatively. Low level of Agreeableness could be associated with individualistic characters, attributes of experts striving for independence. Studying *task-oriented communication utterances*, features of the well established communication strategy has been described. Information gathering questions formulated in open way, affirmation also proved to be efficient way of communication, but what is more important to apply brief and clear vocabulary. The information flow between team members should focus more on the ongoing events and projecting the information to the future and less about the past. Coherent information flow between team members proves to be an efficient strategy for establishing and updating shared knowledge, achieving high performance. Describing team communication under different levels of task load, the results how that team adapts to high task load with increased communication, paying more attention to the management of the occurred failures.
The results of the researches and case studies can be used as directions for human resource management practices, especially in employee selection and development procedures, health promotion program. The revealed sources of task load and features of workload could help to develop and design health promotion programs. Operator teams' selection methodology should take into consideration personality trait patterns of operator teams, as well as the key competencies. Our results may have some important applications in

developing training interventions based on well established competency list, providing greater emphasize on communication. Feedback about team communication should focus on specific aspects of team communication that help to establish and modify accurate shared knowledge and to improve team performance. Instructors and operators are all responsible for developing efficient communication strategy. Although, it is difficult to generalize the results about team communication to all operator teamwork, as long as the presented researches are based on the analyses of communication in simulation environment following a particular scenario.

The presented researches emphasize one of the team processes, namely communication. Future research should go beyond communication, studying other team processes, such as coordination, cooperation, decision making. Furthermore future works could also reveal hidden complex patterns of team processes, in communication, in cooperation related to safe and efficient team performance.

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10. References

Antalovits, M. & Izsó, L. (2003). Assessment of Crew Performance and Measurement of Mental Task Effort in Cognitively Demanding Task Environment. In: G.R.J. Hockey (ed.): *Operator Functional State*, IOS Press and Kluwer Academic Publishers, UK.

Ballard, D.; Tschan, F. & Waller, M. (2008). All in the Timing Considering Time at Multiple Stages of Group Research. *Small Group Research*, Vol. 39 No. 3 pp. 328-351 ISSN 10464964

Banks, A. & Millward, L. (2007). Differentiating knowledge in teams: The effect of shared declarative and procedural knowledge on performance. *Group Dynamics: Theory, Research & Practice, 11,* pp. 95-106, ISSN 10892699

Barry, B. & Stewart, G. (1997). Composition, process, and performance in self-managed groups: The role of personality. *Journal of Applied Psychology*, Vol. 82, pp. 62–78 ISSN 0021-9010

Barrick, M. & Mount, M. (1993). Autonomy as a Moderator of the Relationships Between the Big Five Personality Dimensions and Job Performance. *Journal of Applied Psychology,* Vol. 78. No. 1. pp. 111-118, ISSN 0021-9010

Barrick, M. & Mount, M. (1991). The Big Five Personality Dimensions and Job Performance: A Meta Analysis. *Personnel Psychology*, Vol. 44. pp. 1-26, ISSN 0031-5826

Barrick, M.; Stewart, G.; Neubert, M. & Mount, M. (1998). Relating Member Ability and Personality to Work-Team Processes and Team Effectiveness. *Journal of Applied Psychology*. Vol. 83. No. 3, pp. 377-391 ISSN 0021-9010

Barry, B & Stewart, G. (1997). Composition, Process, and Performance in Self-Managed Groups: The Role of Personality. *Journal of Applied Psychology*, Vol. 82, pp. 62–78, ISSN 0021-9010

Bono, J. & Vey, M. (2007). Personality and Emotional Performance: Extraversion, Neuroticism, and Self-Monitoring. *Journal of Occupational Health Psychology*. Vol. 12, No. 2. pp. 177-192, ISSN 1076-8998

Beaty, J.; Cleveland, J. & Murphy, K. (2001). The Relation Between Personality and Contextual Performance in „Strong" Versus „Weak" Situation. *Human Performance*, Vol. 14 No.2., pp. 125-148, ISSN 0895-9285

Byrne M. & Davis E. (2006). Task structure and Postcompletion Error in the Execution of a Routine Procedure, *Human Factors* Vol 48., No.4, pp. 627-638, ISSN 0301-7397

Blyton P. et al. (1989). Time, work, and organisation, Routlege, ISBN 0-415-00418-7, London, New York.

Cannon-Bowers, J.;, Salas, E. & Converse, S. (1993). Shared Mental Models in Expert Team Decision Making. In Castellan, N. (Ed.), *Individual and Group Decision Making: Current Issues*. pp. 221-246 Hillsdale, ISBN 0-8058-1090-0, NJ: LEA.

Cannon-Bowers J. & Salas E (2000). *Making Decision Under Stress, Implications for Individual and Team Training,* American Psychological Association, ISBN 978-1-55798-767-9 Washington

Cohen, S. & Bailey, D. (1997). What Makes Team Work: Group Effectiveness Research from the Shop Floor to the Executive Suite, *Journal of Management*, Vol. 2 No.3, pp. 230-290, ISSN 0149-2063.

Cooke, N.; Salas, E.; Cannon-Bowers, J. & Stout, R. (2000). Measuring Team Knowledge. *Human Factors*, Vol. 42, pp.151-173, ISSN 0301-7397

Cooke, N. Stout, R. & Salas, E. (2001). A Knowledge Elicitation Approach to the Measurement of Team Situation Awareness. In McNeese, M.; Endsley, M. & Salas, E. (Eds.), *New Trends in Cooperative Activities: System Dynamics in Complex Settings*, pp. 114-139, Human Factors. Westport, Conn.: Praeger Security International, ISSN 0301-7397 Santa Monica, CA

Cooke, N.; Gorman, J. (2006). Assessment of Team Cognition. In P. Karwowski (Ed.), 2nd *Edition- International Encyclopedia of Ergonomics and Human Factors*, pp. 270-275. Taylor & Francis Ltd., ISBN 041530430X UK

Cooke, N.; Salas, E.; Kiekel, P. & Bell, B. (2004). Advances in Measuring Team Cognition. IN Salas, E. & Fiore, S. (Eds.), *Team Cognition: Understanding the Factors that Drive Process and Performance*, pp. 83-106, American Psychological Association, ISBN 978-1-59147-103-5, Washington, DC

Cooper. C. (1998). Theories of Organisational Stress. Oxford University Press., ISBN: 9780198297055

Comer, D. (1995). A Model of Social Loafing in Real Work Groups. Human Relations, Vol 48 No. 6, pp. 647-667, ISSN 0018-7267

Costa, P. & McCrae, R. (1992). Revised NEO Personality Inventory (NEO-PI-R) and NEO Five-Factor Inventory (NEO-FFI): *Professional Manual*. Odessa, FL: Psychological Assessment Resources

Diedrich, F.; Freeman, J.; Entin, E. & Macmillan, J. (2005). Modeling, Measuring, and Improving Cognition at the Team Level. IN Schmorrow D. (2005). *Proceedings of Augmented Cognition, proceedings; International Conference on Augmented Cognition (1st) and on Human-Computer Interaction* Vol. 11, Las Vegas, NV.

Dietrich, R. & Childress, T. (2004). Group interaction under Threat and High Workload IN Dietrich, R. & Childress, T. (2004). *Group Interaction in High Risk Environments.* The GIHRE Project. Ashgate, ISBN 978-0754640110, Burlington

Driskell, J.; Salas, E. & Johnstone, J. (2006). Decision Making and Performance Under Stress. IN Britt, T.; Adler , A.; Castro, C. Military life. The Psychology of Serving in Peace and Combat. Vol I. Military Performance, pp 128-54, Praeger Security International, ISBN 978-0-275-98300-0, Westport, CT

Diegritz, T. & Fürst, C. (1999). Empirische Sprechhandlungsforschung. Ansätze zur Analyse and Typisierung authentischer Äußerungen. Erlangen: Univ.Bilbiothek.

Essens P.; Ad Vogelaar; Jacques M.; Carol B.; Carol P.; Dr. Stanley H.; Joe B. (2005). Military Command Team Effectiveness: Model and Instrument for Assessment and Improvement, chapter 4: Review Of Team Effectiveness Models, NATO Research and Technology Organisation, *The RTO Human Factors and Medicine Panel* (HFM-087/RTG-023) Project on "Team Effectiveness" April 2005.

Fiedler, F. (1995). Cognitive Resources and Leadership Performance. *Applied Psychology* An international review, Vol. 44. pp. 5-28, ISSN 0269-994X

Flin, R., Goeters, K.; Hörmann, M. &Martin, L. (1998). A generic structure of Non-Technical skills for Training and Assessment, *23rd Conference of the European Association for Aviation Psychology*, Vienna, 1418 September 1998.

Flin, R.; O'Connor , P. & Mearns, K. (2002). Crew Resource Management: Improving Safety in High Reliability Industries *Team Performance Management,* Vol. 8, pp. 68-78, ISSN 1352-7592

Fletcher, G., Flin, R., McGeorge, P., Glavin, R., Maran, N. and Patey, R. (2003). Anaesthetists' Non-Technical Skills (ANTS): Evaluation of a Behavioural Marker System, British *Journal of Anaesthesia*, Vol. 90, No. 5 pp. 580-588, ISSN 0007-0912

Gellatly, I.; Irving, P.(2001). Personality, Autonomy, and Contextual Performance of Managers. *Human Performance*,Vol. 14 No.3, pp. 231-245, ISSN 0895-9285

Grommes P. (2007). Contributing to Coherence. An Empirical Study of OR Team Communication. In: Minnick-Fox, M.; Williams, A. & Kaser, E. *Proceedings of the 24th Penn Linguistics Colloquium*. Univ Penn Working Papers Linguistics 7:1, pp. 87–98.

Gudela, G.; Zala-Mező, E. & Grommes, P. (2004). The Effects of Different Forms of Coordination on Coping with Workload. In: Dietrich, R., Childress, T. (2004). *Group Interaction in High Risk Environments*. The GIHRE Project. Ashgate, ISBN 978-0754640110, Burlington

Gudela, G. & Zala Mező, E. (2004). Group Interaction in High Risk Environment of the Daimler-benz-Foundation. *Report on the Psychological Part of the Project*. Swiss Federal Institute of Technology Zurich

Hackman, J.R. (1987). The design of work teams. In Lorsch, J. (Ed) *Handbook of organizational behaviour*.pp. 315-342, Englewood Cliffs, ISBN 978-0133806502 NJ: Prentice-Hall

Hellriegel D. & Slocum W. (2007). *Organisational Behaviour*, Cengage Learning, ISBN 978-0324156843,

Hogan, J. & Ones, D. (1997). Conscientiousness and Integrity at Work. In: Wiggins, J. *The Five-Factor Model of Personality*. The Guilford Press. ISBN 978-1572300682, New York

Hopkins A. (2007). The Problem of Defining High Reliability Organisations, Working Paper 51, *National Research Centre for OHS Regulation*, The Australian National University, January 2007

Horwitz S. (2005). The Compositional Impact of Team Diversity on Performance: Theoretical Considerations, *Human Resource Development Review*, Vol. 4, pp. 219, ISSN 1534-4843

Izsó L. (2001). Developing evaluation methodologies for Human-Computer Interaction. Delft University Press ISBN 90-407-2171-8, The Netherlands

Kiekel, P.; Cooke, N.; Foltz, P.; Gorman, J. & Martin, M. (2002). Some Promising Results of Communication-Based Automatic Measures of Team Cognition. *Proceedings of the Human Factors and Ergonomics Society's Annual Meeting*, USA, Vol. 46, pp. 298-302.

Kiekel, P.; Cooke, N.; Foltz, P.; & Shope, S. (2001). Automating Measurement of Team Cognition through Analysis of Communication Data. In Smith, M.; Salvendy, G.; Harris, D. & Koubek R. (Eds.), *Usability Evaluation and Interface Design*, Mahwah, NJ: Lawrence Erlbaum Associates pp. 1382-1386, ISBN 0-8058-3607-1

Kiekel, P. & Cooke, N. (2004). Human Factors Aspects of Team Cognition. In Vu K. & Proctor R. (Eds.), *The Handbook of Human Factors in Web Design*, Mahwah, NJ: Lawrence Erlbaum Associates. pp. 90-103, ISBN 978-0805846119

Klinect, J.; Murray, P.; Merritt, A. & Helmreich, R. (2003). Line Operations Safety Audit (LOSA): Definition and operating characteristics. *In Proceedings of the 12th International Symposium on Aviation Psychology* (pp. 663-668). Dayton, OH: The Ohio State University.

Krifka, M. (2004). Structural Features of Language and Language Use, In: Dietrich, R., Childress, T. *Group Interaction in High Risk Environments*, The GIHRE Project. Ashgate, ISBN 978-0754640110, Burlington

Lepine, J.; Hollenbeck, J.; Ilgen, D. & Hedlund, J. (1997). Effects of Individual Differences on the Performance of Hierarchical Decision-Making Teams: Much More Than G. *Journal of Applied Psychology*, Vol. 82, pp. 803–811, ISSN 0021-9010

Littlepage, G.; Schmidt, G.; Whisler, E. & Frost, A. (1995). An Input-Process-Output Analysis of Influence and Performance in Problem-Solving Groups. *Journal of Personality and Social Psychology*, Vol. 69, pp. 877–889, ISSN 0022-3514.

Mathieu, J.; Heffner, T.; Goodwin, G.; Salas, E. & Cannon-Bowers, J. A. (2000). The Influence of Shared Mental Models on Team Process and Performance. *Journal of Applied Psychology*, Vol. 85, pp. 273–283, ISSN 0021-9010

Mohammed S.; Klimoski R. & Rentsch J. (2000). The Measurement of Team Mental Models: We Have No Shared Schema, *Organizational Research Methods*, Vol. 3, No. 2, pp. 123-165, ISSN 1094-4281

Molleman, E.; Nauta, A. & Jehn, K.(2004). Person-Job Fit Applied to Teamwork: a Multilevel Approach. *Small Group Research*, Vol. 35., pp. 515- 539, ISSN. 10464964

Moynihan, L. & Peterson, R. (2004). The Role of Personality in Group Process. In: Scheinder, B. & Smith, D. *Personality and Organization*. Lawrence Erlbaum Associates. ISBN 978-0805837582

Mount, M. & Barrick, M. (1995). The big five personality dimensions: Implications for research and practice in human resources management. *Research in Personnel and Human Resource Management*, Vol. 13, pp. 153-200, ISSN . 0742-7301

Mumaw, R. (1994). The Effects of Stress on Nuclear Power Plant Operational Decision Making and Training Approaches to Reduce Stress Effects (NUREG/CR-6127). *US Nuclear Regulatory Commission.* Manuscript. Westinghouse Electric Corporation.

Neuman & Wright, J. (1999). Work-groups; Ability; Intelligence; Personality-traits; Performance-evaluation. *Journal of Applied Psychology* Vol. 84, No.3, pp. 376 – 89, ISSN 0021-9010

Piedmont, R. & Weinstein, H. (1994). Predicting Supervisor Rating of Job Performance Using the NEO Personality Inventory. *Journal of Psychology*, Vol. 128. pp. 255-265, ISSN 128255-265

Pléh Cs.; Síklaki I. & Terestyéni T. (1997). *Nyelv – kommunikáció – cselekvés*. Osiris. pp. 188-197 ISBN 9789633793046, Budapest

Reason J.(1997). *Managing the Risk of Organisational Accidents*, Ashgate Publishing Limited, ISBN 978-1840141054, England

Sorensen J. (2002). Safety Culture: A Survey of the State of the art, *Reliability Engineering System Safety* Vol.76, pp.189-204, ISSN 0951-8320.

Sexton J. & Helmreich R. (2000). Analyzing Cockpit Communications: The Links Between Language, Performance, Error, and Workload. *Human Perforance Extrem Environment*, Vol. 5 No.1, pp.63-68, ISSN 1529-5168

Salas, Dickinson, Converse, and Tannenbaum (1992). Toward an Understanding of Team Performance and Training, IN Swezey & Salas *Teams: Their Training and Performance*, Ablex Publishing Corporation Norwood, ISBN 978-0893919429, New Jersey

Salas E. & Fiore, S. (2002). *Team Cognition: Understanding the Factors that Drive Process and Performance*, American Psychological Association, pp. 83-106 ISBN 978-1591471035, Washington, DC

Salgado, J. (2001). Personnel Selection Methods. In: Robertson, I. & Cooper, C. *Personnel Psychology and Human Resource Management*. University of Manchester. John Wiley and Sons Ltd. ISBN 978-0471495574

Swain, K. & Mills, V. (2003). Implicit Communication in Novice and Expert Teams Land Operations Division Systems Sciences Laboratory DSTO-TN-0474

Sträter, O. & Fokuda, R. (2004). Communication in Nuclear Power Plants (NPP). In: Dietrich, R., Childress, T. M. *Group Interaction in High Risk Environments*. The GIHRE Project. Ashgate, ISBN 978-0754640110, Burlington

Sacks, H. (1992). *Lectures on Conversation*. Oxford: Basil Blackwell ISBN 1557862192

Tett, R.; Jackson, D. & Rothstein, M. (1991). Personality Measures as Predictors of Job Performance: A Meta-Analytic Review. *Personnel Psychology*, Vol. 44. pp. 703-742, ISSN 0031-5826

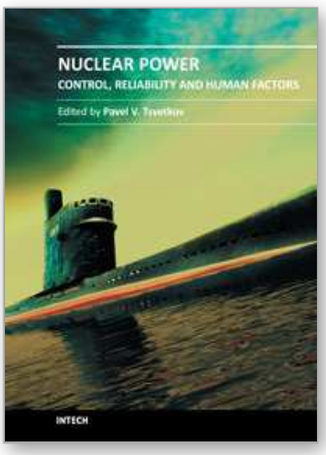
Wagner, J. (1995). Studies of Individualism-Collectivism Effects on Cooperation in Groups *Academy of Management Journal*, Vol. 38, No. 1, pp. 152-172, ISSN 0001-4273

Waller M.; Gupta, N. & Giambatista R. (2004). Effects of Adaptive Behaviors and Shared Mental Models on Control Crew Performance, *Management Science*, Vol. 50, No. 11, pp. 1534–1544, ISSN 0025-1909

Waung, M. & Brice, T. (1998). The Effects of Conscientiousness and Opportunity to Caucus on Group Performance. *Small Group Research*, Vol. 29, pp. 624–634. ISSN 10464964

Witt, L.; Barrick, M.; Burke, L. & Mount, M. (2002). Research Reports. The Interactive Effects of Conscientiousness and Agreeableness on Job Performance. *Journal of Applied Psychology*, Vol. 87. No. 1, pp. 164-169, ISSN 0021-9010

Yule, S.; Flin, R.; Paterson-Brown, S.; Maran, S. & Rowley, D. (2006). Development of a rating system for surgeons' non-technical skills. *Medical Education*, Vol. 40, pp. 1098-1104 ISSN 0308-0110



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Advances in reactor designs, materials and human-machine interfaces guarantee safety and reliability of emerging reactor technologies, eliminating possibilities for high-consequence human errors as those which have occurred in the past. New instrumentation and control technologies based in digital systems, novel sensors and measurement approaches facilitate safety, reliability and economic competitiveness of nuclear power options. Autonomous operation scenarios are becoming increasingly popular to consider for small modular systems. This book belongs to a series of books on nuclear power published by InTech. It consists of four major sections and contains twenty-one chapters on topics from key subject areas pertinent to instrumentation and control, operation reliability, system aging and human-machine interfaces. The book targets a broad potential readership group - students, researchers and specialists in the field - who are interested in learning about nuclear power.

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