Report

GIHRE-Kolleg (group interaction in high risk environments) of the Damiler-Benz-Foundation
"the effects of different forms of coordination in coping with work load: cockpit versus operating theatre

Author(s):
Grote, Gudela; Zala-Mezö, Enikö

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GIHRE-Kolleg (Group Interaction in high risk environments) of the Daimler-Benz-Foundation

Report on the psychological part of the project

“The effects of different forms of coordination in coping with work load: Cockpit versus operating theatre”

Gudela Grote & Enikö Zala-Mező

Zürich, March 2004
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Executive summary

There is a general understanding that rules and standards support safe operation in complex systems. At the same time, it is also known that high levels of standardization may impede flexible adaptation to changing demands. Comparing team coordination in the highly standardized setting of cockpits of commercial aircraft with coordination in anesthesia teams who operate with far fewer standards helps to understand the impact of rules on team performance. In order to analyze team coordination in these two settings, 42 cockpit crews were videotaped during a simulator training session, which required performing a so-called clean approach, i.e. a landing without flaps and slats, as well as 23 anesthesia teams performing anesthesia inductions. The behavior was coded based on four sets of categories, i.e. implicit vs. explicit coordination, leadership, and heedful interrelating. Hypotheses concerning the effects of different levels of standardization and task load were tested, derived from the general assumption that successful teams change between different coordination modes in accordance with changing situational demands.

Contrary to our original assumptions, we found that anesthesia teams coordinated more implicitly than cockpit crews despite having fewer written rules guiding their behavior. Several reasons may account for this finding: cockpit crews have been trained much more to coordinate explicitly even in seemingly obvious situations in order to prevent over-reliance on common standards as basis for a common understanding of the situation and its demands; anesthesia teams share a common field of action and use cues provided by each other’s actions much more for seamless coordination than pilots who operate in different visual fields; there are manifold unwritten rules in medicine which support a common understanding of the situation and the actions required. For the aviation data, a clear link between higher levels of explicit coordination and higher levels of performance could be established, which hints at the importance of backing up standards with a constant effort to reassure a common understanding of the situation and the relevance of the standards for the situation.

A second set of analyses concerned patterns of coordination within each professional setting, comparing work phases with different degrees of standardization and task load. One important finding here was that personal leadership is only required in situations with few standards. In highly standardized situations, the standards act as a form of impersonal leadership, which does not require additional efforts of personal leadership. To the contrary, high levels of personal leadership in highly standardized situations appear to be related to worse team performance. The results help to improve both our theoretical understanding of adaptive coordination as well as practical measures taken to support teams in dealing with changing demands on team coordination. Especially in anesthesia more research is needed, though, to establish sounder links between coordination behavior and team performance than we were able to demonstrate.

In a third set of analyses, the rules themselves were investigated by determining the level of action regulation they concerned: specifying a goal to be achieved vs. specifying the process to be followed to determine the correct course of action vs. specifying the course of action to be followed. In aviation, the vast majority of rules prescribed the course of action to be taken, while in medicine, more often the process to determine the correct course of action is specified. Considering the higher degrees of operational uncertainty contained in handling a patient as compared to flying an aircraft, the less specific rules in medicine seem appropriate. Such analyses may help to support a more systematic rules management taking into account an appropriate balance between guidance and scope of action.
1 Introduction

Much of the literature in the organization sciences in general and relating to the make-up of safe organizations in particular is concerned with analyzing and designing adequate mechanisms of coordination within and between parts of an organization. A key issue in this respect is the degree of standardization of such coordination. Usually the more routine work processes are the more standardized and formalized coordination is, while work processes requiring action in novel situations are less prescribed (e.g. Kieser & Kubicek, 1992; Thompson, 1967; Van de Ven, Delbecq & Koenig, 1976).

Especially in high-risk environments there have been strong efforts to increase the level of standardization in order to make the system’s behavior more predictable and controllable. At the same time there are major disadvantages to high levels of standardization, mainly related to reducing the system’s capability to adequately act in the face of requirements stemming from internal and external disturbances of normal operation (e.g. Perrow, 1984; Grote, 1997). One frequently chosen way out of this dilemma is to use all available experience, e.g. from accidents and incidents, to try to foresee as many situations as possible deviating from normal operation and develop standardized procedures for all these cases as well. While there are clear benefits to this approach, there always have been warning voices also, pointing to the impossibility of foreseeing all that could happen in a highly complex system in a highly complex environment and assuming that by attempting to foresee the unforeseeable the local actors’ competences needed to cope with the unforeseeable are rather decreased than increased (e.g. Amalberti, 1999; LePlat, 1998; Reason, Parker & Lawton, 1998).

Still, standardization is the method of choice and/or the method prescribed by regulators in all high-risk industries. Aviation is one of the foremost examples of a very high degree of standardized coordination where standard operation procedures cover both normal as well as abnormal situations to an extent that even disturbance handling has been partially automated, supporting the human operators with very detailed action sequences to be followed. Medicine on the other hand may be considered as one of the least proceduralized of high-risk operations, with only fairly recent attempts at increased standardization, often as part of quality assurance measures and as reaction to increasing pressures from the public and from regulators based on alarming numbers of ill-managed incidents in this field. The comparison of aviation and the medical field therefore provides a unique opportunity to study the advantages and disadvantages of high vs. low degrees of standardized coordination at a time when research results can potentially have a strong effect on changes in the field of practice under investigation.

Following, research on prerequisites for successful team coordination will be reviewed, with a special focus on standardization. Research questions will be derived and methods and results of a study presented in which coordination in cockpit and anaesthesia teams were compared.

Besides the psychological aspects of the study that are reported here, linguistic concepts of coordination were incorporated as a means to analyze in more detail how communication in work teams serves coordination and how in turn standardization as prescribed form of coordination influences communication. These analyses were partly reported elsewhere already (Grote, Zala-Mezó & Grommes, 2003) and will be subject to a separate research report.
2 Coordination in organizations

Coordination defined as tuning of interdependent work processes to promote concerted action towards a superordinate goal (Kieser & Kubicek, 1992) is needed for any activity which cannot be carried out by one person and which cannot be subdivided into independent parts (Hackman & Morris, 1975). Coordination is therefore a core activity in any work organization. As Tesluk et al. (1997, p. 197) formulate: “The essence of organizational action is the coordination, synchronization, and integration of the contributions of all organizational members into a series of collective responses.” Studying accident and incident reports one can state that failures occur most often not because of technical or individual insufficiency but because a team fails to coordinate its mutual action (Hackman, 1993).

As a consequence of the degree and type of division of labour and specialization more or less effort will be required for coordination and different kinds of coordination mechanisms will be more or less successful. Crucial in this respect is the type of interdependence created by the chosen division of labor in combination with the general demands of the task and the task environment. Generally, three types of interdependence of work activities are distinguished (e.g. Tesluk et al., 1997; Thompson, 1967; Van de Ven, Delbecq & Koenig, 1976):

*Pooled interdependence* is present, when system performance is an additive function of individual performance. The performance of other members of the system can have an effect on the work of the individual members but only indirectly through parallel contributions to a super ordinate goal. Coordination in this case is usually achieved via centrally determined work programs which every individual has to follow independently and which assure that subtask serve the super ordinate goal.

*Sequential interdependence* is a unidirectional workflow arrangement, where individual performance depends on the proper fulfillment of prior subtasks. Synchronization is needed here based on centrally determined programs and plans that spell out the exact content and temporal requirements of subtask fulfillment.

*Reciprocal interdependence* means that information and results of work activities have to be exchanged between team members continuously. Coordination is mainly achieved via direct communication, be it in the form of personal directives or multilateral flow of communication between the individuals involved in self-regulated task performance.

In view of special demands created by task performance in high risk situations like flying an airplane or operating on a patient, Tesluk et al. (1997) have added a fourth form of interdependence called *intensive work situations* where team members work very closely together and work flow is poly-directional, flexible and very intensive, because the team repeatedly faces novel situations with new problems which have to diagnosed and solved within the team. This is also similar to what Van de Ven et al. (1976) have termed team arrangement where coordination has to be achieved by all group members simultaneously.

In order to understand the reasons for and effects of different forms of coordination such as impersonal coordination (through standards and programs), personal coordination (vertical or horizontal) and group coordination (Van de Ven et al., 1976), it is helpful to conceptualize organizational activities in terms of the management of uncertainty. The kinds of uncertainty an organization has to deal with and how these uncertainties are handled by the organization has been a core issue in organization theory. Prominent authors in this field like Thompson (1967), Perrow (1967), Van de Ven et al. (1976) and Susman (1976) have helped to systematize the nature of uncertainties relevant to organizations and the ways organizations deal with them. Two general sources of uncertainties were identified, i.e. the
transformation processes an organization has to perform and the environment within which these processes take place. In order to describe the organization’s capabilities of handling these different types of uncertainties, characteristics like degree of specialization, types of task interdependence, forms of coordination, degree of standardization and formalization, and degree of centralization are used.

There are two extreme approaches to handling uncertainty (see Figure 1). The first one tries to minimize uncertainty or at least the effects of uncertainty in the organization using mainly feed-forward control based on high standardization and programming of work flows. Enormous efforts are put into centralized planning and continuous monitoring of the execution of these plans, providing minimal degrees of freedom to the people in charge of carrying out the plans. If the organization’s environments become more and more complex – or rather the complexity is more and more acknowledged – then more effort has to be put into reducing the uncertainties connected with the complexity. The minimizing uncertainties approach is especially prevalent in organizations where malfunctioning not only endangers business success but also human life and environmental integrity because the production processes handled incorporate major risks for health, safety and environment. In these organizations usually not only the chosen management style is that of minimizing uncertainties, but this approach is even prescribed by external regulatory bodies.

The other approach having been advertised by organization theorists and work scientists for several decades now is – instead of fighting uncertainties in an attempt to minimize the uncertainties themselves or at least their effect in the organization – to enable each and every member of an organization to handle uncertainties locally and to allow for feedback control. From this perspective, planning is understood primarily as a resource for situated action (Suchman, 1987), not as blueprint for centrally determined and monitored action. Local actors need to be given as many degrees of freedom as possible, achieving concerted action mainly through lateral, task-induced coordination. Disturbances are also regarded as opportunities for use and expansion of individual competencies and for organizational innovation and change.

<table>
<thead>
<tr>
<th>Minimizing uncertainties*</th>
<th>Coping with uncertainties</th>
</tr>
</thead>
<tbody>
<tr>
<td>complex, central planning systems</td>
<td>planning as resource for situated action</td>
</tr>
<tr>
<td>reducing operative degrees of freedom through procedures and automation</td>
<td>maximizing operative degrees of freedom through complete tasks and lateral cooperation</td>
</tr>
<tr>
<td>disturbances as to be avoided symptoms of inefficient system design</td>
<td>disturbances as opportunity for use and development of competencies and for system change</td>
</tr>
</tbody>
</table>

*Uncertainties may stem from the system environment and/or from the transformation processes within the system.

Figure 1. Basic principles of organization design (adapted from Grote, 2001)
Another way of looking at the two approaches to uncertainty is to describe them in terms of the distribution of autonomy and control in the organization. Differing from the frequent almost synonymous use of the two terms autonomy and control, they are used here to indicate two quite different types of influence (cf. Grote, 1997). Autonomy is defined as self-determination regarding goals and the rules to be followed in achieving these goals. Control is defined as the influence on a given situation allowing reaching goals, which have been determined either autonomously or by others. When attempting to minimize uncertainty, autonomy stays completely with centrally located decision-makers who also try to maximize their control by prescribing in minute detail how the people implementing their plans have to use their influence in a given situation. Competent coping with uncertainty on the other hand is characterized by maximum local control as well as sufficient local autonomy in order to choose or at least modify goals and rules for goal achievement in view of maximum effectiveness in the exertion of local control.

Standardization can be regarded as the key element in the minimizing uncertainty approach, while the competent coping with uncertainty relies much more on personal and lateral coordination mechanisms. It can be assumed that standardization will work better in situations with few uncertainties while local autonomy and control are needed when uncertainties are high. In those situations standardization may therefore be harmful (e.g. Amalberti, 1999; Perrow, 1984; Grote, 1997). But at the same time, few concrete suggestions exist so far for what coordination mechanisms to use in order to improve the predictability and controllability of a system while at the same time increasing its flexibility (e.g. Perrow, 1984). Following, some concepts will be presented that may help in shaping standardization in a way more conducive to safe operation in high-risk systems.

2.1 Coordination through standardization in high-risk organizations

In most high risk systems, standardization in the form of standard operating procedures has been developed with ever increasing detail in order to streamline human action and to reduce its influence as a risk factor, which is in line with the minimizing uncertainty approach. Procedures are often a direct consequence of incidents and accidents the analysis of which provides knowledge of unforeseen wrongful courses of action against which new rules are developed as a defense. While generally there is an understanding that rules are useful guides for safe behavior, there is also an increasing concern that too many rules incrementally developed will not make up a good system to help human actors do the right thing especially in states of abnormal operation where they would need strong, but also flexible guidance (e.g. Amalberti, 1999). These concerns go back to basic observations on how rules specifying the exact operations to execute can have a detrimental effect on action because they do not allow the performing person to develop an underlying plan of their own, but instead further the atomization of actions and the focus on micro-difficulties (Vermersch, 1985). As Hoc writes (1988, p. 206):

"By giving the impression that they make up a plan, instructions may give users the feeling that no planning activity is necessary on their part for implementation. However, instructions are generally not hierarchized. The action sequence is described, but the goal structure is not explicit and the rationale is never presented. Nonetheless a hierarchical structure linking actions and functions is probably crucial to the development of sufficiently adaptive procedural knowledge. To date there is no clear-cut empirical evidence on this point."

Another basic problem with standardization is that especially in non-routine situations reliance on common standards may turn into an over-reliance, impeding switches to more explicit coordination and with that switches to higher levels of common action regulation, i.e. switches from skill-based to rule-
based or from rule-based to knowledge-based behavior. This problem can be exacerbated by the fact that standardization is a strong force towards shared understanding of a situation and its demands in a team, because it creates a common framework for team behavior reducing the need for explicit coordination. The expectation of shared goals, plans, perspectives, and knowledge bases created by reference to the same set of standard operating procedures, as helpful as it is under most conditions, does involve the risk of not realizing the need for explicit coordination, e.g. in non-routine situations.

Making a similar distinction between minimizing uncertainties vs. competently coping with uncertainties, as was suggested before, Rasmussen has argued that “rather than striving to control behavior by fighting deviations from a particular pre-planned path, the focus should be on the control of behavior by making the boundaries explicit and known and by giving opportunities to develop coping skills at boundaries” (Rasmussen, 1997, p. 191; italics in the original). Rules then would have the function to clarify boundaries and to suggest ways of handling system states close to those boundaries.

In line with this approach to rules, some authors have begun to develop typologies of rules in order to help the design of rule systems directly tailored to the needs for guidance as well as for autonomy and control arising in different stages of action regulation (e.g. Hale & Swuste, 1998; LePlat, 1998; see Table 1). From an action regulation perspective, rules can concern goals to be achieved, define the way in which decisions about a course of action must be arrived at, or prescribe concrete actions.

Hale and Swuste (1998) also suggest some criteria to help decide at which level of the organization these rules should be defined: predictability of the system (the higher the predictability the more action rules decided upon at higher levels of the organization); innovation rate in the system (the higher the innovation rate, the more action rules need to be decided upon on operative levels of the organization); interaction requirements (the higher the interaction requirements, the more action rules need to be decided upon at higher levels of the organization); local expertise (the higher local expertise the more action rules should be decided upon on operative levels of the organization). These criteria can be easily related to the general issue of minimizing vs. competent handling of uncertainties, where minimizing uncertainties through centrally determined action rules is only recommended in systems with a generally low level of uncertainties (high predictability, low innovation rate). Also, these recommendations are linked to the idea of second order autonomy stating that people should be involved in decisions restraining their operative autonomy (Grote, 1997; LePlat, 1998), especially in organizations with high local expertise.

Systematic research into the design and management of safety-related rules has only recently begun, providing tentative classification schemes mainly based on the rules’ relevance for individual action regulation (Hale & Swuste, 1998; Leplat, 1998; Reason, Parker, & Lawton, 1998). From an organizational perspective, rules should also be discussed as elements of the coordination mechanisms operating within and between parts of an organization.

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1 It is to be noted that rule-based behaviour refers to a special kind of action regulation effort, i.e. the selection of behaviour based on choices between fairly prescribed alternative courses of action. Rules in the meaning used above as standard operating procedures can be related to this level of action regulation, but also to the other two levels, depending on the type of rule (LePlat, 1998).
Table 1. Examples for rule types (taken from the flight operations manual of an airline)

<table>
<thead>
<tr>
<th>Type of rule</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rules concerning goals to be achieved</td>
<td>“It must be clearly understood that not all combinations of cumulative operational problems (engine failure plus e.g. terrain, weather, availability of aerodromes etc.) can be covered by this policy. In such situations the solution offering the highest degree of safety should be sought.”</td>
</tr>
<tr>
<td>Rules defining the way in which decisions about a course of action must be arrived at</td>
<td>“In order to complete a replanning, any documented cruise systems and all means available may be used, such as flight management systems and data contained in the respective AOMs (aircraft operating manuals).”</td>
</tr>
<tr>
<td>Rules defining concrete actions</td>
<td>“Every evacuation must be carried out as quickly as possible. The passengers must be assisted to leave the aeroplane without their belongings and directed to a point at a safe distance from the aeroplane.”</td>
</tr>
</tbody>
</table>

During the last decade, coordination in high-risk environments has been addressed in an increasing number of studies. Usually, coordination on team level has been analyzed with no explicit reference to or systematic variation of organizational coordination mechanisms and the types of rules the teams have to adhere to, however. The vast majority of the studies have been carried out in aviation settings, taking for granted a high level of standardization. Following, the evidence on coordination requirements for successful performance provided by these studies will be critically reviewed.

2.2 Studies on coordination in work teams in high-risk environments

Given the definition of work teams as “(...) two or more people with different tasks who work together adaptively to achieve specified and shared goals” (Brannick & Prince, 1997, p. 4), coordination is one of the team’s main activities. “Individuals must coordinate their decisions and activities by sharing information and resources to attain shared goals” (Dickinson & McIntyre, 1997, p. 19). A core concept in many of the studies on team coordination is the distinction between explicit and implicit coordination in relation to coping with high levels of workload. In this concept, impersonal coordination via standards and personal coordination are brought together. Explicit coordination is considered necessary when an agreement must be arrived at about how an action should be organized. It occurs typically during new tasks and new situations or when a new group of people makes up a team to accomplish a job. People have to devote extra resources (very often communication) to organize the activities. Implicit coordination occurs when every one in a team knows his/her job, the actions harmonize with each other based on some kind of shared understanding (cf. also Clark’s, 1996, notion of conventions as tool for coordination), and therefore little noticeable effort for coordination is required.

It is assumed that teams can handle high workload situations better when they are able to reduce effort required for coordinating individual team members’ activities. It is further assumed that less explicit
coordination is needed when teams can rely on shared mental models of the task at hand and of the team itself. These mental models allow team members to predict each other’s needs and actions and to act on them without explicit communication (cf. e.g. Entin & Serfaty, 1999; Stout & Salas, 1993). Finally, it is assumed useful to prepare high workload situations by means of a phase of explicit coordination where a shared model can be built to be able to reduce communication and coordination “costs” in the subsequent high workload phase. (Orasanu, 1990, Orasanu & Fisher, 1992; cited in Orasanu, 1993). Supplying another team member with critical information without being requested to do so is generally considered as one important indicator for implicit coordination (e.g. Stout & Salas, 1993).

The set of assumptions just described has been tested in a number of studies,
- supporting the effectiveness of team training aimed at conscious shifts between explicit and implicit coordination for improving performance in naval air surveillance teams (Entin & Serfaty, 1999),
- showing positive relationships between planning, development of shared mental models, providing unsolicited information, and performance in a complex military flight task (Stout, Cannon-Bowers, Salas & Milanovich, 1999),
- indicating links between shared mental models, task-appropriate coordination, cooperation and communication patterns, and team performance (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000), and
- providing evidence for a positive relationship between team performance and captains’ communicating goals and plans more than giving specific commands in high workload situations in a full mission flight simulation (Orasanu, 1990, Orasanu & Fisher, 1992; cited in Orasanu, 1993).

Another concept often mentioned in connection with team coordination is that of team situation awareness. Artman (2000, p. 1113) describes the relationship between shared mental models – considered to be a crucial prerequisite for implicit coordination – and team situation awareness as follows: “Shared mental models include the team members’ models of the coordinating routines and knowledge within the team, while SA (situation awareness, G.G.) is the conception of the situation ‘out there’ (...)” Thus appropriate situation awareness relies on individual and team mental models, which is also stated by Paris, Salas and Cannon-Bowers (2000), who additionally mention characteristics of team communication that can support the building of team situation awareness: “(...) team members must voice communications that promote collective awareness of the surrounding environment, both internal and external to the team, and make timely and accurate reports of deviations from the norm or potential problems. Team leaders can continually update team members during times of stress to keep them abreast of rapidly changing priorities and performance objectives” (Paris et al., 2000, p. 1067).

Finally, Weick and Roberts (1993) have provided case study based and more qualitative accounts of similar phenomena of more or less effective team coordination in their analyses of high reliability organizations. In order to explain effective team coordination, they suggest the concept of “heedful interrelating” as a particular form of personal, horizontal coordination. A core idea of this concept based on Asch’s theory on group interaction is that safety operations in highly complex situations require deliberate efforts by all actors to constantly (re-)consider effects of their own actions in relation to the goals and actions of others, or in Weick and Roberts’ words: “(...) (to) construct their actions (contribute)
while envisaging a social system of joint actions (represent), and interrelate that constructed action with the system that is envisaged (subordinate)” (Weick & Roberts, 1993, p. 363). As Artman (2000) states, this concept stresses more the process of the active construction of partly shared and partly distributed situation models as compared to the concept of shared mental models, which is more oriented towards describing mental states.

Unfortunately, up to now, the concept of heedful interrelating has remained sketchy and no attempts have been made to derive measurable indicators for coordinated action from it (see Table 2 for tentative indicators of heedful/heedless interrelating derived from Weick and Roberts, 1993). A first quite promising attempt was made to concretize indicators on the basis of linguistic categories, though. According to the approach outlined in Dietrich & Grommes (2003) heedful interrelating is supposed to be related to well-formed, i.e. coherent, discourse structures. Coherent discourse emerges when discourse participants coordinate their discourse contribution in line with a joint communicative task – which itself maybe evoked by demands from the task at hands. This task comprises the formulation and comprehension of a quaestio – i.e. the mental representation of an abstract question the speaker is setting out to answer – and the comprehension of the implications of unfolding events in terms of the interplay of shifting, restoring and summing up linguistic references to certain conceptual entities. In Grommes and Grote (2001) it has been demonstrated that indeed there is a relation between speech production according to the quaestio-model and heedful interrelating. Patterns of smooth quaestio-movements result in more efficient discourse sequences and can be rated as more heedful.

<table>
<thead>
<tr>
<th>Indicators for</th>
<th>Heedful interrelating</th>
<th>Heedless interrelating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detailed representation of others</td>
<td>Less detailed representation of others</td>
<td></td>
</tr>
<tr>
<td>Contributions shaped by anticipated responses</td>
<td>Contributions shaped less by anticipated responses</td>
<td></td>
</tr>
<tr>
<td>Broad boundaries of envisaged system</td>
<td>Narrow boundaries of envisaged system</td>
<td></td>
</tr>
<tr>
<td>Attention focus on joint situation</td>
<td>Attention focus on local situation</td>
<td></td>
</tr>
<tr>
<td>Good comprehension of the implications of unfolding events</td>
<td>Little comprehension of the implications of unfolding events</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Tentative indicators for heedful vs. heedless interrelating (adapted from Weick and Roberts, 1993)

As was stated already, research on team coordination in high-risk environments usually has not explicitly addressed which organizational coordination mechanisms provide the framework for the observed team behaviors. This is partly due to the frequent use of laboratory settings in which no organizational framework exists, but presumably also an effect of taking a high level of standardization for granted in the studied task environments. Besides this general shortcoming, there are also a number of more specific problems concerning the findings on team coordination, which will be addressed before the present study is outlined.
2.3 Limitations of current evidence on effective team coordination in high-risk environments

Central to the assumption of implicit coordination as the most effective way of handling high workload situations in a team is the reduction in communication requirements, which frees resources for dealing with the additional demands in the situation. The indicator most frequently used for this reduction in communication is the amount of unsolicited information provided to other team members and/or an overall reduction in overt communication. There are a number of studies, though, that show an increase in communication or a shift in the nature of the information communicated to be related to good performance in high workload situations (cf. e.g. Mathieu et al., 2000; Orasanu, 1993). Wiener (1993) concluded several years ago that there are no clear-cut results on the relationship between amount of communication and team performance and also argued that looking at the quality of crew communication might be more relevant than looking at quantity. Some more qualitative indicators of “good” communication have been suggested in the meantime, e.g. as part of classification systems for the assessment and training of crew resource management (e.g. Avermaete & Kruisen, 1998; Helmreich, Butler, Taggart & Wilhelm, 1995). The distinction between explicit and implicit coordination and communication, though having stimulated a lot of interesting research, as such has not proven very helpful in deriving indicators because the terms themselves are not very clearly defined. For instance, ‘explicit ’ often seems to be used in the sense of overt or observable communication, but ‘implicit’ is also based on observable communication, e.g. providing unsolicited information. Also, the assumptions about shared mental models as prerequisites for implicit coordination have been criticized. In the epilogue to a journal special issue on shared cognition it has been argued that the concept of creating shared mental models in order to improve coordination and performance is too simple and more knowledge is needed on what knowledge needs to be distributed in what way in a team to further coordinated action (Cannon-Bowers & Salas, 2001). A more theoretically guided approach to what coordination is and how different kinds of communication and shared understanding can contribute to fulfilling different demands on coordination is needed in order to develop more systematic indicators of coordinated action.

When studying team interaction, it is also relevant to analyze the roles different team members have in coordinating the team. Much of the research on team coordination in high-risk environments has focused on lateral, non-hierarchical forms of coordination, with little attention given to leadership behavior (e.g. Flin et al., 2003). Many of these teams are actually hierarchically structured, though, with the role of the leader formally assigned such that problem solving or complex work processes may require the entire team, but final decisions are to be taken by the leader who is also held responsible for team success and failure. However, impersonal coordination mechanisms, i.e. standardization, can serve as a powerful and efficient substitute for personal leadership (Kerr & Jermier, 1978). Therefore, it is important to analyze leadership in the context of other coordination forms, which may change requirements for appropriate leadership. This point has been stressed by Zaccaro, Rittman and Marks (2001, p. 454f) in their concept of functional leadership: “functional leadership is not defined by a specific set of behaviors but rather by generic responses that are prescribed for and will vary by different problem situations. (...) A critical task for researchers in team leadership, then, becomes the definition and validation of the contextual influences that enhance the efficacy of some leadership actions and diminishes some others.” Zaccaro et al. (2001) describe effective leadership as the ability to supply subordinates with needed guidance and good feelings which are not being supplied by other sources, in situations, for instance, where the tasks and roles are clear team leaders should let teams work on their own and provide only little direction. One important situation factor is the level of uncertainty as pointed
out by Chemers and Ayman (1993). Operational settings that are lacking in predictability and standardization are inherently more uncertain and more stressful, implying a stronger need for leadership.

A more systematic approach to team coordination seems also warranted because situational demands can vary drastically within the generally used classification of high vs. low workload, potentially requiring very different communication and coordination strategies. Is high workload, for instance, mainly generated by increasing numbers of routine tasks within a given time, making it necessary to reduce resources spent on each of these tasks, or is high workload created by facing an unknown system failure? Each of these situations will require quantitatively and qualitatively different patterns of communication.

To add to these problems, there is no clear use of the term workload itself. In the following, we will use the term task load, when we describe objective difficulties connected to the properties of a task, e.g. landing on a particularly short runway. We will use the term workload, when referring to how a situation is perceived by the people facing the task. It is quite likely, for instance, that a very experienced pilot perceives less workload compared to an inexperienced one when confronted with the same task. In general, workload for individuals depends on the relationship between the cognitive resources of the individual and the demands of the situation (Norman & Bobrow, 1975). Many studies from laboratory and field settings prove that practice enhances resource efficiency, which can be related back to a reduction in workload (for an overview see Bowers, Braun & Morgan, 1997).

To complicate the issue, when looking at team performance, there should also be some understanding not only about individually perceived workload, but also about team workload. In an early attempt to study team workload, it was assumed that coordination involved additional task load, which should be kept as small as possible. It was found that performance and communication are negatively related: if a team has to communicate, performance declines. Due to this fact teams should be designed such that verbal communication is not required (Williges, Johnston & Briggs, 1966). In a similar vein, Bowers, Braun and Morgan (1997, p. 90) compared team and individual workload based on the difference between task workload and team workload. They argue that coordination tasks in teams add extra task load: “Team performance requires team members to engage concurrently in two broad categories of activities; namely, task work and teamwork activities. Task work refers to a team’s interactions with tasks, tools, machines and systems. Teamwork refers to the interpersonal interactions among individuals that are necessary for exchanging information, developing and maintaining communication patterns, coordinating actions, maintaining social order, and so on.” To draw attention to this additional task in teams is important for our understanding of how teams operate. However, this distinction should not be stressed too much as one should keep in mind that coordination and its main tool communication are an inherent part of the team assignment.

An important question is how coordination patterns change when workload increases. Some observations show that there is a clear change in communication patterns due to workload (Orasanu, 1990, cited in Kanki & Palmer, 1993). Orasanu has found that an effective strategy is to plan before something happens, namely in the low workload phase. There are no systematic results about coordination strategies that help to overcome high workload situations, however.
3 The present study

The objective of the present study was to analyze coordination in cockpit crews and anaesthesia teams in order to investigate relationships between degree of standardization, task load, coordination patterns and team performance. Based on the research on implicit vs. explicit coordination, it was generally assumed that successful teams change between different coordination modes given different situational demands. In order to obtain more detailed knowledge on the level of standardization in the two work settings, the rules relevant in the two settings were analyzed, using Hale and Swuste's (1998) classification scheme of safety rules as an operational framework.

More specifically, the study was designed to answer four questions:
- Are there differences in patterns of coordination behaviors between cockpit crews and anaesthesia teams as a result of differences in degrees of standardization?
- Can these differences be linked to team performance under varying degrees of workload?
- Can these differences be described in terms of different patterns of explicitness vs. implicitness of coordination, heedful vs. heedless interrelating, and leadership?

Based on the answers to these three questions, we hoped to also find first answers to a fourth question:
- Which types of rules in what combination, and derived from that, which specific forms of standardization support successful coordination?

While the study design was basically exploratory, there were some assumptions that guided data analysis. Comparing the two work environments we assumed with respect to the effects of standardization that
- in the highly standardized cockpit setting there would be more implicit coordination (and less explicit coordination, since explicit – implicit coordination are mutually exclusive categories) than in the less regulated working environment in medicine;
- in the cockpit there would be less leadership behavior because standards can be used as substitutes and can be seen as an impersonal form of leadership;
- in the cockpit there would be less heedful interrelating behavior because standards also can be used as substitutes for lateral coordination behavior. Or rather: heedful interrelating can still exist in a latent form of readiness to interact and attention to notice if something unexpected happens, but less in an observable overt behavioral form.

Table 3 summarizes our expectations considering standardization, which concerned the comparison between work settings but also the comparison between work phases with different degrees of standardization within work settings.

The expectations concerning the effects of task load were based on a definition of task load as demands inherent in the objective circumstances like increasing complexity, uncertainty, and time pressure, not the subjectively perceived workload, which depends strongly on the individual's experience and capacity. The hypotheses concerning task load were studied within the professional fields by comparing different work phases. We expected that teams under high task load have less cognitive capacity to process information, so they should use more economic ways of coordination, i.e. more implicit coordination, and less leadership. To manage high task load situations successfully, teams have to be prepared for it. This is done through explicit coordination and leadership in a preparation phase, but not in the high task load phase itself. Heedful interrelating plays a decisive role in high task load situations, because team success
depends strongly on the team members’ autonomous behavior based on thorough knowledge of their tasks and strong individual motivation and effort. In Table 4 expectations considering task load are summarized.

<table>
<thead>
<tr>
<th>Low standardization - Medicine</th>
<th>High standardization - Aviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit coordination</td>
<td>&lt; Implicit coordination</td>
</tr>
<tr>
<td>Leadership behavior</td>
<td>&gt;</td>
</tr>
<tr>
<td>Heedful interrelating</td>
<td>&lt; Heedful interrelating</td>
</tr>
</tbody>
</table>

Table 3. Expectation considering standardization by comparing anesthesia and cockpit teams

<table>
<thead>
<tr>
<th>Low task load</th>
<th>High task load</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit coordination</td>
<td>&lt; Implicit coordination</td>
</tr>
<tr>
<td>Leadership behavior</td>
<td>&gt; Heedful interrelating</td>
</tr>
</tbody>
</table>

Table 4. Expectation considering task load by comparing different work phases within anaesthesia and cockpit teams

So far, standardization and task load have been discussed as independent factors, but in each situation they of course operate together in various combinations. When comparing Table 3 and 4, it can easily be seen that for most combinations of different levels of standardization and task load there are no consistent predictions possible. Only for the combination low task load/low standardization, expectations of explicit coordination and high leadership coincide. In all other cases, one would have to assume the dominance of either task load or standardization to be able to make predictions. Or one might assume new qualities of coordination needs in the sense of an interaction effect between standardization and task load. To date, there is no theoretical or empirical basis for such assumptions. Therefore, we focused on the hypotheses concerning main effects of standardization and task load in our analyses, even though exploring potential interaction effects as much as that was possible with our data.

Regarding the comparisons between work settings, one crucial assumption was the comparability of the two settings. Using Sundstrom et al.’s (1990) description of action teams, this comparability seems to be given. Both types of teams operate in high-risk environments, where they are expected to avoid irreversible failures, which endanger human life. Also, the following more specific characteristics hold for both team settings: (a) Teams are highly differentiated from other teams through exclusive membership of expert specialists. (b) The integration within the organization is high as the teams are closely synchronized with co-workers and support units. (c) The work cycle is short. (d) The teams execute brief operations or missions repeatedly under new conditions, which requires extended training and preparation.
However, beyond these task-related similarities between cockpit crew and anaesthesia team, the organizational background, the team composition and the strategy to fulfill tasks are very different in these two work environments. Also, the types of uncertainties the teams have to handle differ. While flying an airplane involves mainly uncertainties stemming from the environment, preparing a patient for surgery in the emergency room is characterized by uncertainties stemming from the transformation process, in this case the patient’s physiological conditions and processes. Thus, any comparison between these two settings is difficult because these differences have to be kept in mind when interpreting and generalizing the results obtained. At the same time, the risk-related task characteristics are sufficiently similar to provide interesting input for improving safety in both settings.

4 Method

In Figure 1 the overall design of the study is presented. The effects of varying task load and varying degrees and types of standardization on coordinating behavior and indirectly on team performance were analyzed in two settings: the cockpit and the anaesthesia induction area.

There are two independent variables in this design: degree of standardization and task load. The degree of standardization varies between professional teams (cockpit teams and anesthesia teams) and within teams during different work phases. In both settings, there are phases with more and fewer rules, even though overall there are fewer rules in the medical situation. Task load varies between different work phases. Task load was defined as situational demands placed on the team based on expert rating by an experienced pilot and an anaesthesia resident respectively. This measure is not equivalent to workload which depends on the relationship between the resources of the individual and the demands of the situation (Norman & Bobrow, 1975). This relationship is influenced, among other things, by practice, which enhances resource efficiency and thereby reduces workload (cf. e.g. Bowers, Braun & Morgan, 1997). As workload very much depends on the individual’s resources, it is difficult to define the workload for a team. Task load as an objective account of situational demands was taken as an approximation for team workload.

Coordination behavior in the teams was rated based on video-recordings of team behavior, using both psychological and linguistic categories and linked to performance measures based on expert ratings. In this report, only the psychological categories are discussed, however.

![Figure 1. Study design](image-url)
4.1 Data

In both professional fields, video recordings were used. The aviation data stem from one scenario within a simulator session, which was part of a training day. Tapes from 42 teams consisting of two persons, captain and first officer, were analyzed. The data of 23 anaesthesia teams were recorded from live inductions in an emergency department of a university hospital. In addition to the video recordings, interviews were carried out with relevant staff of the hospital department, i.e. anaesthetists, residents, nurse anaesthetists, and surgical personnel, in order to obtain background information on working conditions, written and unwritten rules, and perceptions of relevant influences on team performance. The results of these interviews are described in detail in Künzle (2003). In the present report only some directly relevant information from the interviews is included.

In both settings, different work phases could be distinguished regarding standardization and task load. Level of standardization and task load were assessed by expert ratings (airline captain, anaesthesia resident) on a broad scale of high – moderate – low. Additionally, rules relevant in the two settings were analyzed to arrive at a more detailed account of the level and type of standardization in the two work settings and in the different work phases in each setting.

Aviation. In the simulator scenario, teams take off for a flight from Turin to Zurich, but are called back to Turin. When preparing for the approach to Turin, they discover that flaps and slats are jammed which requires a so-called clean approach.

The work phases during the flight are

1. Normal take-off: standardization high and task load low. After an uneventful take-off, the team, because of weather conditions, gets the order to go back to Turin, and to reduce speed. As they try to reduce speed they realize, that the flaps and slats on the wings are jammed. Mean duration: 3 minutes.

2. Problem solving: standardization low and task load low. This phase starts when the crew realizes what the problem is and lasts as long as they need to solve the problem, i.e. prepare the special landing. For this phase, general checklists exist, but no detailed prescriptions for action sequences. In the scenario, there is no time pressure, as the airplane can be kept in a holding pattern for as long as the team wants it. Mean duration: 10 minutes.

3. Special approach and landing: standardization high and task load high. A clean approach is characterized by high speed and an unusual attitude of the aircraft. It is a very rare event, requiring very good technical skills. Mean duration: 3 minutes.

Medicine. The work phases during induction are:

1. Preparation: task load low and standardization high (41% of all standard anaesthesia rules concern this phase, see Chap. 5.1)). This phase comprises the preparation of monitoring (electrocardiogram, blood pressure, oxygen saturation of the blood) and providing the patient with an intravenous drip, to which the drugs will be administered. Mean duration: 11 minutes.

2. Preintubation: task load moderate and standardization moderate (19.5% of the rules apply to this phase). The phase starts with the administration of the first drug and ends when the patient has a complete neuromuscular blockage, the main task in this phase is monitoring the patient. Mean duration: 7.5 minutes.

3. Tracheal intubation: task load high and standardization moderate (19.5% of the rules apply to this phase). The anaesthetist introduces an endotracheal tube into the trachea through the
mouth. The phase ends, when the anaesthetist confirms correct tube position, connects the tube to the ventilator, and fixes it to the patient’s face. Mean duration: 3 minutes.

4. Additional preparation: Task load high and standardization low (12% of the rules apply to this phase). In this phase, the repositioning of the patient happens with the ventilator and sometimes the monitoring having to be disconnected. Good coordination and especially good leadership are vital for this process, where the anesthesia team has to work together with the surgical team. Mean duration: 12 minutes.

5. Transport: Task load low and standardization low (no rules for this phase). After anesthesia induction and monitoring the team wheels the patient into the operating theatre. Ventilator and monitoring are regularly disconnected, so time is of crucial importance, but this task is highly routinized. Mean duration: 2 minutes.

4.2 Data analysis

Quantitative content analysis of rules
Documents from both the national airline and the university hospital were collected that described rules and standard procedures relevant to the tasks studied. These documents were analyzed using the following main categories: The content of the rule can prescribe a goal, a process to be followed to define an action, or a concrete action (Hale & Swuste, 1998). Also the degree of strictness of a rule (order versus advice; amount of scope provided) and whether exceptions to the rules and reasons for the rule are mentioned, were analyzed. In the medical setting, also a work phase specific rules analysis was carried out based on one of the documents, which concerned the different tasks during anesthesia induction very directly. In aviation no such direct and exclusive assignment of rules to particular work tasks was possible.

Observational categories
The video recordings were rated based on a number of observational categories, using the ATLASi program (Thomas Muhr, Scientific Software Development, Berlin, 1997). Three main groups of categories were developed driven by both theoretical and inductive considerations. Two behavioral marker systems for the evaluation of crew resource management, LOSA (Helmreich et al., 1999) and NOTECHS (Avermaete & Kruijsen, 1998) were used as references. While LOSA and NOTECHS provide overall ratings of individual and/or team performance in cockpit crews on a number of quite general characteristics, our categories had to allow coding of all utterances in the two settings, cockpit and anesthesia teams. Therefore, we had to develop more specific categories within each of the content areas covered by LOSA and NOTECHS.

The first set of categories concerned the information flow on a general level without much reference to the content of the information. The aim was to create mutually exclusive categories covering all utterances and to be able to differentiate between elements of explicit and implicit coordination (Entin & Serfaty, 1999).

The category type Information flow-explicit coordination contains the following categories:
- Provide information
- Request information
- Provide information upon request
- Information containing a summary of a state of affairs or a process
- Reassurance
- Give order
- Ask for help
- Discussion
- Standard communication (specific for aviation)

The category type *information flow-implicit coordination* contains the following categories:
- Provide unsolicited information
- Provide unsolicited action (only used for the medical data, as the video-recordings in the cockpits did not allow to identify actions unambiguously unless they were commented on by the pilots)
- Offer assistance
- Silence
- Chatting

In the case of silence and chatting the whole situation in the team had to be looked at in order to decide whether these categories indicated implicit coordination or absence of coordination. In the second case the interaction was not coded. An important point regarding the first three categories, i.e. providing unsolicited information/action and offering assistance, is the anticipation effect, namely that a team member realizes the needs of other team members and provides the needed information or support without being explicitly requested to do so (see Appendix for more information on the categories and coding examples). All utterances except those that were not in any way linked to team coordination (see above) were assigned to either explicit or under implicit coordination such that the frequencies for these two types of communication add up to the total frequency of communication units related to the work process and team coordination. The information flow categories also provide a general quantitative account of the observed communication, concerning e.g. speaker dominance and proportion of standard versus non-standard information exchange.

The other two groups of categories are not fully exclusive and do not cover all utterances. The category type *leadership* included behaviors that are expressions of personal forms of coordination building upon the hierarchical structure of the team. The categories were chosen so as to study the question of standardization serving as a substitute for coordination through leadership and vice versa. Therefore the categories covered mainly task-oriented elements of leadership, not so much relations-oriented aspects (cf. Yukl, 1999). The categories used were the following:
- Make plans
- Assign task
- Give order
- Make decision
- Initiate an action
- Accept decision or initiated action
- Question decision
- Ignore initiated action
- Autocratic behavior

The third group of categories contains elements of *heedful interrelating*. These categories were derived from Weick and Roberts` (1993) description of this concept. Even though heedful interrelating is conceptualized as a form of lateral coordination, there can also be leadership-related behaviors that
express heed or heedlessness. Therefore there is some overlap between the categories for heedful interrelating and for leadership. The categories used were the following:

- Consider others
- Consider the future
- Consider external conditions
- Initiate an action
- Question decision
- Provide unsolicited information
- Offer assistance
- Correct the behavior of others
- Teach others
- Give feedback about performance

**Performance measure**

In the aviation setting, an instructor who had conducted the session and observed the teams rated their performance on a scale from 1 to 6. Additionally, based on the video recordings, it was checked whether the teams had carried out four compulsory tasks (anti ice on/off; informing cabin crew after discovering technical failure; organizing fire brigade before landing; responsibility for flying the aircraft clearly assigned at all times) resulting in ratings on a scale from 1 to 4. These two scales were combined into a performance index ranging from 1 to 10.

In the anaesthesia setting, an experienced anaesthesia resident watched the video recordings and rated team performance on a scale from 1 to 10. An additional scale based on rule violations was not used because teams disobeyed hardly any rules. Such a measure would therefore not have differentiated between teams.

5 Results

5.1 Rules analysis

The rules analysis for aviation was performed on the relevant sections of the “General Basics Manual” and the “Aircraft Operations Manual” of the airline in which the simulator training took place. The "General Basics" contain rules about navigation, routing, use of equipment, communication with air traffic control, fuel management, weather conditions, warning systems, case of fire or smog, team work, etc. The aircraft operations manual includes technical details of the aircraft and rules for the handling of the aircraft under normal and abnormal conditions, including checklists for several technical defects, like the problem in the simulator scenario used in the study (flaps and slats jammed).

The rules analysis for anaesthesia was based on documents from the same hospital department, where the observation of anaesthesia teams took place. One general characteristic of the rules in the hospital studied was that the rules were partly department specific. As a consequence those personnel that circulate between departments - anaesthetists, residents, student nurses - have to work under different regulations, when they work for different departments. Also, rules are often written by and for particular professional groups, i.e. anaesthetic nurses are not always familiar with the rules written for the
residents and vice versa. Finally, the assumption in the hospital was that rules exist mainly for normal situations and should not be over-generalized. Therefore, there should always be the possibility to disobey a rule if someone has a good reason to do so. When interpreting the rules analysis in the medical setting, it also has to be kept in mind that there are many unwritten rules, which could not be included in the analysis. These unwritten rules are partly passed on through education and training, and partly based on individually developed standards, which people use to keep in mind and/or optimize steps of work processes. As training in the hospital is based on a systematic “learning by doing” with inexperienced team members working together with senior team members, unwritten rules are handed down informally and often implicitly to new members. Before a person is authorized to decide alone he/she has to work and consult for a long time with superiors. At the same time, the general attitude expressed by anaesthetists and nurse anaesthetists is that of a management by exception: “let the new member work, observe if everything goes well and intervene only in case of inappropriate performance”.

For the rule analysis in anaesthesia the following four documents were selected:

- Standard anaesthesia: describes the material, equipment, and activities required during standard anaesthesia
- Residents’ duties: regulates work obligations and responsibilities for the residents
- Shift organization: instructions on how to change shift, how to arrange holiday schedules, etc.
- Instructions to fill out the anaesthesia protocol: exact description of scales used in the protocol. (The protocol is a very important document, containing all crucial information about the patient and about the anaesthesia process. In case of changing personnel it is a very central instrument to avoid human failure and loss of information.)

The analysis followed the typology from Hale and Swuste (1998) and differentiated between three main types of rule: rules describing goals; rules describing processes to follow in determining the right course of action; and rules describing concrete actions. Also, some characteristics related to the strictness of the rules were analyzed (see Table 5).

<table>
<thead>
<tr>
<th></th>
<th>Aviation (n=650)</th>
<th>Anaesthesia (n=204)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal rule</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Process rule</td>
<td>19%</td>
<td>32%</td>
</tr>
<tr>
<td>Action rule</td>
<td>78%</td>
<td>65%</td>
</tr>
<tr>
<td>Advice</td>
<td>10%</td>
<td>15%</td>
</tr>
<tr>
<td>Explanation provided</td>
<td>29%</td>
<td>27%</td>
</tr>
<tr>
<td>Scope provided</td>
<td>47%</td>
<td>40%</td>
</tr>
<tr>
<td>Exception mentioned</td>
<td>6%</td>
<td>13%</td>
</tr>
</tbody>
</table>

Table 5. Results of rule analysis according to categories from Hale & Swuste (1998)

The rules within the document Standard Anaesthesia concerned very directly the observed phases of anesthesia inductions. Therefore it was possible determine the exact number of rules pertaining to each work phase (see Table 6). A similar analysis in aviation was not possible as not all rules could be assigned to particular phases within the flight scenario studied.
Table 6. Results of the rules analysis according to the process phases during anaesthesia induction

<table>
<thead>
<tr>
<th>Total number of rules</th>
<th>Rule concerning</th>
<th>All phases</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
<th>Phase 4</th>
<th>Phase 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>51</td>
<td>4</td>
<td>7.8%</td>
<td>21</td>
<td>41%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>19.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>19.6%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>11.7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0</td>
<td>0%</td>
</tr>
</tbody>
</table>

The most important difference between the documents from the two professional fields is the amount of process rules and action rules. Process rules seem to be quite useful in environments with a high level of uncertainty as the operating theatre is. They do not give any illusion that a ready-made solution exists for every situation, while still providing support through indicating the steps to go through for defining the right course of action in an unknown situation. Some other differences between the two professional fields also indicate more openness of rules in anaesthesia, as rules in anaesthesia are more often an advice and mention exceptions more often. However, in aviation rules provide more scope. This latter finding may be related to the higher degree of action rules whose flexibility is increased by providing some decision latitude.

From the analysis as such, it cannot be concluded what would be a “healthy” proportion of the different rule types. Observational data on rule violations may provide some indication of the goodness of regulation practice. The four tasks that were used for the performance index for the cockpit crews were carried out properly only by 4 of the observed 42 teams. Overall, 63 violations were observed. However, this might also be an effect of the simulator setting, e.g. regarding the two tasks of informing cabin crew and organizing fire brigade. More serious is the violation of the very basic rule that responsibility for flying the aircraft should always be clearly assigned, which occurred in 16 of the teams. Of the 23 observed anaesthesia teams, ten violated rules, adding up to 11 violations overall (mainly unannounced manipulations and intubation taking too long). When interpreting this result, it is important to take into account that in the anaesthesia setting it was generally difficult to decide, whether certain behaviors constituted a rule violation or a very subtle, implicit way of improving coordination in line with the general philosophy expressed in the hospital that rules need to be adapted to new situations or even disobeyed in certain situations.

5.2 Coordination patterns

5.2.1 Aviation data

Table 7 shows the result of the comparison between different work phases within the aviation scenario. The percentages were calculated based on the sum of observations in a given category during the given phase divided by all coded communication units in that phase.
Table 7. Coordination patterns during different work phases in the aviation setting.

Generally speaking in the first - highly standardized, low task load - phase standards are sufficient as coordination tool. Teams need comparatively less explicit coordination and leadership behavior, and they show very few acts of heedful interrelating. The second flight phase, where teams have to find out how to carry out the landing under the special conditions (flaps and slats are jammed; clean approach), explicit coordination, leadership and heedful interrelating play an important role in team coordination. This phase is less standardized: teams, for instance, have to decide on the division of work themselves. Task load is rather low, since there is no time pressure and the task to be accomplished is clear. Explicit coordination is crucial, as team members have to create a common picture of the situation and plan the difficult landing to be carried out in the next phase. Leadership behavior like planning and assigning tasks is important to perform well in the actual phase as well as prepare for the next phase. Heedful interrelating as a non-hierarchical form of coordination is also important in order to make optimal use of all team members’ resources.

The last phase – the clean approach and landing – is characterized by high standardization and high task load. There was generally more communication observed than in the first phase as there was more uncertainty in the situation even though both phases are highly standardized. As expected based on the findings by Entin and Serfaty (1999), more implicit coordination was found, corresponding to the high task load which calls for a less resource intensive way for coordination. We found few leadership actions again as expected, as this kind of coordination is more useful in the planning (second) phase (Orasanu, 1993). Heedful interrelating occurred most in this phase – even though only with a minor increase compared to phase 2. Yet again, this non-hierarchical way of coordination helps to make use of all resources in the team, in this phase particularly to support the pilot flying during the highly demanding clean approach and landing.

The appropriate phases to test the hypotheses concerning standardization are phases 1 and 2 where task load is constant. In the low standardization phase we could observe more explicit coordination, more
leadership and more heedful interrelating. All these differences were statistically significant, using the Chi-square test ($p < .001$). The effect of task load was analyzed by the comparison of phase 1 and phase 3, where the level of standardization is constant and the task load varies. The amount of explicit coordination decreases under the high task load condition, the amount of leadership behavior does not show a relevant difference, and the amount of heedful interrelating increases. Again, the reported differences were statistically significant (Chi-square test, $p < .001$). With the exception of leadership for which an increase under low task load was hypothesized, our expectations were supported by the data. Regarding leadership, it could be assumed that standardization works as an appropriate substitute for leadership also under low task load conditions, especially when there is no anticipation of higher task load as was the case in phase 1 in the scenario studied.

### 5.2.2 Medical data

The observed anaesthesia teams showed differences in coordination behavior between the phases as well. Table 8 shows the summary of the results. Percentages are calculated in the same way as for the aviation data.

<table>
<thead>
<tr>
<th>Induction phase</th>
<th>1 Preparation</th>
<th>2 Preintubation</th>
<th>3 Intubation</th>
<th>4 Additional preparation</th>
<th>5 Transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average duration (min.)</td>
<td>11</td>
<td>75</td>
<td>3</td>
<td>12</td>
<td>2</td>
</tr>
<tr>
<td>Task load</td>
<td>Low</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Standardization</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Low</td>
<td>None</td>
</tr>
<tr>
<td>Communication units (CU) overall</td>
<td>1561</td>
<td>1605</td>
<td>916</td>
<td>1780</td>
<td>372</td>
</tr>
<tr>
<td>CU explicit</td>
<td>59%</td>
<td>69%</td>
<td>71%</td>
<td>74%</td>
<td>70%</td>
</tr>
<tr>
<td>CU implicit</td>
<td>41%</td>
<td>31%</td>
<td>29%</td>
<td>26%</td>
<td>30%</td>
</tr>
<tr>
<td>CU leadership</td>
<td>10%</td>
<td>15%</td>
<td>17%</td>
<td>17%</td>
<td>22%</td>
</tr>
<tr>
<td>CU Heedful interrelating</td>
<td>6%</td>
<td>9%</td>
<td>12%</td>
<td>10%</td>
<td>15%</td>
</tr>
</tbody>
</table>

Table 8. Coordination patterns during different work phases in the anaesthesia teams

For the first four phases holds that the fewer rules are available the more explicit coordination is observable. The most explicit coordination occurred during phase 4, when teams have to reposition the patient. In this phase, team size (new team members join the team) and therefore coordination needs increase. The main task becomes to gain a shared mental model of the situation, so that every team member knows what to do. In the last phase, where teams transport the patients to the operating theatre, there are no written rules available. However, there are certainly some unwritten rules about the process and division of labor. In this phase we observed the highest share of leadership behavior, presumably enforcing the unwritten rules. The amount of heedful interrelating is generally rather low.
Even in the high task load situations there is little support provided through this non-hierarchical form of coordination. Especially in phase 4, this is also due to the fact that the team cannot operate from a shared mental model of the situation, which is crucial for both implicit coordination and heedful interrelating.

To explore the two hypotheses concerning standardization and task load we again compared different phases where one of the independent variables is constant. The standardization hypotheses were tested by comparing phases 1 and 5, where the difference in standardization is considerable - most of the rules concern phase 1 and there are no rules at all concerning phase 5 - and task load is constant. The task load related hypotheses were tested by comparing phases 2 and 3, where the level of standardization is constant. This comparison is not optimal, because moderate task load instead of low task load is compared with high task load. However, these two phases were the only ones with the same level of standardization.

In phase 5 (without written rules about the task) we observed a higher share of explicit coordination, leadership behavior, and heedful interrelating than in phase 1, which by comparison is highly regulated. Those statistically significant results (Chi-square test, p < .001) support our hypotheses: we can assume that standardization can substitute for explicit coordination, leadership, and heedful interrelating, allowing an economic way of coordinating, i.e. implicit coordination. The effect of task load is not as clear: in phase 3 with higher task load teams show more heedful interrelating than in phase 2 in accordance with our expectation (Chi-square, p < .05). For all other types of coordination, the differences were in directions opposite to our hypotheses, but all very small and statistically non-significant. One reason for these results may be that we compared a moderate – instead of a low – task load phase with a high task load phase.

5.2.3 Comparison between cockpit and operating theatre
Table 9 summarizes the results of the analysis across professional fields. The differences between the professional groups are all statistically significant (t-test, p < .001), though not all in the expected directions.

<table>
<thead>
<tr>
<th></th>
<th>Aviation</th>
<th>Anaesthesia</th>
</tr>
</thead>
<tbody>
<tr>
<td>Explicit coordination</td>
<td>72.3%</td>
<td>67.7%</td>
</tr>
<tr>
<td>Implicit coordination</td>
<td>27.7%</td>
<td>32.3%</td>
</tr>
<tr>
<td>Leadership</td>
<td>8.4%</td>
<td>14.6%</td>
</tr>
<tr>
<td>Heedful interrelating</td>
<td>14.5%</td>
<td>9.3%</td>
</tr>
</tbody>
</table>

Table 9. Share of the coordination forms according to frequencies

As we see from Table 9 cockpit crews employed explicit coordination more frequently than anaesthesia teams, which does not support our hypothesis. Anaesthesia teams showed more leadership behavior than cockpit teams, as we expected, but they showed less heedful interrelating than the cockpit crews. In
order to interpret these mixed results other situational and task specific factors influencing team coordination have to be considered such as the following:

- Shared visual information in the anaesthesia team and different visual information in the cockpit teams is a possible reason for coordinating explicitly more often in the cockpit. The pilots need an intensive and overt information exchange to complement each other’s information basis.
- Cockpit teams have to deal with an unusual flight task in the simulator; while the anesthesia teams work in routine situations in real life. Well known task situations can have the same effect, as standardization, namely reducing the need for explicit coordination.
- There are also differences in communication practices: cockpit teams have attended “Crew resource management” trainings, where they had a chance to practice certain coordination forms and they are probably more conscious about the importance of explicit coordination.

5.3 Coordination and performance

For the aviation data, a statistically significant positive relationship was found between the overall amount of explicit coordination and performance (r=0.37, p<.05). Only for leadership, work phase specific results were found in the aviation data. There was a positive relationship (r=0.31, p<.05) with performance during the low standardization phase and negative relationships for the two high standardization phases (for phase 1 r=-0.42, p<.05; for phase 3 r=-0.24, n.s.). These findings support our hypothesis: standardization can be a substitute for leadership behavior (Kerr & Jermier, 1978), and too much leadership in situations, when team members can work on their own, not needing much direction, can even have a negative effect on team performance.

Regarding single categories within the four category groups, a number of correlations were found with performance. However, considering the large number of correlations tested, this may also be a chance finding. Focusing only on the largest correlations found, it seems that performance was positively linked to more initiation of actions be the captain, when he/she was also pilot flying (r=0.52, p<.05) and to more positive feedback from the captain to the first officer, when the first officer was pilot flying (r=0.48, p<.05). The latter finding was also supported by interview material from anesthesia teams where often the importance of positive feedback during and after team work was emphasized, while at the same time giving feedback was often neglected by the team leaders. In situations when the first officer was the pilot flying, performance appeared to be negatively linked to the captain providing information upon request (r=-0.50, p<.05), the first officer requesting information (r=-0.57, p<.01), and the first officer correcting behavior (r=-0.52, p<.05). Especially the first two of these correlations seem to point to the importance of implicit coordination, there were no significant correlations found for the respective categories, however.

In the medical setting, the relationships between the observational categories and performance were even less clear. One possible explanation for the generally rather inconclusive results regarding the relationship between coordination behavior and performance is that coordination might be crucial only in extremely high task load situations, where the right distribution of resources and attention really matters and cannot be compensated for by individual abilities of team members. Therefore, repeating
our study with teams operating in even more challenging situations than the ones we analyzed, might be a better test of our hypotheses. An important task for the future is also to develop a reliably discriminating performance measure for anesthesia induction. The overall expert rating used in the study turned out to be too global. Specific technical parameters of the work process, which were not available in the present study, would be required to improve the quality of the performance rating.

6 Conclusions

There is partial support for the hypotheses related to the observational categories and the general assumption that adaptive coordination is needed for successful performance. The aviation data support most predictions: we observed adaptive coordination behavior mirroring the effects of standardization and task load, i.e. more implicit coordination and less leadership and heedful interrelating with higher levels of standardization and more implicit coordination and heedful interrelating with higher levels of task load. The findings for the anesthesia data were less consistent: While the effect of standardization could be demonstrated for all coordination forms, for task load only the assumed relationship with heedful interrelating was supported. When looking at the patterns of coordination behavior across different combinations of levels of standardization and task load, the effect of standardization appears to be stronger, as usually the patterns confirmed more to what was hypothesized on the basis of the level of standardization. However, a more systematic variation of all the possible combinations of standardization and task load would be needed to obtain conclusive results. Additionally, the task load related hypotheses are also based on assumptions about sequences of low and high task load phases, e.g. explicit coordination being helpful in low task load phases to prepare for high task load phases (cf. Entin & Serfaty, 1999; Orasanu, 1993). The actually studied work phases did not always conform to these sequences.

Reasons for not finding more extensive evidence for the effectiveness of certain types of coordination lie in the generally low variance in the performance measures – basically all teams could be considered quite good teams – and especially for the anesthesia teams in the rather global nature of the performance rating. More specific reference to technical details of the anesthesia process in each team would have been necessary to derive more detailed performance assessments. Another possible explanation for the generally weak relationship between performance and coordination behavior of the teams is that good coordination or generally speaking good team work makes no difference until the work load is extremely high, which was not the case in our settings Teams have many possibilities to compensate for bad coordination. They have time to correct mistakes or even one person might manage the task alone at least for some of the time.

Comparing the two professional fields, we did not find support for the assumption that the generally lower level of standardization in medicine would be associated with less implicit coordination. Overall, there was even some more implicit coordination in the anesthesia teams. Possible explanations are the coordination force of the shared visual field (cf. e.g. Hindmarsh & Pilnick, 2002) and the higher familiarity in the anesthesia teams, which overcompensate the lack of common ground through standardization. There was more leadership and less heedful interrelating in the anesthesia teams, which corresponds to
the higher degree of hierarchical structure in those teams compared to cockpit crews and also to the assumptions about standardization acting as impersonal leadership and thereby substituting personal leadership (Kerr & Jermier, 1978).

On a more general level, the results indicate flexibility in the way uncertainties are handled in the two professional settings, with a tendency to follow more the route of competent coping with uncertainties instead of minimizing uncertainties (Grote, 1997, 2001). While there are more and also more specific rules in aviation, there is often some scope of action provided and there is much effort put into explicit coordination to ensure the appropriate course of action. In anaesthesia, there was an astonishing amount of implicit coordination, but not based on generally set standards, but on more informal rules and the immediacy of common action in a shared visual field (cf. for a discussion of awareness created in such settings Heath, Sanchez Svensson, Hindmarsh, Luff & Lehn, 2002). However, team members also expressed some ambivalence regarding the benefits of implicit coordination. They see it as a desired form of seamless coordination while at the same time they are quite aware of the dangers it implies in terms of relying too much on a presumed shared understanding of the situation. More focus on a systematic “rules management” might be needed to keep the flexibility of non-prescribed action and provide enough orientation on a more abstract level to ensure swift switches between coordination forms. The distinctions provided by Hale and Swuste (1998) in their classification scheme for rules have proven very useful for developing a more fine-grained perspective on kinds and levels of standardization operating in a given setting. They could also be good framework for such a systematic rules management.

Finally, some limitations of our study have to be pointed out. Besides the overall rather small numbers of teams observed, especially in anaesthesia, and the already mentioned problem of the performance measures used in the two settings, the general approach of comparing aviation and medicine and of comparing real life data with data from a simulator can be questioned. For instance, the higher numbers of rule violations in the cockpit crews may very well be a simulator effect and therefore are a questionable indicator of team performance or of the appropriateness of the rules as such. Also, the mix of formal and informal rules in medicine could not be taken into consideration sufficiently. More in-depth analyses of our current data on a qualitative level as well as further studies using better performance measures and explicitly analyzing informal rules are needed to confirm our assumptions on the benefits of adaptive coordination and the effects of standardization and task load on coordination.

**Acknowledgements**

We gratefully acknowledge the financial support for this project by the Daimler-Benz-Stiftung as well as the stimulating discussions in the umbrella project “Group interaction in high risk environments (GIHRE)” to which our project belongs. Also, we are very grateful for the enormous support by the GIHRE aviation project (Capt. Werner Naef, Dr. Barbara Klampfer, Ruth Häusler) through making their raw data available to us.
References


Appendix

I. Information flow

Explicit coordination:

Provide Information
A team member gives any kind of information.
“I go back to position zero with the flaps.”
“The manual respiration goes well.”

Request information
A team member asks a question:
“Is it the smallest tubus we have?”

Provide information upon request
A team member answers a question:
“Yes it is the smallest (tubus we have).”

Information containing a summary of a state of affairs or a process
A team member summarizes the situation the team is in:
“So, we are going to make a ILS-approach with a longer final. We take the longest available runway. We will use the autopilot as long as it normally functions…”

Reassurance
A team member provides feedback about comprehension of communication - often closed loop communication:
(“Speed is one hundred.”) “Speed is checked.”
Or in normal communication:
„O.k.‟ „That is right.“ I agree.”

Give order
A team member gives a simple instruction to carry out actions.
“Have a look at it!” “Enter this data, please!”
“Can you give me the ECG cable?”

Ask for help
A team member asks for help.
“You have to watch and tell me if the attitude is too high.”
“Will there be more help from somewhere?”

Discussion
Several persons speak about a common subject almost in parallel.

Standard communication (specific for aviation)
Predetermined communication, which has to be carried out always in the same way.
Pilot flying: “Gear up”
Pilot non-flying: “Gear is up”

Communication with Air Traffic control (specific for aviation)
Communication to and from members of Air Traffic control (not included in the analyses).
Communication with patient (specific for medicine)
Communication to and from patient (not included in the analyses).

Implicit coordination:

Provide unsolicited information
If a team member anticipates a need for information from another team member and provides the information without being asked to do so.
E.g. In a difficult landing situation the pilot non-flying sees the runway and informs the pilot flying about it without being asked to do so: “Runway is inside straight ahead.”
“I would adjust the frequency first, because it alters the volume.” (This was an advice from an experienced team member, as somebody tried to adjust the respirator and it did not work out.)

Offer assistance
If a team member anticipates another team member’s need for help and offers this help.
“Should I enter the data?”
“May I give you the breathing bag?”

Provide unsolicited action
If a team member anticipates an action being required for a smooth work process performed by another team member and takes this action without being asked to do so.
E.g. Handing the waste box for a used needle.

Silence
Nobody speaks but the process goes on smoothly.

Chatting
The team talks about non-work related issues but the work process goes on smoothly.

II. Leadership

Make plans
A team member creates a plan which includes several steps of the future work process.
“We go in the holding and prepare the clean approach. We have to inform the ATC and the cabin crew.”
“As soon as they are ready with the preparation we will wheel the patient to the operating theatre.”

Assign task
A team member allocates tasks among the team.
“I read the quick reference and you can prepare the FMS and ask about the weather.”
“If you agree I will give the administer the drugs.”

Give order
As above.

Make decision
A team member announces a decision defining the way or the timing for carrying out an action.
“In this case we will make clean approach.”
“We wait one more minute.”
Initiate an action
A team member tries to influence the action but wants to get an agreement from the team. It is a sign of thinking together with the other actor(s) actively.
“Should I try to recycle?” “Alright we are ready. Should we make the approach briefing.”
“Should we give some more Fentanyl?”
Accept order, decision or initiated action
A team member gives a verbal affirmation or acts directly as an affirmation.
„Yes, I agree.“

Question a decision
A team member expresses doubts about a decision.
“(By auto break I would select maximum.) Maximum? I've never heard about it.”
(“Probably we could change the position of the head.”) “We could do that but it would not change anything.”

Ignore initiated action
There is a suggestion but nobody reacts on it at all.

Autocratic behaviour
A team member takes a decision without reaching an agreement with the team.
„We are going to land now and we can discuss it later.”
“We have to do it as it is written in the instructions.”

III. Heedful interrelating
For the coding of these categories, it is important to decide whether a behavior has a positive influence or not. If somebody does not support the aims of the team with his behavior, than it is heedless interrelating: e.g. excessive and superfluous teaching can be interesting for the teacher but not for the team.

Considering others
A team member considers or checks the state of the other team members.
“Are you ready?” „Do you have a question?” “Can you do it alone?”
“Do you agree?”

Considering the future
A team member thinks about the consequences of the situation in a timely fashion.
“We will use autopilot as long as it functions normally.”
“We are going to reposition the patient in the operating room, that is better.”

Considering external conditions
A team member keeps in mind the external conditions influencing the task fulfillment.
“We have to check the weather, particularly the wind.”
“If the table too much up you can hardly lift the patient.”

Initiate an action
See above.

Question a decision
See above.
Providing unsolicited information
See above.

Offer assistance
See above.

Correct the behavior of others
A team member reaffirms the right course of action and thereby points to a mistake made by another team member.
"We did decide for flaps zero position, didn’t we? It isn’t correct in that way."
"You could fix the tube better."

Teach others
A team member explains something, in a way that is more than to answer a question.
"It is not difficult to land as long as it doesn’t get choppy."
"Try to administer the Venflon steep into the skin and afterwards drive it further horizontally."

Give positive feedback about performance
A team member provides a supportive evaluation of somebody’s performance.
"Congratulations. You have managed the approach really nicely."
"Yes, the respiration is all right now."

Give negative feedback about performance
No observation in this category.