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PROBLEM-SOLVING TEAMS: COMMONALITIES AND DIFFERENCES OF OPERATIONAL AND DESIGN TEAMS

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1. Introduction

Technology has a strong impact on the work of operational and design teams. To understand how they deal with new capabilities and new venture, we have to take a closer look at the characteristics of the tasks teams has to cope with [Busby 2001]. Consistent excellent performance of design teams is based on distinctive task performance strategies and a highly structured knowledge base that enable experts to adapt their actions to the various task characteristics and demands, to anticipate adequately future developments and to react to situation changes. To build shared mental models is the central phase of action regulation of problem solving teams [Schaub 1997, 2007], [Goldschmidt 2007].

Design teams need, like operational teams, shared team mental models for different type of teams acting in complex technical systems [Langan-Fox et al. 2004]. This paper will further explore the contrast of mental models in operational teams and design teams [Badke-Schaub et al. 2007]. The significance of contextual characteristics of the task in terms of performance suggests that adaptation to the specific operational demands is essential for performance. Waller [1999] finds support for this expectation and reports that the extent to which operational teams, e.g. cockpit crews [Mathieu et al. 2000], power plant operators [Waller et al. 2004], or astronauts [Musson et al. 2004], adapt especially to new situations is predicted by crew behaviour under specific task conditions such as ‘search and transfer of information’, ‘prioritizing of tasks’ and ‘distribution of tasks’. Dealing with novelty is a task characteristic that operational teams sometimes, yet design teams often have to cope with. Novelty is a key factor of critical situations in which problem-solving teams show (or fail to show) their ability to solve problems [Badke-Schaub and Frankenberger 1999].

Research on expert performance indicates that consistent excellent performance is based on distinctive strategies and a highly structured knowledge base, which enable experts to adapt their actions to critical task characteristics and workload, to correctly anticipate future developments and to respond adequately if the situation changes (adaptive expertise, [Holyoak 1991]). Consequently Ericsson and Lehmann [1996] define expertise as the maximal adaptation to task constraints. Adaptive expert teams have a specific knowledge: They know about the conditions for successful execution of the task in regard to the situational limitations for certain actions.

To understand the importance of task characteristics, we will have a look at some of the typical challenges that problem-solving teams (operational teams and design teams) have to deal with. These challenges are mostly related to reducing complexity to comprehensible and operational dimensions. Problem-solving teams especially need to share a common set of goals and an understanding of the task. Although design teams and operational teams differ in certain aspects, how they deal with complexity and build up a manageable representation of their task are largely similar. Problem-solving teams have to:

- Find and define their problems.
  This means that they have to synchronize their goals and task definition.
- Combine intuition and rationality in decision-making.
  Above all this means that the team members have to explicate (to themselves and to the team) their strategies, knowledge and assumptions.
- Tolerate ambiguity and cope with unexpected events.
  Mainly, team members have to control their emotional reactions.
- Develop appropriate measures to handle novel situations.
  Novelty might be a risk for operational teams and a chance for design teams. Both operators and designers need to recognize new situations or elements as new and thus its distinctive potential as innovation or risk.
- Cope with stress and time pressure.
  Lack of time is a standard feature of the modern world. Any working team, designer, operator or problem solver has to cope with limited time.

There is diversity in emphasis of these factors regarding design or operational teams. But problem-solving teams in general have to deal with these challenges to build up a down-to-earth view of their task (task mental model) as well as a realistic view of the team abilities (team mental model).

2. Elements of 'typical' tasks

The challenges that operational teams face are a result of the characteristics of their working environment. As a result of the increased complexity of work and the considerable change of environments, operational and design teams often have to work in complex, distributed organizations, and their work has typically shared and distributed aspects. In a broader sense, the general features of their working environment can be described by using the following categories [Dörner 1996], [Schaub and Strohschneider 1997]:

- Complexity:
  The environment consists of a large number of important aspects and actors that influence each other in complicated ways. The environment thus constitutes a network of variables. One of the important consequences of this network-like feature is that there is no possibility 'to press just one button'. Each and every attempt to influence single variables causes waves in the whole network; each action may lead to the desired main effect but may also result in unexpected long-term and side effects. Complexity is a challenge for operational and design teams, because they have to find measures to reduce complexity to a manageable amount.
- Novelty:
  As actors never know all aspects of the environment, it is impossible to learn about the motives and moves of all the 'players on the board'. This means that the problem at hand remains at least partially in-transparent and decisions must be taken under uncertainty. Moreover, there are only few possibilities for the reutilization of everyday work since new and important aspects will frequently require changes of routines. The general meaning of novelty is different to operational and design teams. Operational teams experience novelty as a risk, because it might obstruct the achievement of objectives. Design teams perceive novelty as a chance, because it might open a new way to achieve their objectives. In general problem-solving teams have to factor novelty or the expectation of novelty into their mental model.
- Dynamism:
  The working environment of problem-solving team's changes. For standard tasks, some variables may change quickly, but the overall characteristics of the situation do not change and the actor can analyse effects and ramification of their actions. However, complex tasks change on their own not only in respect to certain variables, but particularly to their general attributes. Operational teams may not have enough time for analysis and reaction; design teams may lack the time for knowledge acquisition and analysis. In general, problem-solving teams may not have enough time to calculating the risks and stakes of decisions, which adds time pressure to uncertainty. This essentially may result in an inappropriate model of current situation.

- Goals:
  In many cases the goals are too global to derive criteria that allow detailed planning. What exactly does it mean to create an 'unpolluted environment' or a 'sound company'? However, in complex work environments, it is often difficult to decide on the concrete meaning of such goals, because sub-goals can be contradictory and cannot be achieved at the same time. The kind of goals may differ between operational and design teams ('efficiency' vs. 'creativity'), but problem-solving teams must develop a common understanding of their goals as a part of their team mental model.
- Risky measures:
  Complex work environments are rarely characterized by routinely available and safe measures. Since the situation changes, also the consequences of measures might be different: what seemed adequate yesterday may lead to a disaster today. Therefore, continuous checks of the effects of implemented measures need to be taken, desired main-effects and undesired long-term and side effects have to be analysed. For operational teams this might obstruct the achievement of their objectives. For design teams this can also be an opportunity because it might open new perspectives.

3. The use of mental models

All the above mentioned characteristics are related to each other, as they require 'Dynamic Decision Making' [Brehmer 1990, 1992], 'Natural Decision Making' [Klein et al. 1993], or 'Action Regulation' [Dörner 1980, 1996], [Kuhl and Beckmann 1985], [Schaub 1997]. As the whole process of action regulation in a complex environment is often subdivided into different tasks and involves different persons, it is of primary importance to synchronize the view on the situation between the people involved, or in other words: to build shared mental models of the task and of the team. We could ask: What is modelled? From the point of view of operational teams the major problem is the missing information about the network of variables constituting the complex (technical or organizational) system they are dealing with. To build up a model of the situation (including a model of the team itself) it is necessary to collect information about the system at hand and about its development in order to build hypotheses about the inner structure of the system. Operational teams should, but often do not, build up a shared mental model of the task. If the team has efficient information about the system structure and its current state, it should develop prognoses about the future development of the system. Unlike traditional decision making tasks, complex systems have their 'built in' dynamics and thus show evidence of autonomous development. Hence it even might be the case that it is not necessary to act at all to achieve one's goals as the systems' development produces the goal state without any further action.

Once familiar with the developmental tendencies of a system and aware of the internal structure, it is necessary to prepare a goal-directed course of actions and to decide how to implement it. Planning depends on the structure of the domain of reality one has to cope with. Planning might be easy if there are not many different actions available to influence the systems development, if these actions have no undesirable side- and long-term effects and if the plan can be implemented in a straightforward manner. In a domain in which actions have a lot of side- and long-term effects, however, planning can be extremely difficult and time-consuming.

When a course of action has been selected and implemented, the process needs to be monitored. Due to long lead times in complex systems, this is not a simple task. Monitoring the effects requires a lot of effort and analytical reasoning to separate the effects of the team actions from the autonomous development of the system. As a result of this monitoring, the team can prove whether their task mental model helped to achieve their goals. This does not mean that the model is necessarily correct.

Last but not least, the team needs not only to monitor the development of the system but also their own strategies of information processing, such as hypothesis formation, information collection, forecasting, planning and decision-making. In short, teams need to engage in self-reflection. Tackling problems in a complex, dynamic domain is a rather long-winded activity. It may turn out that the initial strategies of information processing were sub-optimal and need to be improved. This reflection enables the team to check if their team mental model helped to support their problem-solving process. Again, this does not mean that the model is necessarily correct [Bødker et al. 2000].

Mental models are simplified representations of the world [Badke-Schaub et al. 2007]. These mental models of the world, of the task and of the team are shared beliefs, which may sound stupid in terms of rationality, however, they serve a function for the problem-solving team in so far as they avoid uncertainty, convey a sense of mastery, and therefore make problems of apparently overwhelming difficulty 'manageable'. Thus, it is obvious that team mental models should be of high quality. The accuracy of the model is a strong predictor of team performance [Badke-Schaub et al. 2007]. However, there are some shortcomings that characterize the difficulties teams have in dealing with complex tasks:

- 'All members of the team are striving for the same goal'.
  A common problem in teams is the lack of attention to the, often diverse, goals of the individual team members. The daily stress of operational teams leads to micro management and to a loss of a strategic perspective. The concentrated efforts of the team in firefighting leave no room for expatiating and discussing goals and strategies. Following this argument we can give an answer to the question which content should be shared: Sharing goals seems a kind of prerequisite for successful teamwork.
- 'Our view of the world is correct'.
  Sharing mental models in operational teams and establishing one common view typically leads to 'channelling errors' during information collection. The team is not prepared to take into account a broader range of information but focuses on the narrow part that jointly is considered to be important [Reason 1990], [Dörner and Schaub 1994].
- 'We are a successful and competent team'.
  Many operational teams produce, on the micro level, a sequence of successful actions. Even if they are wrong concerning the overall strategy, they often succeed in fighting the daily 'fires'. This leads to the misinterpretation to be successful and competent in general. Which parts of a mental model should be shared and which could be distributed. In order to enforce criticism it is essential to create some diversity evaluating the results of the work.
- 'There is no need for reflection'.
  Spontaneous reflection can be virtually never observed in operational teams. The abandonment of reflection is often caused by the tendency to avoid doubts about the appropriateness of the abilities of the team. Self-criticism implies the recognition of mistakes the team has made, and this could threaten the feeling of competence and team efficacy [Tisdale 1998]. To build up an accurate team mental model, operational teams most focus not only on their daily work, but also on the team itself to increase their performance, like the lead paper state, that team performance is better among teams sharing higher-quality team mental models.
- 'All important issues are on our control panel'.
  Operational teams often develop unique routines of data collection, which remain stable during the work process. This 'control panel' metaphor is a primitive version of a mental model. It is typically an unconnected list of items and it serves a useful function in reducing uncertainty by introducing a degree of reutilization with respect to keeping track of different aspects. It is, however, important to note that the control panel not only shows what operational teams consider, it also influences what operational teams consistently ignore [Ramnarayan et al. 1997].
- 'Blame others for mistakes'.
  Individuals but even more so teams seem to be unwilling to take personal responsibility for their decisions and non-decisions. They are more likely to blame others for all the ills, and thus miss opportunities to learn from their mistakes. The relation between mental models and performance is task-dependent [Badke-Schaub et al. 2007]. When ignoring their own impact on success and failure of actions, operational team will not change their mental models and attributions of their work.

Taking all these assumptions into account, there is one critical ‘parameter’: to be accurate, every member of the team and the team as a whole have to deal with all these error tendencies of human information processing.

5. Conclusions for design teams

What does this mean for design teams? The use of mental models, especially in dealing with complexity, is a challenge for any problem-solving team. The challenge problem-solving team’s face is a result of the characteristics of their work environment. Thus understanding the characteristics of the task is essential to understand the demands and shortcomings of mental models in different types of teams. Operational teams tend to Importance of task characteristics perceive novelty as a risk to accomplish their task, while design teams often seek novelty as condition for their creative work.

We have shown some shortcomings problem-solving teams typically exhibit in dealing with complexity. Often teams neither lack expertise nor motivation to solve the problem; especially they have to learn how to build, to use and to share their assumptions and their models of the situation and the team.

Design is the creation of a plan or convention for the construction of an object or a system, one can’t expect, that *all members of the team are striving for the same goal.* Therefore, design teams must carefully analysis and explicit goals of every team member.

Design is a component of product design, industrial design and engineering. Many overlapping methods and processes can be seen when comparing these different areas, but they have in common, that there are many people with different perspectives, many stakeholders, e.g. users. Therefore design teams must be very carefully to prevent the attitude: *Our view of the world is correct.* Operational teams (e.g. firefighters), in contrast to design teams are typically directly confronted with success or failure of their work. And they immediately may start a lessons learned process to improve their own processes. Design team have always the problem that they are not directly linked to the end users, and therefore they may judge *we are a successful and competent team* not as a result of the success of the products or systems they designed, but only as a result of the perceived quality of the design process.

Having only one perspective in the whole life cycle of a product or a systems, design teams may be troubled with the illusion that *all important issues are on our control panel*. But if something goes wrong, there is also a danger, that design teams may run in a problem avoidance modes: *Blame others for mistakes* therefore: *there is no need for reflection.*

The often stressful direct link of operational teams to success or failure of their work at the sharp end of the organisation, is sometimes a fruitful corrective maintenance of erroneous behaviour. A strong recommendation could be given to design teams: Make a valid link to all stakeholder and all phase of the life cycle of your products.

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