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TEAM COHESION AND PROCESS ASPECTS OF TEAMWORK IN DESIGN

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1. Introduction

Numerous studies have pointed to the importance of efficient collaboration between experts for successful innovation. Diverse expertise is required to develop successful products yet a group of experts does not automatically form a highly functional team. In order to support teamwork in design, we need a thorough understanding of the cognitive and social processes of knowledge creation in teams. Design ideas should therefore be studied as a function of the relationship and roles between the individual designers that generate them [Cross & Cross 1995]. Identifying what makes teamwork effective is thus a major topic for understanding the social processes in collaborative design.

For successful coordination, team members not only need a shared understanding of the vision and issues, they also need to be aware of the skills and abilities of their colleagues and how the other team members approach the task. For many routine jobs, standard operating procedures have been suggested as a means to enable coordination and shared understanding. However, this approach is not very suitable for design tasks, which are typically ill-defined and requirements can change as the design evolves. In such cases, the way how team members coordinate and exchange ideas cannot be predefined but has to emerge from the current task at hand. Mature teams who have worked together for a long time sometimes achieve this coordination implicitly. However, if teams lack such implicit coordination they may have to face misunderstandings and priority conflicts, low productivity, duplicate work, and missed deadlines [Epinosa et al. 2004]. On the other hand, more insights into how teams share their representations about the task at hand and the team might also help to overcome misunderstandings in teams by creating better-synchronized and synergistic teamwork [Sinreich et al. 2005].

Although teamwork has become a popular topic, the majority of research investigating human behavioural aspects of design still focuses on the individual. A recent review also found that design researchers only make limited use of the psychological literature from which knowledge and research methods for studying cognition and social processes in design could be derived [Lauche 2007]. To fill this gap, we propose a method to measure shared representations in design teams and show how this was applied in an empirical study. This approach, we argue, will help to understand the underlying cognitive processes for coordinating collaborative design. The question we are trying to answer in this study is how does team cohesion and process coordination influences team functioning? We expect that those that function better as a team will also show more implicit coordination of the process and more signs of team cohesion.

2. Theoretical background: Shared representation in design

In order to use the team members' individual knowledge and skills efficiently, it is beneficial for all team members to develop a shared understanding. From a cognitive perspective, each member of a team holds mental models that may or may not be similar to those of the others. The term team mental models refers to members of a team sharing their individual mental models [Klimoski & Mohammed 1994]. These mental models can be thought of as knowledge or believe structures about key elements of the teams environment that allow team members to anticipate one another's actions and to coordinate their behaviours. Developing a team mental model might therefore help individual designers coordinate their ideas and activities.

Several studies have shown the beneficial effects of team mental models on team performance, especially when the task is complex, unpredictable, or novel [e.g., Marks et al. 2000]. Team members who have their mental models in common It is usually assumed that the mental models to be shared can be about the *task*, that is what the team is working on, as well as the *team*, the interaction processes within team members.

In Figure 1, the concept ideas are depicted as sketches by the individual designers. Clearly, the individual concepts are very different, as may be the ideas the members hold about their team. The question remains how to distinguish the relevant aspects of team mental models for designers and how to measure the whether or not sharedness between team members is achieved.

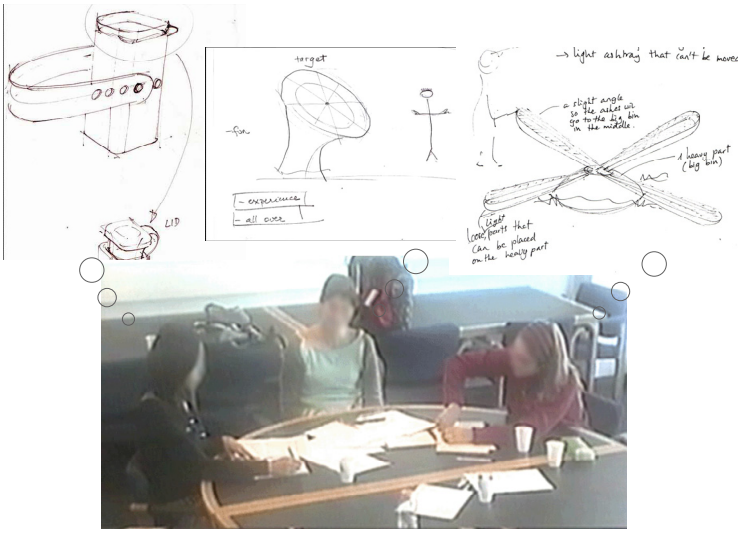

Figure 1. Design team at work

Badke-Schaub, Neumann, Lauche, & Mohammed [2007] argue that team mental models offer a good theoretical concept to study design teams. A distinction into task, team and process aspects of mental models help to capture all issues that are domain relevant in design. The task model includes all aspects regarding the actual design task, thus problem definition and analysis and solution finding. Process involves all coordination aspects that are needed to structure the course of action and methods how to approach the task. The team model comprise two issues: the team coordination, that is coordination of each others actions based on knowledge about competences and skills of the other team members, and team cohesiveness, aspects that keep the team together as a social entity.

As mental models are cognitive constructs that can not be observed directly, so those wishing to study them have to try to elicit the content of someone's mental model and to make inferences based on the analysis of externalizations. In team settings, verbal communication provides a natural angle into the mental models of the members, as they themselves can also not read each other's mind and have to

rely on what is said to develop shared understanding. Our approach was therefore to observe teams' natural interaction while designing without interrupting the process and then to code verbal utterances. In order to draw conclusions about the sharedness from overt behaviour a theoretical model is required. During group interaction, groups can coordinate their actions implicitly, based on expectations, or explicitly, based on formal agreements and plans that are verbally expressed [Wittenbaum et al. 1998]. In order to be more efficient, groups have a natural tendency to coordinate their action tacitly rather than explicitly based on their knowledge about each other and the task. We argue that teams, after a start-up time, develop sharedness and, as a consequence, need less explicit coordination.

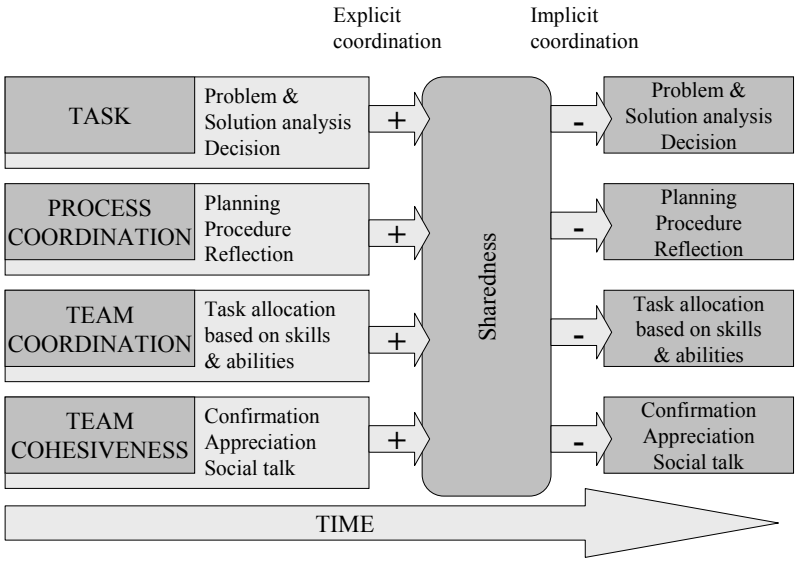

Figure 2. Development of explicit coordination in teams according to Badke-Schaub et al. 2007

Figure 2 shows our theoretical model on the development of sharedness and explicit coordination in teams [adapted from Badke-Schaub, Lauche, Neumann & Ahmed 2007]. The model depicts two different processes related to the development over time: 1) the part of creating shared understanding on the and; 2) the effects of shared understanding on the basis of a team mental model. Groups that have achieved shared understanding continue to employ the same cognitive processes, yet the frequency of certain activities decreases once shared knowledge on how to collaborate on the task and within the team has been acquired. The task model refers to information exchange that is related to the problem definition and evaluation, and to the solution space including the generation, analysis and evaluation of an idea. The process model refers to approach and methods with which the team solves a task. At the beginning of their collaborative process, team members need to explicitly coordinate their action. Once a common understanding has been achieved about how and when to do what, only minor adaptations should be necessary and, in turn, implicit coordination will suffice. The team coordination model refers to roles and responsibilities and is based on the awareness of other team members' knowledge, skills, and experience. Team cohesion refers to the team climate and the preference of the members to be part of the team. As the team stabilizes over time, team members are expected to put less effort into keeping the team together. This should lead to a decrease in team cohesion utterances.
As team members gain more sharedness in time, it is assumed that they need less explicit coordination since they can synchronize their mental models implicitely. In turn, they should talk less about these aspects. In order to test these theoretical assumptions, design teams were observed under experimental conditions.

3. Method

In this study, we conducted an experiment with the same design task given to eleven teams, which was video-taped, transcribed and analysed. For the analysis we applied a categorization scheme based on the above mentioned theoretical assumptions about team mental models to investigate whether team members reach shared understanding and which aspects are of major importance in doing so.

3.1 Sample and experimental design

Thirty-three industrial design master students were asked to create a concept design for a product development task. The participants were assigned into ad hoc groups of three, resulting in eleven teams. The average age of the subjects was 24.5 years, nine subjects being male and 24 female.

Subjects were handed out written instructions at the beginning to develop a concept for an ashtray for outside events that is easy to relocate and assemble. The task duration for group design was one hour, which was split into three stages of 20 minutes per interval. At the beginning and in the middle (between the second and third stage) of the task, subjects had to write down and draw their ideas individually for ten extra minutes per phase. At the end of this task, subjects were asked to give a short presentation about their concept design. The whole experiment was videotaped using two installed cameras.

Team functioning was assessed as an observer's rating of the quality of team functioning based on five criteria. Well functioning was defined as more indications of building on each others' ideas, contructive solution analysis, proactive behaviours towards each other, and giving each other time to finish their sentences, and less indications of being irritated and misunderstood by others. The classification was done by one person. Although the measure remains subjective, we argue that is is sufficient for the purpose of this study as the goal was mainly to distinguish well functioning from less well functioning teams.

Table 1. Categorization scheme

TASK	
Problem definition & elaboration	Defining the problem, elaborating and analyzing the constraints, the requirements, and the goal of the task
New solution idea or new solution aspect	Stating a new product-idea or a new solution for an earlier defined problem or sub-problem or new aspects building on an earlier mentioned solution idea
Analysis	Analysis of properties and the feasibility of a solution idea, analysis of the usage of a product idea and its potential applications, e.g., by referring to similar products, and evaluation of a solution idea by appraising its feasibility or analyzing failure and safety aspects
Solution decision	Making a solution definitive by accepting it in the whole team
PROCESS	
Statements on the organization when to do what (**planning**), about how to approach the task, e.g., how to apply a method (**procedure**), and utterances about what and how the team is doing (**reflection**)	
TEAM COORDINATION	
Role allocation to team members and references to personal abilities, knowledge, skills, or experience	
TEAM COHESIVENESS	
All aspects that indicate signals about group coherence are included in this category: Appreciations, confirmations, and informal communication (e.g., joking)	

3.2 Categorization scheme

Table shows the categorization scheme that was applied to the video recordings. For the task, a distinction was made for Problem Definition and Evaluaion, New Solution Ideas, Solution Analysis, and Solution Decision. Additionally, the content of the task related utterance was coded, e.g., product properties, manufacturing, costs. Regarding the process Planning, Peflection were coded if they were used to coordinate the process. Coordination of roles and responsibilities and references to skills and abilities was coded as Team Coordination. Confirmations, appreciations, and informal talk were coded

as Team Cohesiveness. The rest category of all utterances that could not be categorised otherwise was applied less than 0.5% off all times, showing a good coverage of the categorisation system.
The data were coded by one rater. An interrater-reliability check on the same coding system on a different data set [Badke-Schaub et al. 2007] revealed a Kapp-coefficient of 0.72, showing sufficient objectiviy of this categorization scheme.

4. Results

On the basis of the observer's rating of team functioning, six well functioning teams and five poorly functioning teams were identified. Figure shows the frequencies of coherence utterances for the six well functioning teams (a) and the five less well functioning teams (b). Comparing these two graphs, two obvious differences can be seen: Well functioning teams show a decrease in coherence utterances in time, and they use slightly more coherence utterances in general. Although both effects cannot be statistically supported, the trend is as expected and offers support for the model. The findings support the notion that teams who function better also develop more sharedness in terms of team cohesion, and in turn need to work less on it.
It was also found that the frequency of team cohesiveness correlated with the frequency of new solution ideas at 0.39. Although the number of data points does not allow for statistical conclusions about this relationship, it shows that team cohesiveness may be linked to the innovativeness of the team, and both tend to be higher in well functioning teams.

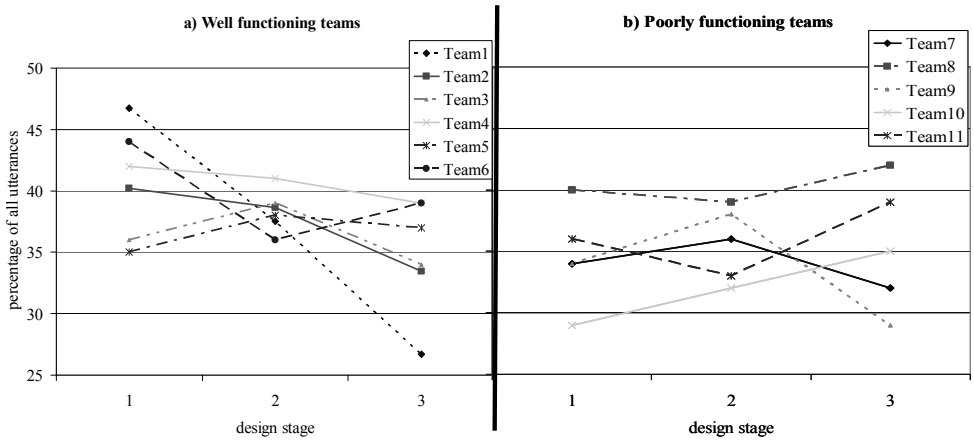

Figure 3. Coherence utterances for well functioning teams (a) and poorly functioning teams (b)

Our theoretical model predicts that teams that share their representations about the process earlier later on require less explicit coordination . It has been shown that better planning, which is one major aspects of process, helped to increase the sharedness between team members and by this improved team performance [Stout et al. 1999]. Figure shows the frequencies of process utterances of well (a) and less well (b) functioning teams. The well functioning teams showed comparatyively more process utterances in the beginning of their collaboration, and the frequencies of process utterances decreased in the well functioning teams but not in the other teams.
No conclusive results were found for team coordination. The category occurred only very infrequent (around 1% of all utterances) and no changes over time or between groups could be identified. A plausible explanation for this is that the design task was limited to a short time period, so there was no opportunity or need to learn about each other's strengths and weaknesses.

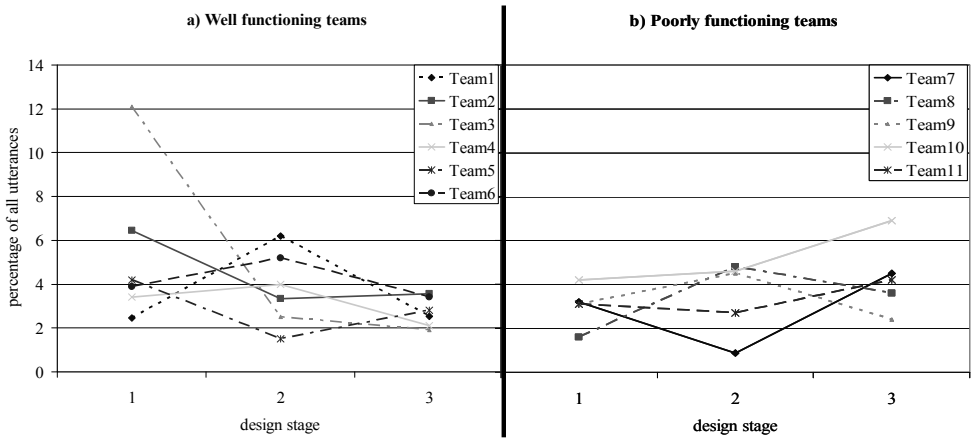

Figure 4. Process utterances for well functioning teams (a) and poorly functioning teams (b)

5. Discussion

The results offer support for the theoretical model of how mental models in design teams are shared and how this influences the coordination between team members. Firstly, cohesiveness was identified as one important factor for good team functioning, and it was also correlated to a higher rate of new ideas as an indicator for more innovative teams. Teams that function well seem to care more about the team, however, as some level of shared understanding has been reached, the number of utterances decrease during the design process.

Secondly, teams that perform well seem to reach a team mental model about the process coordination. The number of explicit process coordination utterances decreased more in the well functioning teams than in the others. Sharedness about the process coordination seems vital for good teams functioning. This would mean that teams should not only apply a design method; they need to share their view on how to apply this method to the task at hand.

The proposed research method provided a useful approach to study and understand factors that influence successful product design in teams. Although implicit coordination is generally difficult to asses, this method offers a good framework to conclude how sharedness is developed in teams. The findings offer useful insights and conclusions for collaborative design research and team diagnosis in practice. The results have shown that both team cohesion and process coordination are both important aspects of deisign collaboration and that reaching a sharedness about those aspects can help successful team functioning.

The findings have direct practical implications for design teams in industry. The results clearly demonstrate that coherent teams function better than teams that do not. Teams perform better if they work in a team formation in which the team members share their perceptions about important contextual factors and in which they feel safe to perform. These findings are in line with previous research that has suggested that a strong team climate improves innovativeness [Anderson & West 1998]. Consequently, the effectiveness of teams can be improved by fostering team coherence, either by a careful selection during the team composition, by applying effective team trainings and by maintaing the same team composition for longer time intervals.

Regarding the process, it seems that teams that spend time on clarifying how to approach the current task function better than teams that do not. The proposed model and the results indicate that such teams indeed develop early more sharedness about the process. According to a method or design approach, well functioning teams do not only talk more about the process, they develop a shared view on it. That means that effective teams internalize their understanding of the process in a similar manner. In turn, they coordinate their process more efficiently, resulting in better performance. The

effectiveness of teams could therefore be improved if team members not only follow the instruction of a specific design method, but rather share their understanding of *how* to apply a given method. As a consequence, teams should be encouraged to explicitly discuss their views on the right approach and they should take the time to do so. Both the findings related to coherence and for process clarification support that time spend on team secondary processes is not a wast of time but an investment well worth making.

More studies in this area will help to better asses the underlying cognitive processes that influence team coordination and to improve the understanding of mental models in design teams. In particular, more studies in design situations in industry are needed to expand the results from this study to teams in industry. Ongoing and planned studies aim to apply this method to gain a better understanding of the social and cognitive processes that guide design teams. This will help to form a better understanding about the forces that distinguish between good and poor collaborative design.

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