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BARRIERS TO SHARED UNDERSTANDING IN COLLABORATIVE DESIGN PROJECTS

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Abstract:

Collaborative design requires extensive communication between participants. Participants have to create shared understanding about the design content. The individual perspectives of the participants must be brought into coherence in order to develop new products successfully. Communication during collaborative design may lead to barriers, because participants have different perspectives and interests that may interrupt cooperation. Besides, there is no shared understanding between the participants due to lack of knowledge of each other's work domains.
Literature describes barriers on three different levels, the participant-, project and organizational level. However, literature does not provide inside into what types of barriers occur during collaborative design. Therefore a hierarchical case study was done.
The purpose of this empirical study is to map barriers that occur during collaborative design. To do that, we interviewed people from different disciplines in an automotive company. All participants were involved in the same project.
The interviews were analyzed according to the learning history method. This method appeared to be suitable to map communication barriers in collaborative design. We found barriers on the three levels the literature acknowledged.
The empirical study demonstrates which barriers occur in which phase in the NPD process. It also provided insight in the types of communication barriers that occur during a particular design task of the participants.

Keywords: Collaborative design, shared understanding, integrated product development

1. Introduction: communication in collaborative design:

More and more product development projects are performed in multidisciplinary teams to meet the demands of shorter development time and the growing complexity of products [1], [2]. This collaborative design raises new organizational and social issues in new product development.

Many companies have introduced stage-gate model (see for example [3]) to synchronize activities in the product creation process. These stage-gate models provide clear process steps for different phases in the new product development (NPD) project and separate these steps with tollgate decision making. The rationality behind this type of model implies an undisturbed flow of activities in collaborative design. Practice, however, still shows that collaborative design projects do not run smoothly at all.
The reason for this is that the actual participants of new product development projects are human beings, who are not just cogs in a machine, but who have individual beliefs, interests, knowledge and experience. In effective collaborative design these individual perspectives must be brought into coherence [4]. Shared understanding on the design is needed in order to

work together efficiently [5] ,[6], [7]. This shared understanding must be created through communication between all participants in the project. Communication in collaborative design projects involves information and documentation on the design (e.g. lists of requirements, briefings, cad-files) as well as the oral communication on these design issues and the design task.

Communication may cause problems in collaborative design. Participants have different backgrounds and therefore different perspectives.
They also come from different departments within the company, which may lead to contradictory responsibilities. Participants may very well be in competition with each other and negotiations and trade-offs are required to bring participants' efforts into coherence [4]. For example, an electro technical engineer will argue for an optimal solution for the electronic circuit in the product. An ergonomist, however, will argue for optimal ease of use. It may be the case that the electro technical engineer needs a certain space for the circuit board, but using this space will make it impossible to create an easy to use product, because it is too big to handle. The electro technical engineer and the ergonomist will have to negotiate. Negotiating is difficult, because the electro technical engineer will describe the product by means of circuits, calculations and voltages. The ergonomist will describe the same product in terms of measurements of the human body and consumer demands. The engineer and the ergonomist communicate in a different way about the product and from different perspectives. They use different language and different representations on the design, which complicates the creation of shared understanding between them [7], [8]. We do not know much about these problems in design communication or their consequences. We call them barriers, because they hamper collaboration within the design project and therefore the product development process.
In this research project we will investigate these communication barriers in collaborative design. This will lead to the identification of barriers and investigation of types and relations. We will do an extensive empirical study in an automotive company. To analyze communication barriers intensely case studies will be done. In this paper we will describe the empirical study and its results. The first step, however, is a deeper theoretical investigation on barriers in collaborative design projects.

2. Theory: barriers in collaborative design projects:

We look at barriers to shared understanding to collaborative design. Barriers are events that hamper cooperation and communication.
Communication barriers between participants of a collaborative design project executing a (design) task in a product development project are called barriers on the *participant level.*

Empirical research of Bucciarelli [8] and Valkenburg [7] indicates that communication between participants from different disciplines is difficult, because different disciplines use different languages and representations of the new product. This impedes the creation of shared understanding between participants from different disciplines [6], [7]. Bucciarelli emphasizes the participants' different perceptions on the design task, which he calls 'object worlds' [8]. Object worlds contain someone's: used language, perception on the project and the product, experience and knowledge. During collaborative design people 'act' as if they live in their own object world. Object worlds are expressed during communication. (E.g. by drawings, schemes and texts.) An example of a barrier, which we see, on the participant level is: *The developer does not know how to interpret information from the marketer, needed to fulfill his task.* This example shows a communication problem between two participants from

different disciplines, which makes executing the design task difficult. Barriers on the participant level are defined as: *Communication barriers on the participant level have to do with the way direct communication takes place between two participants executing the design task.*
During product development participants are organized in a project team. The project team forms the context for participants to execute their design task. There are also barriers due to this context. We call these barriers communication barriers on a *project level.* Barriers on a project level are related to project management factors like time, money, quality, information and organization of product development projects. [9], [10] Communication barriers on this level have to do with the planning, organization and control. In a project there are always unexpected issues, which hampers the monitoring and control process. An example of a barrier on the project level is: *A key figure of project X leaves the project.* The knowledge of the key figure is gone and within the team tasks need to be reshuffled. A new communication structure is needed. The project structure needs to be redefined. Change does not concern the whole organization, but it changes the project team. Barriers on the project level are defined as: *Communication barriers on a project level have to do with the project management factors time and money or factors of organizational nature specific for a particular project.*

The project itself also has a context; the organization. The organizational context may also cause barriers. Communication barriers on an *organizational* level are related to interface problems between different departments within the company [11], [12]. An example of a barrier on the organizational level is: *The location of production plant is 80 kilometers from the development department.* This complicates communication between production and development, because the distance hampers face-to-face contact between the two departments. This leads to less communication and interpersonal activity. Another problem is that informal talks around the coffee machine do not take place, which delays decision-making. Barriers on the organizational level are defined as: *Communication* b*arriers on an organizational level are specific for the company, but not specific for a certain project or person.* Change needs radical measures, for example, moving the production plant. In this research project we consider organizational barriers as context variables for communication between the participants.

In this research project we focus on the participant level, because we want to improve communication between participants. Improvement is needed, because effective communication proves to be a determinant of success of collaborative design [4], [5], [7], [11], [13].
The literature on communication in a collaborative design project is very young and explorative. Empirical studies indicate the problems that participants face in collaborative design practice. However, these studies do not yet provide us with answers to the problems indicated. We do not know what exactly the kinds of barriers are that occur during collaborative design.
Therefore we will do empirical research. In an empirical study we want to investigate which type of barriers originate during a collaborative design project due to inefficient communication between participants from different disciplines. We will investigate if we can detect barriers and if there are barriers on different levels. We will use the three levels, participant, project and organization as a starting point.

3. Research method: Hierarchical case study:

In order to get a deep understanding of communication barriers in practice, case study research will be the best research strategy [14]. An extensive case study was done in an automotive company with 6.500 employees. The research project was about a product development project of a midlife update of an existing car. The project team was multi-disciplinarily and team members worked dedicated to the project. The project took two years and was conducted according to the stage gate model of the company.

We choose to research the product development project from the perspectives of different key figures from different disciplines. To do this, the Learning History method was used. [15] This method provides a structured and transparent way of analyzing cases. The goal of this research method is to create a learning organization. The way to achieve a learning organization is by telling stories of projects. The stories are realized by interviewing people involved in a certain project, as we did in our study. One interview gives the perspective of one participant on (a part of) the project. It represents his experiences and understandings; his history. The second step of the method is the transcription and analysis of the data. From the transcriptions of the interviews key themes and 'plots' are established. By combining the histories, of the different participants a story originates. The transcribed part of interview of one participant is put in a column on the left side of the page. The analyses are put in a column on the right side. The analyses are called the 'jointly told tales'. The 'jointly told tales' reflect a project from the participants' perspectives. Learning takes place because lessons can be learned from the jointly told tales. The interview provides the context in which activities took place

3.1. Data gathering:

We collected data by interviewing seven participants involved in the project. All key figures, we selected for our study, were concerned with the development of the interior of the car. The key figures were: the two project leaders (case 1), the market researcher (case 2), the program description book maker (case 3), the ergonomist (case 4), the mechanical engineer (case 5), and the electro technical engineer (case 6) the production manager (case 7).
The roles of the key figures within the team differed with respect to department they represented and organizational level within the company.

The interviews lasted three hours and were taped. The interviews were done to get the perspective of the participant on the product development project. The base of the interviews was communication between disciplines. We asked each participant how he experienced the communication between the team members. No further structure was given, because we did not want to influence the perspective of the participant. Next to the interviews desk research was done. Important documents of the participants were read in order get a better understanding of the project and to verify the content of interviews.
The interviews lead to 20 hours of tape. Desktop research provided more than 250 pages of text and 150 slides from presentations held during the product development project.

Data collection took place over a half-year period. The case study was done during market introduction, so it was retrospective for the participants involved. The perspective of one participant was considered as one case. With exception of the case of the two project leaders, because their responsibility in the project was sequential, we indicate their interview as one case over the whole NPD project. The research project contained seven cases.

3.2. Data analyses:

The next step was the analyses of the data. The case study analysis was executed hierarchic. First each case was analyzed separately, on the existence of communication barriers. Second, a cross case comparison was made. The barriers of all cases together were analyzed and categorized.

3.2.1. Identification of the barriers:

The learning history method was used to analyze the data. We chose to make separate learning histories of each case, because they may help explaining the barriers. The seven cases were ordered in a chronological way according to the stage gate model of the company. The interview was coded and was put in the left column on a page.
The coded pieces of interview were analyzed. The analyses are put in a second column on a page. Both columns form the learning history of the product development project according to one participant.

From the learning histories communication barriers were distilled. Barriers are events that hamper cooperation and communication. Barriers have, for example, to do with the interfaces between departments, communication about the planning and control of the project and communication about the design task. Two researchers distill the barriers by analyzing the Learning histories on these kinds of activities.
Barriers are represented in clear statements of one or two sentences, describing what exactly the problem is. The barriers were put in the third column on a page. An example of a barrier is: *Development changed the concept in a way that the assembly of certain parts was impossible.* The lack of knowledge of the developer about assembly techniques caused a communication barrier between the developer (case 5) and the production manager (case 7).

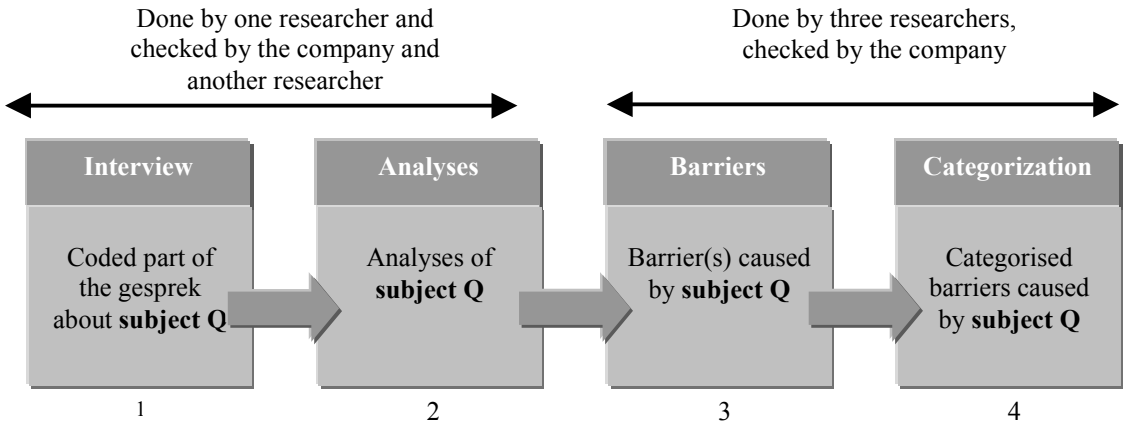

Figure 1: Schematic representation of the research steps

The cases were represented on a page according to the four columns of figure 1. Presenting the case study like this makes it possible to provide a clear view of the different steps and the accompanying interpretations of the researchers. This makes it possible to check the data with the participants involved as well as with different researchers. The participants actually checked the second and third column; the analyses of the interview as well as the distilled barriers.

When a researcher finds an interesting barrier in the third column, the context in which the barrier took place can be found in the second column. The exact quotation of the participant can be found in the first column. The fourth column gives the categorization of the barrier.

3.2.2. Categorization of the barriers:
The next step of the data analyses was the categorization of the barriers. In this research step the cases were united. The barriers of all seven cases are categorized according to the three levels found in the literature; barriers on the participant level, project level and organization level. Categorization is done in a multi-coder setting in a workshop with three researchers. The researchers got definitions of all three categories, as described in the theory section of this paper. The researchers were asked to categorize the barriers. The researchers also categorized according to the phases of the stage gate model used by the company. This was done to order the barriers in a chronological way. If a barrier could not be categorized the researcher had to put it in a rest category. After individual categorization, the three researchers had to synchronize their choices.

The three researchers categorized the barriers according to the three levels: participant, project and organization. 30% of the barriers were put immediately in the same category by all three researchers. 64% of the barriers were put in the same category by two researchers. The three researchers categorized 6% of the barriers differently. In the discussion all differences could easily be explained and solved.
The researchers also categorized the barriers according to the phases of the stage gate model. 52% of the barriers were put immediately in the same phase by all three researchers. 49% of the barriers were put in the same phase by two researchers. The three researchers categorized 1% of the barriers differently. In the discussion all differences could easily be explained and solved.

4. Results:

From the learning histories 97 barriers were distilled. There were 44 barriers on the participant level. An example of a barrier on the participant level is: *The engineers do not exactly know the purpose for what the new car is developed.* The cause of this barrier is the lack of shared understanding between the market researcher (case 2) and the developer (case 5). The market researcher thought it is obviously that a developer knows what kind of car was meant, but the engineer did not know and thought that the market researcher had formulated wrong requirements.

There were 33 barriers on the project level. An example of a barrier on the project level is:
The project delayed due to the long decision making process about the project authorization.
Because of this the market researcher and the ergonomist (case 1and 3) got more time to fulfill their tasks and share their information with other participants. However the project had a strict deadline, so the development participants (cases 5,6 and 7) had less time to fulfill their task.

An example of a barrier on the organizational level is: *At the end of the development process, problems are not solved adequately, because engineers are no longer dedicated to the project.* At the end of a NPD project the project came in the maintenance phase. During the maintenance phase less and other participants are involved in the project than in the development phase. This leads to lack of knowledge and experience of the participants. There were 20 barriers on the organizational level found.

Figure 2 shows the distribution of the barriers over the different cases. The cases are ordered according to the stage gate model of the company. The figure shows two remarkable things.
First, the last three cases had almost twice as much barriers as the first three cases. This can be explained by the fact that the developer, the production manager and the software developer had tasks on an operational level in the concept- and engineering phase.
Second, the ergonomist executed his task on the operational level in the concept phase, but he did not face many communication barriers. This was because the team around the ergonomist did a comparable project before. The team used the knowledge and experience from that project to avoid barriers.

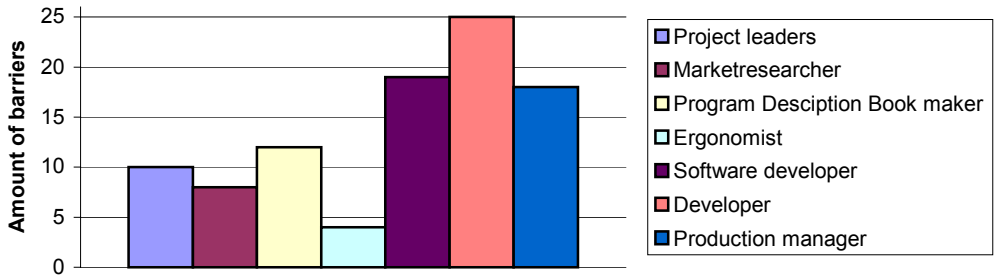

Figure 2 The amount of barriers in each case

Figure 3 shows that of the 44 barriers on the participant level five occur in the definition phase, seventeen in the concept phase, nine in the engineering phase, five in the volume validation phase and eight were phase independent. The concept phase clearly had the most barriers on the participant level. It is not surprising, because during this phase there was a lot of interaction between participants from different disciplines. Communication in this phase was about concepts and ideas, traditionally difficult subjects to communicate, because the product does not exist in reality. People from different disciplines represented the new product in different ways, which may have lead to communication barriers.

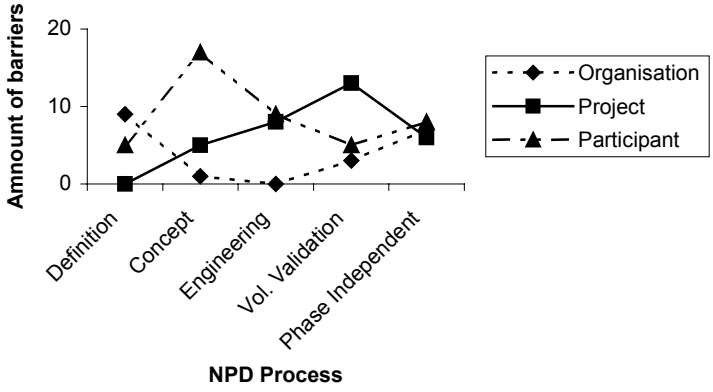

Figure 3: Types of barriers in each phase in the NPD process

A typical barrier on the participant level in the concept phase was: *The CAD engineers of a supplier had a 'family car' frame. This causes imagination troubles by the development of 'an exclusive sports car'*. There was no shared understanding between the engineers of the supplier and the automotive company. The experiences in the family car industry made

the CAD engineers use expensive tools and techniques. The engineers of the automotive company did not know that. The consequence was that the engineers of the automotive company could not contract out as much work as they wanted. They had to help the supplier.
Looking at the 33 barriers on a project level none occurred in the definition phase, five in the concept phase, eight in the engineering phase, thirteen in the volume validation phase and seven were phase independent. The amount of barriers increased as the NPD project progressed, because the planning and control became more and more critical.
A typical barrier at the volume validation phase was: *Test vehicles had to be changed because of quality issues.* This barrier was caused by problems that were postponed.
Of the 20 barriers on a organizational level nine occur in the definition phase, one in the concept phase, none in the engineering phase, three in the volume validation phase and seven were phase independent. From this can be concluded that most organizational barriers occur during the beginning of the NPD project and that organization barriers are often phase independent. Organizational barriers occurred in the beginning of the project because at the project start, people and resources were removed from the organization to the NPD project, which may cause communication barriers. A typical barrier at definition phase was:
At the project start there were not enough participants dedicated to the project.
At the project start, not enough participants could be dedicated to the project, due to other activities in the organization.

There are many phase independent barriers on the organizational level, because the organization is independent from the stage gate model followed by the NPD project team. So, organization barriers occur independent from the stages of the project. A typical barrier at phase independent was:
In the automotive company, there is too less job-rotation, which causes lack of shared understanding between disciplines.

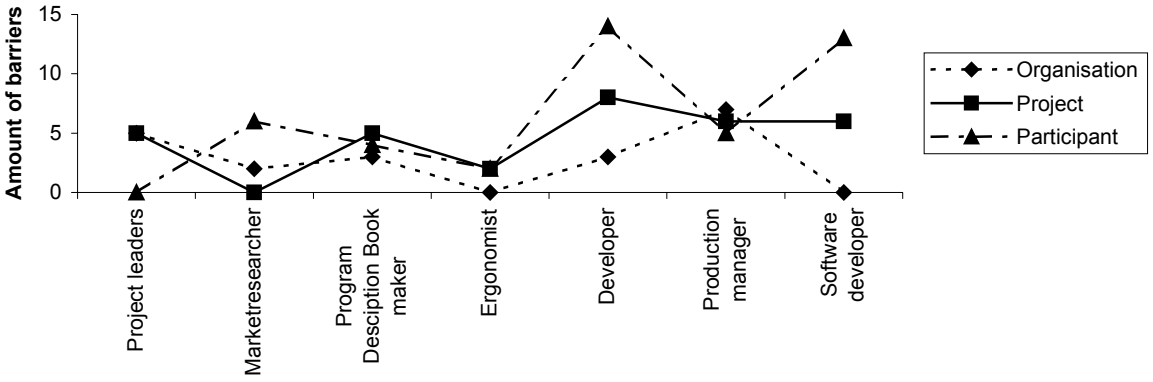

Figure 4: Types of barriers in each case

Figure 4 shows that barriers on the participant level mainly occurred in the cases of the market researcher, the developer and the software developer. They are operational parties who have to communicate much about the design content with different disciplines within and outside the organization. The market researcher is responsible for the translation of market information into information useful for the different developers. Developers need to absorb the information of the market researcher and have to communicate this information other developers within and outside the organization. This is a difficult process because the representation of the information of the customers is different from the representation of the

market researcher and the developers, especially for participants outside the organization. They have communication barriers on the participant level, because they have to understand what the people from within the organization mean with certain concepts and representations of the new product and they did not know the solution space of their design task. This problem also plays with inexperienced participants within the company.
The project leaders do not have barriers on the participant level. They communicate less about the design content, because they do not have a task concerning the content of the NPD project.
Looking at figure 4 at the barriers on the project level it is remarkable that all parties have about the same amount of barriers on this level except for the market researcher. This could be because the market researcher performed his task before the NPD project started. During the project he was responsible for knowledge transformation, not concerned with planning and controlling a certain task, so no barriers at the project level occurred.

Barriers on an organizational level occurred mainly in the cases of the project leaders and the production manager. The production manager had for example problems with human resources, because the project came in the maintenance phase, which made developers leave the project. Other developers replaced them; information and experience about the project got lost, and may cause communication barriers.
Project leaders are closely related to the organization. They form the interface between the project and the organization, which explained communication barriers on the organizational level.

5. Conclusions:

In this paper we showed barriers on the three levels, the literature acknowledged, exist (participant, the project and the organizational level). The empirical study proved that barriers could be distilled. Categorization in a multi-coder setting showed the barriers could be categorized on the three levels.

Categorization of the barriers provides insight to the types of barriers that occur during collaborative design. The empirical study demonstrates which barriers occur in which phase in the NPD process between operational participants. Barriers on the participant level are occurring most in the concept and engineering phase. In this phase, a project leader should, more than in other phases, pay attention to the actual communication between the participants from different disciplines. Looking at the content of barriers on the participant level, it may be concluded that the existence of object worlds [8], is the main cause of communication barriers.
Barriers on the project level increase during the project. A project leader may control this by not pushing existing problems forward.
Barriers on the organizational level occur mostly at start up of the project. A project leader should be aware of developments the organization, because they influence the NPD project.

Looking at the barriers on the different levels we found themes of barriers, e.g. barriers due to the interface between marketing and development. It seems that there is a relationship between barriers on a different levels. If there is a barrier on the organizational level, there will also be barriers on the project and participant level. This has consequences for the decisions to be taken to solve the problems. In future research we will further investigate what exactly the relations are and what the consequences of this relationships are.

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