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DESIGN COMMUNICATION IN INDUSTRY: A SURVEY ANALYSIS

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1 Introduction

Design processes are changed by the progression of globalization. Consequences are, among other things, that more and more design teams are not located at one spot anymore, but work locally distributed [1]. The performance of distributed working design teams compared to collocated working teams is observed as less efficient. One possible reason for this is that communication in distributed working teams is less effective than in collocated teams. [2]. However especially in distributed teams communication, as well as sharing and management of information, is necessary to maintain the collaboration [3]. Thus, communication media play an important role when investigating distributed design.

Our objective, concerning distributed teams, is to find out, which communication media enterprises are using now and what kind of communication media are desired by designers in practice. To achieve this, a survey among engineers from industry was carried out. The survey is part of the DFG funded Project: "Integrierter Kommunikationsraum für die verteilte Produktentwicklung" (DFG – Li 699/11-1)

2 Method

In addition to the question what communication media are used in industry generally, we were interested in the question if different situations concerning the distributed development process require different communication media.

2.1 Situations regarding different levels of product abstraction

It is assumed that the suitability of communication media depends on the kind of information to be transferred. Taking into account that effective support of the exchange of product information plays an important role during product development in distributed environments [4], it can be deduced that different "kinds" of product information will affect the suitability of communication media. The authors claim that the level of abstraction of the product information influences the suitability of communication media. Pahl and Beitz [5] and Ehrlenspiel [6] divide the design process into the following sub processes: Clarification of Task, Conceptual Design, Embodiment Design and Detail Design. Over the entire process product information becomes more and more concrete. Ostergaard et.al. [7] introduce a taxonomic classification of collaborative design. Among other factors they state that the stage of the design phase may affect the collaborative design process. They identify the levels of abstraction classified as Concrete, Intermediate, and Abstract as a possible influence factor, too.

Considering means of communication broken down into the communication elements: Speech, Text, Sketch and Gesture by Huet et.al. [8] it becomes apparent that working on very abstract product information e.g. a requirements list in the stage of task clarification needs other communication elements and media compared to working on a more concrete product information e.g. a function structure in the stage of conceptual design.

This leads to the following classification of situations:

- Working on abstract product information, like working on requirements lists, reports, specifications or other information in the form of text.
- Working on intermediate product information, like working on sketches, function structures, diagrams or other information in the form of abstract models or diffuse product models.
- Working on concrete product information, like working on CAD-models, technical drawings, DMU-models or other information in the form of precise product models.

The following proceeding was applied to obtain information about the use and the importance of communication media in general and according to the above specified situations:

A survey was carried out by means of a questionnaire about the use and importance of communication media. 30 copies of the questionnaire were handed out as printed paper. Additionally the questionnaire was published in internet via website. Engineers from industry were asked via E-Mail to visit the website and to fill out the questionnaire, which was linked to a SQL-database. The participants where asked to leave their E-Mail addresses. To provide anonymity the E-Mail addresses were separated from the collected data. Afterwards they were used to invite the participants to a workshop in which the results where presented and discussed. The discussion during the workshop was recorded by writing minutes.

2.2 Questionnaire

The survey was composed of three different parts. Most of the questions had to be answered using “multiple choice”. Some of the questions included the possibility to frame an answer.

In the first part facts about participant and company were asked to get a general impression. One focus was the size of the company and the number of distributed locations:

- Field of activity of participant
- Number of employees of company
- Number of locations of company
- Spreading of locations

In the second part general questions about media in distributed development were asked. Amount and effect of distributed work and available and desired communication media were collected. One focus was to find out if the participants felt that communication media affect distributed working.

- Percentage of overall working time characterized as distributed working
- Negative effect on work due to distribution
- Potential of improving communication media
- Available communication media

– Desired communication media

Part three focused on the use and importance of certain different communication media in specific situations. The particularly examined media(groups) were: Mail, Fax, E-Mail, Telephone, Videoconference, Shared Application, File Sharing, Chat and Virtual Reality (VR) based communication media. To prevent misunderstanding, the media, apart from Mail, Fax, E-Mail, Telephone and Videoconference were shortly explained:

Shared Application provides the possibility to observe the screen of your dialog partner and to interact on the computer of your dialog partner. File Sharing provides the possibility to exchange and deposit files by means of a common server. Messenger/Chat provides the possibility to send and receive text messages which appear instantly on the screen of your dialog partner. Virtual Reality (VR) based communication media provide the possibility to display "real 3-dimensional" objects using stereo visual effects, usually by means of special hardware.

Use and importance of media were examined according to the specific situations discussed in section 2.1. A certain pattern of questions was asked regarding each of the above stated media to investigate the relationship between use and importance of certain media and specific situations, to gain information about special strength of media and to understand why certain media are not used:

– Use of medium
– Frequency of medium usage
– Importance of medium
– Strength of medium
– Weaknesses of medium

2.3 Workshop

To obtain further information and feedback about the results a workshop was organized. After the results of the questionnaire had been evaluated the participants of the questionnaire along with other interested people from industry were invited to participate. The results of the questionnaire were presented by means of an oral lecture. Following the lecture a discussion was held. Topics of the discussion were:

- characterization of communication in distributed collaboration,
- general basics for distributed collaboration and
- important aspects if one wants to provide suitable communication media.

The main aspects of the discussion were recorded by writing minutes.

3 Results

In this section results of the survey and results of the workshop which followed the survey are presented.

3.1 Results of the survey

30 paper questionnaires were handed out of which 13 returned. 17 questionnaires were answered using the internet version. Altogether 30 people from 19 different companies participated in the survey.

Concerning general information about the participants (Figure 1) it can be deduced that the majority's field of activity was Research and Development (R&D) and Design Engineering. Some had activities in Management. (In this question multiple answers were possible). The typical company the participants work for has more than 2000 employees and more than 10 locations which are spread over several continents.

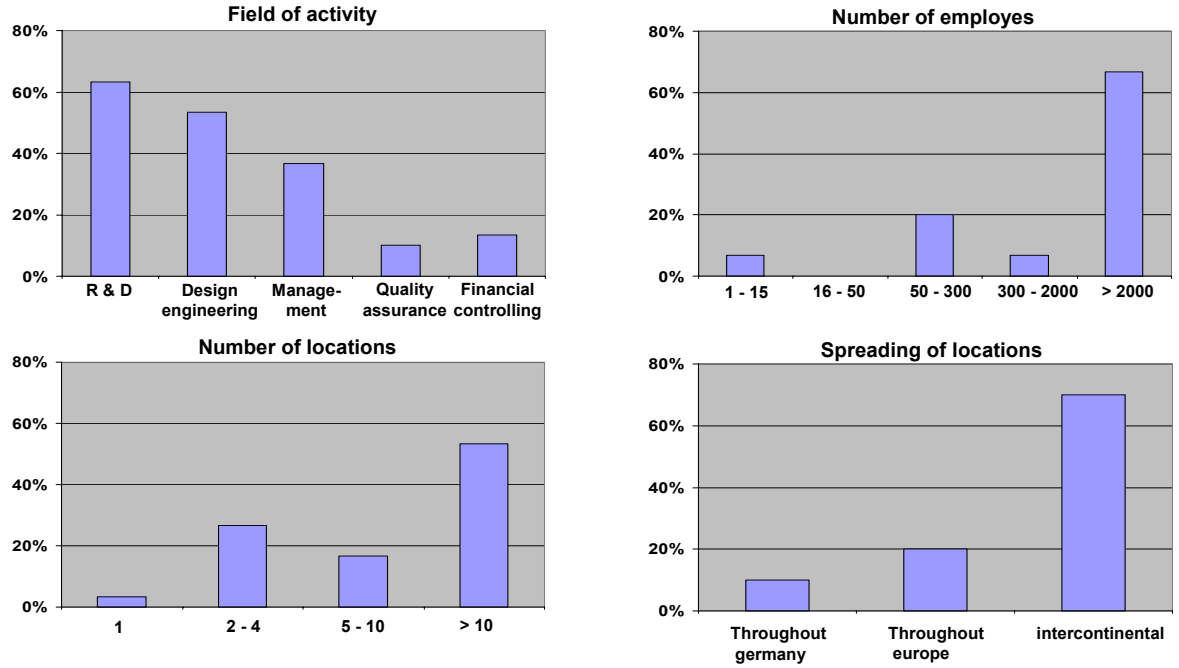

Figure 1. General information about participant and employer

Only 3% of the participants stated that they spend less than 5% of their working time distributed (using communication media). 50% of the participants do this 5%-20%, 17% of the participants do this 20%-50% and 30% of the participants are working more than half of their time distributed using communication media. (Figure 2)

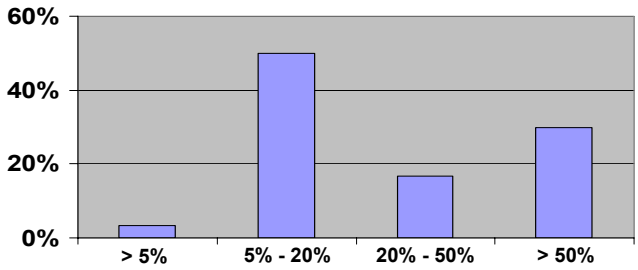

Figure 2. Percentage of your working time characterized as distributed working (using communication media) on projects?

The negative effect on their work due to distributed work was estimated variously. 7% stated that they did not feel negatively affected at all, but most of the participants answered that

distributed work influences their work in a moderate to pronounced negative way (Figure 3). The potential to enhance the design process by improving the communication media was considered an average of moderate to high. 44% of the participants state a high or very high potential to enhance the design process by improving communication media. 33% declare moderate potential and 23% specify a low or very low potential to enhance the design process.

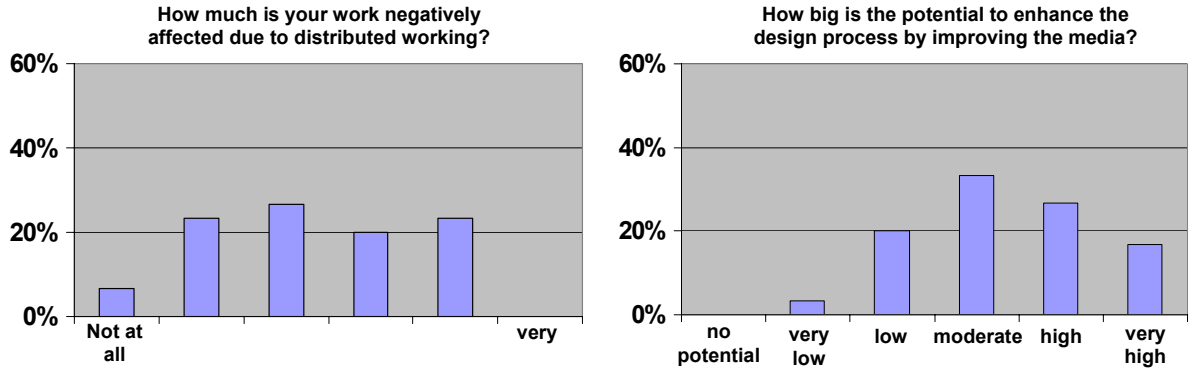

Figure 3. Negative effect of working distributed and potential through media enhancement

The communication media Mail, Fax, E-Mail and Telephone were available to all of the participants (Figure 4). File Sharing was available to more than 87% and Videoconference to 70%. Shared Application was available to 47% and Chat to 20%. VR-Media (7%) were nearly not available.

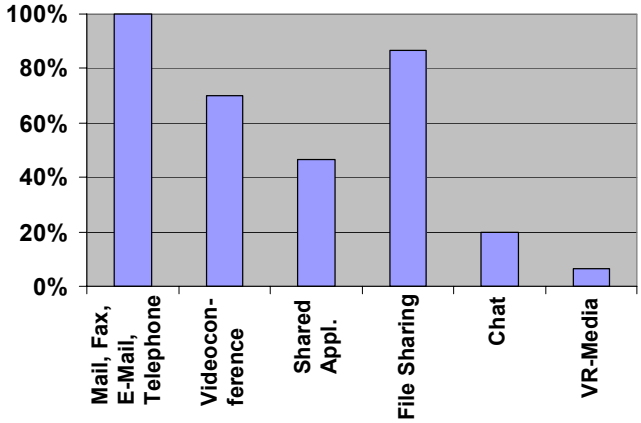

Figure 4. What kinds of communication media are available at work?

Figure 5 shows the kinds of communication media the participants would like to have additionally. Interesting is that Shared Application is desired by 37% of the participants. VR media are desired by 13% of the participants. File Sharing (7%), Videoconference (3%) and Chat (3%) are less desired.

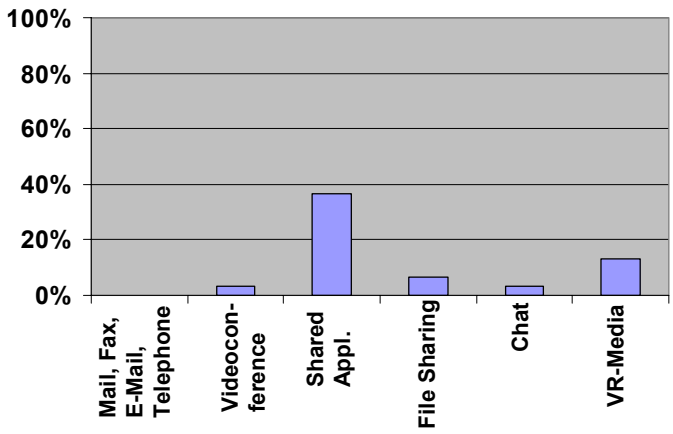

Figure 5. What kinds of media are wanted additionally?

Frequency of use and Importance of media were asked in two independent questions to obtain more precise information about the roles of these media in communication.

Considering the frequency of use of these different media, it can be stated that E-Mail, Telephone and File Sharing are more frequently used then other media (Figure 6). In view of the different process situations, it can be observed that generally in situations with very precise product representations the frequency of using E-Mail is a little lower than in situations with more abstract product representations. Fax is used moderately. The frequency of use of Videoconference, Mail and Shared Application is low. There is nearly no change in media use according to the situations. Chat and VR media are barely used at all.

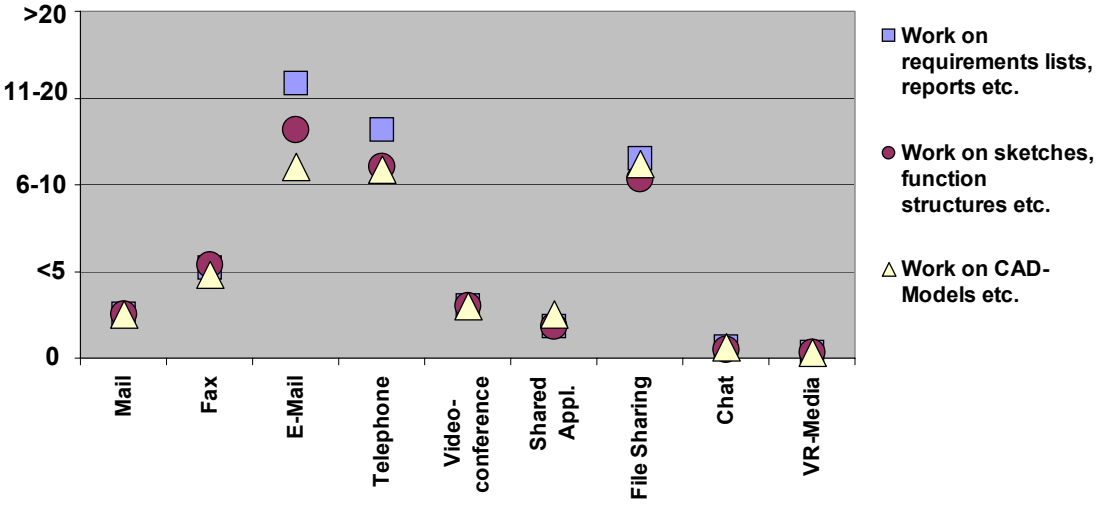

Figure 6. Frequency of utilisation per week (Average of respondents multiple choice)

Considering the evaluated importance of the different media the results show similarities to the frequency of utilisation (Figure 7). E-Mail, Telephone and File Sharing are accounted most important. The evaluated importance of E-Mail and Telephone is slightly decreasing with more precise product information. Videoconference, Chat, Fax and Mail are considered mediocre important. Shared Application is considered moderate important in process situations with very abstract product models. The evaluated importance is increasing with increasing product concretion to a quite high level. VR communication media are considered not important apart from working on concrete product data. On the one hand the importance

of the media E-Mail, Telephone, Mail, Fax and Videoconference decreases with increasing product concretion while on the other hand File Sharing, Application Sharing and Virtual Reality based communication media are considered more important when working with precise product representations.

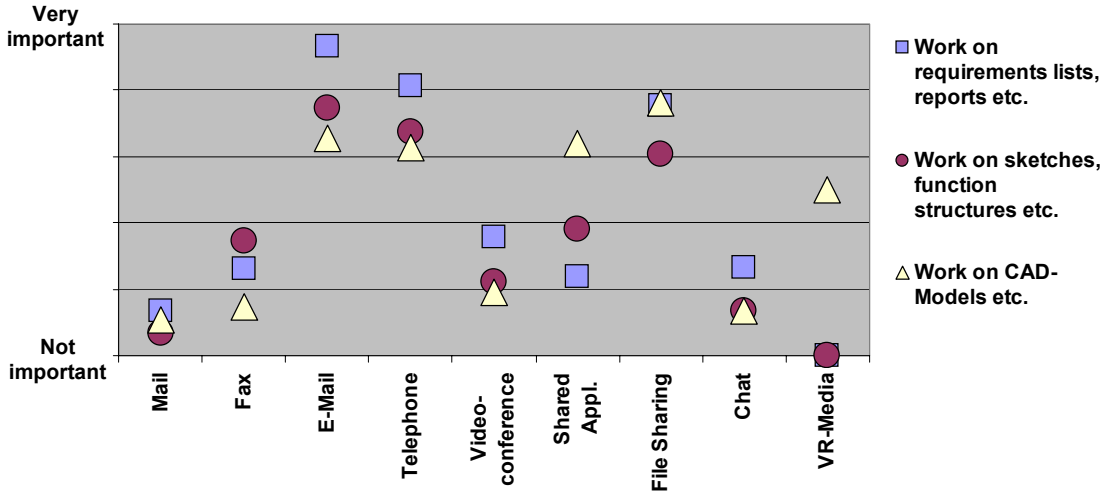

Figure 7. Rating of importance (average of users)

Strengths and weaknesses of the considered media were asked in open text questions. The answers are summarized in the following table.

Table 1. Strengths and weakness of the considered media

Medium	Strength	Weakness
Mail	Mainly security related issues: transfer of confidential information, contracts, certificates, legal documents	Very slow
Fax	Fast transfer of sketches and notes, legal documents	Further treatment of documents is difficult/unhandy
E-Mail	Fast transfer of information and documents to several recipients, good documentation	No direct interaction
Telephone	Swift transfer of information, discussions, especially political, vague or personal topics, quick informal consulting,	Dialog partner should be known, technical details difficult to explain without the support of additional media
Videoconference	Locally distributed discussions with multiple participants (group discussions), difficult topics (conflict potential)	Special Hardware needed, High Bandwidth needed.
Application Sharing	Complementing Video or Audio conference if the topic is complex, graphical representation is needed	Difficult to set up (Firewalls, needs IT support to set up)
File Sharing	Conjoint worldwide access to common data, prevent redundant data in joint projects, distributed work on documents	-
Chat	Quick transfer of short information	E-Mail and Telephone fulfill the same functions better
VR-media	-	Unclear benefit, Ratio of benefit to cost is not acceptable

3.2 Results of the workshop

21 participants from 17 different companies attended the workshop. During the workshop the results of the survey were presented. Afterwards aspects of distributed collaboration and possible support of communication media were discussed. Main statements of the discussion are summarized below:

Aspects which have to be regarded when considering communication media in collaborative environments were discussed. Main aspects were stated as:

- Distribution of team: International, National, Regional
- Number of participants: Single Persons, Groups

Organization of work process (frequency of meetings): Team members work in a completely independent way, team members have regular meetings to share and discuss results, team members work jointly on all tasks.

- Distribution of tasks: within own company, working with supplier
- Nature of problem and concretion of task

Thereafter basic principles and experiences with group working were discussed. Main aspects were stated as:

- As a basic principle the personal face to face meeting between people cannot be substituted by whatever communication media and should be preferred if possible. This is mainly due to the "human touch" of face to face meetings.
- If there are language barriers, mostly psychological barriers appear, too. To cope with these, face to face meetings are best suited.
- If permanent collocated working is not possible, it is strongly recommended to arrange a "get to know" meeting to establish a personal relationship at the start of the project.
- Tasks should be divided properly. The coordination of work should take place in regular meetings.
- Communication is a process between humans. Therefore it has to be kept in mind that it is dependent on mood, motivation, character, feeling comfortable etc. of the participants

Finally aspects of establishing communication media were discussed. The main aspects were stated as:

- The used technology should have reached a certain degree of maturity. Shared Application for instance causes frequent problems and requires usually IT-assistance to set up.
- Security issues, especially firewalls in networks are often more problematic than the local distance.

4 Discussion

4.1 General results

Due to the limited number of participants the data gained in the survey as well as in the workshop can not be stated to be representative for distributed collaboration in general.

Nevertheless it can provide an insight into the status quo of media use in distributed collaboration, especially in German industry. Since most of the participants are working in the fields of R&D and Design engineering, it can be assumed that these results are relevant when considering distributed development processes. Nearly all of the companies the participants work for have several spread locations, a factor which probably enforces the need to work locally distributed.

The majority of the participants spent only a small amount of time working in distributed teams. During survey and workshop it was frequently stated that collocated teams work better than distributed ones. The discussion of the workshop showed that companies try to avoid distributed working if it is possible. But since there are a lot of people working from time to time in distributed teams obviously this can not be prevented totally. This is supported by the proportion of 30 % of the participants which spend more than 50 % of their time on distributed work.

According to the insight that people with personal contact work in a more efficient way (e.g. [3], [9]) the participants of the survey stated that their work is affected negatively by distributed work. A large number of participants claim potential to improve design processes by improving the media. Törlind [10] showed a possible way to do this by finding out that high quality use of audio and video makes it easier to work together in distributed teams.

4.2 Available communication media in industry

Figure 4 and 5 give an overview over generally available media. Common “every day” media like Mail, Fax, E-Mail and Telephone are available to all participants.

File Sharing is available to all but 13% of the participants and of these 50% would like to use it. It is assumed that File Sharing will become a commonly available medium like E-Mail and Telephone shortly.

Even though Videoconference and Chat are only available to some of the participants they are not desired by the participants who can not use them. This might be, because they are not needed by these participants. Vajna et.al. [3] describe the result of a survey carried out with student test persons to evaluate the importance of communication tools. In this survey Chat was considered very important. In that situation the students did not have access to Telephone. This leads to the conclusion that Chat is an important medium when there is no Telephone, but is substituted if Telephone is available.

Application sharing seems to be the most interesting medium. It is partly available, and heavily desired if not available. Only 16% of the participants have no access to Application Sharing and do not want it. However only 47% have the possibility to use it. Application sharing might be a medium of very high interest for designers, because designers transport information within the technical context through, or aided by sketches, physical models and CAD [11]. On the one hand these means, especially sketches and CAD models, are supported best by media with Application Sharing functionality. On the other hand the workshop discussion showed that the establishment of Application Sharing usually causes a lot of problems especially concerning security aspects and requires IT-assistance.

Very few VR media are available to the participants. Some more are desired, but a large percentage of the participants does not want them. It is observed that VR media are only needed in very special situations. E.g. Törlind [10] states that VR programs are useful when dealing with complex geometry. Since they only make sense in very special situations and

usually are combined with the purchase of extreme cost intensive hardware these media will not develop to commonly used media in short time.

4.3 Use of communication media in different situations

Regarding the frequency of media utilisation it can be deduced that the frequency of utilization per week of E-Mail and Telephone slightly decreases with increasing product data concretion (Figure7). This could be a hint that the amount of needed communication is higher when working with more abstract data. The usage of the remaining media does not show a dependency according to the specified situations.

Regarding the evaluated importance of the media, E-Mail, Telephone and Videoconference are rated less important with increasing product data concretion (Figure8). These media provide a more personal communication. Therefore, it is assumed that personal communication in distributed development is more important when working with abstract product data compared to working with more concrete product data. Otherwise the importance of Application Sharing is rated more important with increasing product data concretion. This supports the above statement that Application Sharing is suitable to support the communication based on sketches and CAD models (more concrete product data). The statement that VR media are only suitable when dealing with geometry is supported by the rating, too.

Regarding the specified situations there is, except VR, no dependency that states that a medium is not useful at all in one of these situations. Though some media are used more or less frequently and considered more or less important depending on the situation.

5 Conclusions

Even though distributed teams are less effective then collocated teams distributed work is not avoidable. Communication media play an important role in distributed teams, but it can be observed that not all available media come into operation in industry. Especially new and complex communication media like Shared Application and VR based communication media are only available to some designers. However the request for using these more complex communication media can be identified, but is hindered by technical and security issues. The participants of the survey considered E-Mail, Telephone and File Sharing as the three most important media.

The importance of communication media according to different accuracies of product representations is varying. Main focus of E-Mail and Telephone are situations with more abstract product representations, main focus of Shared Application and Shared VR are situations with more precise product representations. Nevertheless, there is no media (except VR) which is considered not important at all in one of the specified situations.

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