A User-Centered-Design Perspective on Systems to Support Co-located Design Collaboration

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Abstract. This paper describes a contextmapping study that was conducted with designers from three companies to elicit design design-relevant insights into systems that can more optimally support co-located design collaboration. The study aim is to better understand the current and envisioned way of working of design professionals. The main results are a series of considerations regarding preferred ways to: 1) bring and share information in meetings, 2) document their outcome, 3) support multi-user interactions, 4) deal with social norms and protocols, 5) fit the exiting workflow, and 6) facilitate remote collaboration.

Keywords: Groupware, Human activity modeling and support, Ambient and Pervasive Interactions, CSCW, UCD.

1 Introduction

We study co-located collaboration in industrial design teams in order to increase our understanding of the context, people, and tasks, and with the goal to inform the design of interactive spaces that better support such practices. We elicit from such teams problems and issues that they regularly experience, and probe them to envision an alternative future in which the identified issues are resolved with the help on new (and speculative) support systems.

2 Background

Conducting design activities in teams is becoming increasingly popular due to the growing technological sophistication and complexity of new products. In fact, research has shown that in some cases team co-location can lead to higher productivity with shorter schedules [7, 8].

The emergence of novel hardware such as interactive displays, ambient sensors and digital pens at relatively low prices, together with advances in computer vision and speech recognition, are providing new opportunities to create previously unimaginable interactive spaces, including those to support co-located collaboration.

New technologies only provide new opportunities, and determining the specific requirements for systems that fit a particular community of practice is not a trivial

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task. Scott and Wallace [9] argue that in order to design usable and effective systems, a clear understanding is required of common interactions between the users, accounting for social, cultural, activity based, temporal, ecological and motivational considerations.

3 Related Work

A number of relevant studies can be found in literature. Tang [6] carried out a series of observations on teams conducting group-drawing activities. He found out that hand gestures of participants are not only used to *mediate interaction*, such as negotiating turn-taking, but also to *express ideas* and to *convey information*. He observed that while creating and discussing drawings, much information is conveyed, some of which is not retained in the sketches that are the output of the session.

Bardram [1] describes collaborative work as a highly dynamic activity and suggests different levels of activities including *co-ordination*, *co-operation* and *co-construction*. He concludes that in order to be able to meaningfully support group activities, we must carefully examine the work activities at all three levels, and pay especially attention and support to the transitions between them.

Gutwin and Greenberg discuss the difference between designing systems for individual and group work [2]. According to these authors, individuals demand powerful ways to interact with the workspace, while the challenge for group work is to maintain awareness between the participants. They propose a series of techniques to minimize the tradeoffs between these two sets of requirements (i.e., provide multiple viewports, process feed through, include action indicators and view translations).

Amongst others, the aforementioned principles have been an inspiration for recently developed systems. The authors of such systems have also conducted different forms of user studies that revealed additional requirements. An example of such work is the *NiCe* discussion room from Haller et al. [3], for which its authors conducted an exploratory field study with a large steel company. A series of interviews and workshops were carried out for determining requirements in terms of business modeling, mock-up evaluation or requirement specification. Such studies led to new requirements such as: designing to support a *Diversity of Tasks,* to make *Use of Space and Accessiblity,* to *Foster the Creation of Shared Content,* or the *Integration of Individual and Shared Workspaces.* As part of the design of the WeSpace, a Shared Multi-Surface Collaboration System for data visualization, Wigdor et al [10] carried out a series of ethnographic studies to analyze the current practice of research-related group meetings of astrophysicists. These ethnographic studies lead to the following requirements: *Provide a Shareable Display, Allow the use of Personal Laptops, Maintain Interactivity of Existing Applications, Retain User Control Over Personal Data, or Provide a Record of the Meeting.* Some other systems have followed a more technology-push approach, as their aim was to solve technical challenges. An example of this latter approach is *Pictionaire,* where Hartmann et al. [4] created a collaborative system that integrates Physical and Digital

artifacts by means of interaction techniques such as *Searching & Tagging, Physical-to-Digital Transitions, Remote Highlighting and Image Organization.*

Our approach differs slightly from the previous studies, mainly because the aim of our research was not to collect particular requirements, but instead to gain an improved insight into what motivates designers when conducting group activities, into the pitfalls they encounter, or their visions and aspirations for future systems.

4 Study Description

4.1 Subjects of the Study

Fifteen participants participated in our study; five from each of the three companies. These companies were active in very different application domains: document management and printing systems (Company A), food processing equipment (Company B) and automotive (Company C). Additional information on the background of the designers involved is provided in table 1.

Table 1. Number of participants for each of the domains of practice

Domain of Practice	Number of Participants
Product Designer	2
Interaction Designer	1
Usability Engineer	1
HMI Specialist	2
Sales representative	1
Mechanical Engineer	2
Mechanical R&D Designer	2
Visual Designer	1

4.2 Method of the Study

Contextmapping is a generative research method that actively involves users and stakeholders in the design process through a series of exercises. The primary goal is to understand their everyday life experiences and to gain tactic knowledge about the context of use [5]. Contextmapping can also provide access to people's visions, aspirations, fears and ideas about the future. We utilized this method in our study because we not only wanted to learn how designers hold co-located collaborative meetings, but also to understand their visions about the ideal way of conducting them in the future. Hence, we wanted insight in both current practices and future aspirations.

Phases of the Study. Our implementation of the Contextmapping method distinguished three phases. A first individual activity spanned approximately three weeks and required participants to fill in a cultural probe documenting different kinds

of design-related meetings (sensitization). Secondly, two workshops carried out in the same day, one on eliciting existing problems during meetings, and a participatory design workshop on generating futuristic solutions.

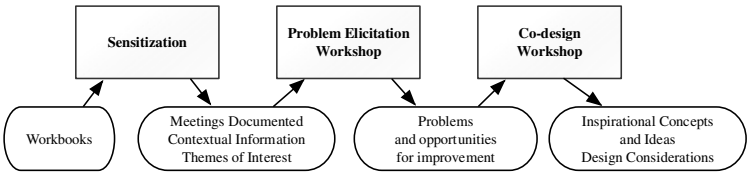

Fig. 1. Distinctive phases in the Contextmapping study, as well as created outcomes

Sensitization. The sensitization phase is used to prepare participants for a group session, by helping them "*remember past experiences, express their memories, opinions and dreams*" [5]. In order to promote this, participants were given a workbook to help them reflect on, document, and analyze their own context some time before the session. Our workbook asked them to describe occurrences of design-related face-to-face collaboration. In each entry participants were asked to write down the aim of the meeting, the people involved, a brief description of how the meeting went, describe what they liked or disliked about the meeting, and what they came and left with. Additionally they could attach a picture or a sketch.

The Workshops. The workshops were planned as a one-day activity involving all participants from all companies. The aim of the first workshop was to identify issues and concerns related to the current way of conducting co-located design-related meetings. The participants were divided in three groups, one per company, which created a series of storyboards that highlighted one or more problems or issues that reflected their current experience, which were subsequently discussed in a plenary meeting. The sensitizing workbooks were returned to the participants for inspiration.

In the second workshop each group was asked to create a product concept that addressed the issues raised in the stories. Participants were encouraged to make use of futuristic technologies, such as intelligent environments. To inspire them, participants were presented a video with extracts of futuristic concepts from science fiction movies. In addition, they were given the opportunity to experience three interactive working demos. The first was made by projecting an existing single-user tool (*Photoshop*) on a wall display and providing all participants with an individual input device (Bluetooth stylus) that they could use for turn-taking. The second demo was a large horizontal area for digital sketching that maintained a historical archive. The last demo used a horizontal 52 inch multi-touch table with stylus and finger input, with pictures that could be resized, rotated, scaled with the fingers, and sketched that could be created with the help of a stylus. The table could also receive pictures send wirelessly from a smartphone.

5 Results

5.1 Sensitization

A total of twelve workbook diaries were completed with an average of 5 reported meetings per workbook. We found the following themes of interest in the diaries:

Absence of Desired Material. During meetings, practitioners do not always have access to desired material, such as images, or videos. (S6) "*I would have liked more information instead of being dependent on what the others bring along*". Even in cases when the relevant material was available in the meeting in the laptop of a participant, it is often too difficult and time consuming to share it publicly with the rest of the group. (S7) "*I dislike that it is difficult to share images on a computer, we lack a proper sharing tool*". (S6) "*I would have liked to show the old website during the meeting which was only visible on my laptop*". This lack of material may lead to making uneducated decisions. "(S1) "*I did not like worrying that wrong choices are made based on incorrect assumptions*".

Creating Combining and Transforming Material. Often, material needs to be combined or transformed. (S7) "I would have liked a light way to create and visualize our ideas, being able to walk around it with the stakeholders and make easy adaptations, creating a preview of how it will look like". It happens that more than one participant wants to provide direct input for multiple participants to manipulate the material, rather than simply stare while others do it, which leads to loosing input and interest while waiting. (S14) "I disliked the fact that I could not physically interact, but only verbally … …I would have liked to be able to give input on the fly by shaping ideas" (S8) "I would have liked a quick drawing tool to be used by both". We also found that it is often hard to describe an idea involving dynamic behavior using only static sketches. We found that the current media that articulate design artifacts have limitations in the amount or kind of information that they can convey, and practitioners are in need of novel tools that allow them to quickly and easily express complex dynamic ideas in such settings. (S4) "I disliked that it was hard to express my ideas because I didn't have the proper medium to do so… I would have liked the availability of an interactive sketching tool "

Capturing and Documenting the Results. Currently, when a session is over, participants leave with a set of individual notes and sketches. Such notes are not shared between participants, and even if a person creates a summary or takes meeting minutes, some information is excluded, as it is restricted to those notes that were made, affected by personal perception of what was being said and done. (S8) "*I disliked that it was difficult to take all the information with you after the meeting*"(S2) "*I would like to avoid lots of papers which are later on not understandable and I would have liked a simple summary from everything that was discussed / sketched with comments*".

Social. We found that some people tend to dominate, leaving too little time for others to provide input. (S2) "*I would like to avoid a decision without giving a fair chance to every opinion*". Decision-making is a difficult aspect of meetings. It can take large amounts of time, and can create uncomfortable situations, like someone feeling emotionally offended. (S8) "*I'd like to avoid discussions that are not relevant, it's always the same people who comment and discussions that are going nowhere*". It also happens that the focus of the meeting gets lost as a discussion heads off in other directions. Participants often realize too late that they may have lost valuable time. (S3) "*I like to avoid getting stuck in an accidentally though technically interesting topic*".

5.2 Problem Elicitation Workshop

Company A described three stories. The first story concerned a co-design meeting where all parties involved are working closely together, but where the entire team needs to make a sudden shift, due to an external factor. Suddenly, additional unforeseen material needs to be consulted and the challenge is to quickly get acquainted with and adapt to a new situation.

The second story described a multidisciplinary meeting were participants have to reach a collective agreement with a potentially large impact on the final specifications of a design concerning large textual documents. Each member needs to know the details of his/her part of the design, but also needs to assess the interaction of their own part with the rest of the system. Such meetings pose frequent problems, as participants continuously get confused, and there are frequent clashes between proposed functionalities. Often, it is only some time after the agreement has been reached that individual participants realize that they have agreed on details that they were not fully aware of or had misinterpreted.

The third story talked about meetings where practitioners in the same field, usability engineers for instance, come together to align their graphics and interaction designs across different products. Participants frequently have different opinions on what the best solution might be, so there is a lack of shared interests and shared responsibility, but despite that they have to come up with a shared agreement. The main problem expressed is that as such meetings do not take place frequently, from meeting to meeting people slowly forget, and tend to personally reinterpret previous agreements, eventually leading to substantial differences in designs across projects.

Company B described a situation where two persons from different fields, in this case an engineer and a salesman, meet to discuss about a design for a client. The salesman has met previously with a client and has collected a request for a custom part. The salesman believes that the changes will be minimal, while the engineer thinks the opposite. The engineer tries to explain the magnitude of the consequences that derive from the required changes, but the salesman does not really understand, as he sees only the overall picture, which in his opinion does not appear to be so complicated. There is a lack of common understanding, there is a lack of material that can help them better reach such common understanding, and there are external factors that oblige them to come to an agreement quickly. The engineer feels forced to make

a decision and commits to a plan of which he is not even sure if it is possible to implement, as he believes that a proof-of-concept prototype is needed for such a decision. As a side note, the participants who described this story were still arguing about a particular recent similar case.

The first story from Company C was about co-design meetings where designers of diverse backgrounds come together to work on, and further elaborate a concept (see Fig 2). These meetings happen because the deadline of the project is close and they do not have enough time to finish the standard distributed procedure. For this purpose, the two or three participants sit together behind a computer operated by one of them, the visual designer in their particular story. During the meeting there is an iterative process of discussion, refining and making changes to the design. The first problem expressed in the story is the inability to perform simultaneous interactions on the artifact. When a person that is not controlling the computer wants to propose a change, he / she has to rely on his verbal capabilities, as he / she can only talk but not act. There are continuous misinterpretations and confusions, followed by intense discussions on how things should look or behave, and a feeling of too much waiting for the other participants to carry out the changes in the artifact being discussed.

The second story talks about an evaluation meeting involving a multidisciplinary team of designers, engineers and management stakeholders. Normally they discuss over PowerPoint presentations, but in some cases the information they convey is insufficient, as ideally they should rely on simulations to reach an educated agreement.

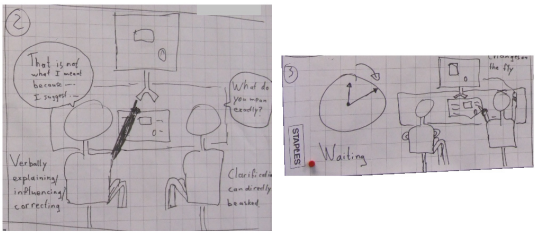

Fig. 2. Fragments of the Storyboard by Company C describing a co-design meeting where one of the participants regularly has to wait for the other to perform changes on the artifact

Cross Company Discussion. In general all of the problems were acknowledged and recognized by all companies, even those that were not present in their own story(s). This includes misunderstandings between people from the same or different disciplines, having different readings on the outcome of the sessions, forgetting and reinterpreting the decisions made, or suffering sudden unexpected changes in the agenda. Companies A and B do not conduct the kind of design meetings where two or more people work synchronously on a particular design case sharing the same computer. On the other hand they do experience similar limitations when conducting brainstorms or focus groups. However all companies expressed their skepticism of having tools that can enable simultaneous interactions, or that bring rapid replication

and sharing of artifacts. The key issue in this respect is the emotional response from participants when experiencing a loose of control and ownership of their creations, or of their role in the process.

5.3 Group Design Workshop

For this workshop each company formed a group, and was asked to design a concept addressing some of the problems expressed in the storyboards. The groups were encouraged to make use of recent technological developments presented (see Phases of the Study), finishing with a group presentation and discussion.

Company A created an iPad application concept to support design meetings that provides a shared and a private area, and that is connected to personal and shared multimedia libraries. The documents can be loaded during a meeting on the private area of the application to visualize, interact with, or sketch on them and can be transferred to the shared area, which is common for all participating devices. The users can take private notes of the meeting that can be shared and donated to the archive, which also includes a history of all changes over the shared area. The devices can sense what is happening outside the screen, keeping track of how much time each person is participating or know which part of the agenda the meeting is currently at, and uses this information to intelligently moderate the meeting (i.e. suggest a dominant person to become less participative, or suggest to move to the next item of the agenda). The application offers an in-meeting secret messaging channel to coordinate thoughts, and remote users can participate in the meeting using a similar device. Finally, the application offers a post-meeting twitter like mechanism to update other members of the progress of the agreements reached.

Company B proposed a domain-specific interactive tabletop application for groups to create and discuss design alternatives of food processing machines, which can simulate a variety of different parts and parameters (speed, size, etc.), and can also intelligently detect conflicts such as collisions of parts. New parts can be created collaboratively by shaping 3D polygons with finger gestures. Existing 3D models, images, videos and other media can be imported into the application to build new parts. Finally, the system can connect to a similar system in a remote location where other participants can equally interact with all of the material.

Company C designed a multi-user application running on a vertical display and a tabletop. Designers approach it to combine their work, and make changes, visualizing the outcome in a virtual driving simulation context. Users can import multiple types of CAD and graphic files and combine the material visually. It is possible to make changes on the fly, but the system must offer a mechanism to avoid conflicts in simultaneous interactions, to prevent the session from becoming chaotic. The application also tracks all changes and provides a historical view. At any moment the designs can be placed inside the cabin of a virtual vehicle to show different driving scenarios and conditions to help the stakeholders visualize and experience the designs under various conditions. Finally, the created concepts can be sent directly from the application to a real test driver in a vehicle, who is wearing a pair of magic goggles (augmented reality) and can provides immediate feedback on the concept.

Cross Company Discussion. Participants spoke about their concerns of having too many screens and devices to interact with, as it may lead people to loose attention and focus. It became apparent that future systems should offer some mechanisms to avoid this, (S8) "*Maybe the chairman can limit the activities to things that are only relevant for the meeting, and not your email*". Simultaneous editing may be interesting, but there are many concerns of how this can be properly supervised. (S11) "*When working together, how do we prevent that it becomes a big mess? I am more scared for getting some kind of clash*". Others feared the sense of lost responsibility and authorship of the content. (S9) "*I wouldn't like it if everyone is making changes to my design, that's my responsibility*".

The topic of remote collaboration was present in all of the designs. All companies saw this almost as a basic requirement, and remarked that one should not focus merely on the interactions around the table, but must keep remote access in mind, as it is part of the reality of their practice.

There was a general concern with privacy, especially for Company A. Even if the system is capable of capturing and storing everything they do, people will feel reluctant to interact if they do not feel as if they have sufficient control over their data. (S3) "*Some things you want to remember just for yourself for later on*".

6 Discussion

The study revealed a series of positive and negative considerations that are relevant to the design of interactive systems and spaces to support co-located design collaboration.

Designers often find it *difficult to access and share material* during meetings. This may turn into frustration or even become a problem as it may lead to making choices based on incorrect assumptions, or may require to postpone decisions. Similarly, designers often want to *create, combine or transform material in a collaborative way*, but they are unable to do so due to the (single-user) nature of the interfaces of existing tools. However, providing multi-user functionality is also looked upon with some skepticism. Designers generally do not want to lose ownership of their creations, and therefore do not necessarily have a positive attitude towards others altering their designs; some fear that allowing this may even lead to chaos. Designers are also concerned with how *social norms and protocols might be facilitated or enforced* by *meeting-ware*, and if this will respect the users privacy and will be based on their personality, cultural background, and particularities of the design situation. Design meetings most frequently do not consist of a single continuous activity, but instead of a *series of sub-activities that are carried out dynamically over time*. There is an expectation that systems may be designed just for a particular type of activity, or that they may constrain the users in switching from one activity to another. At the same time, such dynamic nature often makes it difficult to *communicate the outcome* of a collaborative session, as *capturing and documenting the results and interactions* is a cumbersome venture. Designers acknowledged that this area offers technology many opportunities for improvement. However, they also see it as a challenge, as the

outcome is not always something that can be materialized into concrete artifacts, as on occasion it may be a more subjective quality such as a gut feeling or a mindset. Overall, there is a concern if new technologies will indeed *fit into the existing workflow and process*, meaning that one should not only consider what happens while they are being used, but what is required before and after doing so. We have also seen concerns regarding the *technological saturation and sophistication of the environments*. Designers identified the risk that more technology may distract individuals from the group tasks, it may lead participants to become immersed in individual activities, or the situation might become dominated by excessive interaction.

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