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LESSONS LEARNED AND FUTURE CHALLENGES FOR DESIGN OBSERVATORY RESEARCH

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ABSTRACT
Video observation has been used for ethnographic studies for decades and is becoming more popular in engineering design research. This paper presents some of the lessons learned of using design observation in research. The paper focuses on the design and usage of physical environments designed specifically for design team observation – *Design Observatories (DO)*. The paper argues that in the past DO focused on observation, whereas DO of the future will provide real time analysis and the possibility to intervene to improve the design activity. Five different types of studies are identified and categorized. Three different design observatories and the rationale for their design are described, as well as twelve design studies ranging from short experiments to long ethnographic studies in industry. Finally, the implications for design observatory research are presented – DO must *support an iterative research approach*, since design experiments are emergent and are not defined up front. There is a need for a more *longitudinal capture of data* and the emergence of *robust coding schemes that enable machine coding* needs to be supported.

Keywords: Design observation, Design observatory, video analysis

1 INTRODUCTION
Carrizosa et al. in 2002 [1] first constructed the Design Observatory as an integrated environment to observe, analyze and intervene into design activity. Since then, numerous studies have been conducted using Design Observatories built by design researchers [2,3,4]. This paper presents an updated perspective on the use of Design Observatories to study design activity and lists some of the lessons learned and challenges yet to overcome. The paper also tries to answer some common questions raised regarding Design Observatories, such as *What is a DO and why do we need a DO? Where are DOs and how are they designed? What kind of research does a DO lead you to do? What do we miss? What questions can you frame and what are the limitations and assumptions associated with DO?*

2 WHAT IS A DESIGN OBSERVATORY?
Carrizosa et al. [1] proposed the name Design Observatory to a facility for improving 'data collection and analysis procedures associated with in-situ observations of designers'. The first Design Observatory built at the Center for Design Research at Stanford University incorporated audio and video recording facilities, a certain flexibility in design to accommodate the needs of different researchers, and the use of digital data analysis techniques which was a novelty in 2002. This was the Design Observatory of the past. What is the Design Observatory of the present and the future? Is it just a room with multiple cameras for audio and video recordings of design activity?
The methodological framework for the previous Design Observatory was the Observe-Analyze-Intervene cycle proposed by John Tang [5]. This Design Observatory focused more on the Observe part of Tang's framework. Currently, the Observe part has become less cumbersome due to developments in video recording technology and digital storage. The Analysis part is still time-consuming for video data and needs to be addressed to permit real-time analysis. The current Design Observatory is thus not so much defined by what it can observe, but what it can analyze in real-time. Similarly, a future Design Observatory could be defined by not what it can analyze, but what real-time interventions can be designed to improve the design activity therein.

Design Observatory of the past – Real-time video Observation of design activity
Design Observatory of the present – Real-time Analysis of design activity
Design Observatory of the future – Real-time Intervention into design activity

3 WHY DO WE NEED A DESIGN OBSERVATORY?

The Design Observatory was designed as a facility to observe design activity without being limited to any observation medium. However, due to the interests of the researchers who initially designed it, video became the primary observation tool. Later, Milne and Winograd [6] created interactive workspaces with embedded technologies, such as interactive whiteboards to facilitate designers' work and to capture and store the processed information. Such spaces could be considered a non-video based Design Observatory, since they too facilitate observing design activity, albeit without the use of video. The Design Observatories in current practice are still video based; hence, the justification for a Design Observatory is tightly coupled to the justification of video as a medium to observe and record design activity. Although video is the primary medium of observation, it is not the only medium and some studies have used other media like computer desktop capture [7].
We need a Design Observatory with video as a primary observation medium to:

1. **Observe social aspects of synchronous team based design** – Video is well-suited to record synchronous interpersonal behavior in a design team, in particular gestures and emotional expressions that are not captured through information technology tools such as interactive whiteboards, e-mails and computer logs. The Design Observatory provides a flexible and convenient space for observing synchronous social behavior.
2. **Understand design activity using a paradigm of iterative prototyping** – The main argument for using a Design Observatory is to go away from a paradigm of describing design towards a paradigm of instrumenting design. The intention of intervening, i.e. designing instruments, in design to improve design performance is the key driver of Design Observatory studies. However, due to the complexity of design activity, the objective is not to understand it completely and then design an intervention, but rather to iteratively prototype an intervention while increasing our understanding of the design activity. Since the amount of prototyping we can do in the real world is limited, a Design Observatory provides a semi-controlled setting to understand design activity through iterative prototyping.

3.1 Comparing Design Observatory studies with other types of studies

Placing the usage of Design Observatory in perspective with other types of studies that observe and analyze design activity is worthwhile.
Although it may be argued that design research should always be carried out under perfectly 'real' conditions (in vivo), in practice the researcher has to choose which type of study or experiment is appropriate for his objectives. This means that 'real world' design observation can range from university projects and fieldwork on industrial sites with professional designers to controlled experiments in a Design Observatory (in vitro). Studies can also be divided into ethnographic study or experiments, where the ethnographic studies are more qualitative and experiments tend to be more quantitative.
Traditionally, ethnographic methods are often used in industry when following real design teams, arguably providing the researcher a more accurate description of an industry-related problem [8]. However, industrial projects are often restricted by confidentiality. Industry often believes that design researchers are interested in the results, i.e. the product. In fact, design researchers do not focus on the product, but instead on the process or the people (team dynamics). To overcome this, Hicks et al. [9] propose the usage of professional designers (employed for solving a specific problem). Using this approach, the designers are both professional designers who are used to working in unfamiliar environments and researchers who 'own' the complete dataset with no confidentiality problems.
Studying student projects also has several advantages, such as close proximity to research subjects and the possibility to intervene and study the change. Many Design Observatory studies described in section 5 involve the use of student teams. However, an argument against using student projects and staged experiments is that the experiments are not "real" in design. Hence, each approach has its advantages and limitations.

The following table presents an overview of the different types of studies.

Table 1. Different types of studies.

Team members	Industry professionals			Students	
Type of study	In Industry	Off site experiments	Hired professionals	Student projects	Experiments with students
Group size	Often complex projects in large teams.	3-15	4-8	3-10	
Type of study	Ethnographic fieldwork	Design observatory experiment	Design observatory experiment	Ethnographic fieldwork, video observation	Design observatory experiment
Confidentiality	Use of video recording is often restricted due to company regulations and is thus limited to interviews, field notes, etc.	Depending on project, often highly confidentiality	Researchers have complete ownership of the dataset	Depending on project, industry sponsored projects may have higher confidentiality	Researchers have complete ownership of the dataset
Possibility to intervene	Low. The process of deploying new tools and processes in industry often follows strict regulations	Medium	High	High. The environment can be controlled and methods, tools, and technology can be easily deployed.	High
Professionalism	High	High	High	Medium	Low
Team environment	Meeting-rooms, team-rooms, workplaces hard to	Specifically set up for the experiment	Specifically set up for the experiment	Meeting-rooms and team-rooms	Specifically set up for the experiment

4 WHERE ARE THE DESIGN OBSERVATORIES?

Design Observatories and rooms for capturing meetings have evolved in recent years, with some recent implementations done by Open University (UK) and the AMI Project [10]. Three examples of Design Observatories being used to conduct design research are as follows.

4.1. Stanford Center for Design Research

Figure 1.The Design Observatory at the Center for Design Research consists of a studio room (left) for design activity and a recording and analyzing room (right).

Carrizosa et al. [1] started the Design Observatory at the Center for Design Research at Stanford University. The methodological framework discussed in section 2 was the observe-analyze-intervene cycle proposed by John Tang [5]. However, most studies conducted so far at the Design Observatory have focused on the observation and analysis part of the cycle. The Stanford Design Observatory has proved instrumental in rapidly iterating over experiment designs and prototyping new tasks, physical setups, information tools and video capture technology. This low barrier to trying new design scenarios has enabled researchers to run a number of student and professional teams through different design tasks and refine dissertation research questions through an iterative prototyping approach.

4.2. Luleå Design Observatory

The usage of design observation at Luleå University of Technology in Sweden started in 2001, initially using ethnographic methods to observe design teams in industry and follow student design teams. In 2003, the emerging need for an environment to conduct experiments in a more controlled environment was raised. The underlying rationale for this environment is further described in Larsson et al. [4]. The methodological argument proposed was based on scoping ethnography (ethnography conducted with no specific relationship to technology design in view) [11] on engineering work that is carried out to identify issues that appear to be relevant for the research. This can be further studied in detail in the design observatory through a iterative process of implementation and evaluation (experiments), where the significant research issues are further studied in a continues process of rapid implementation and evaluation.

The Luleå design observatory is designed to provide researchers with a flexible environment for design research, where design observation and experiments can rapidly be designed and implemented. The studio is designed similar to a theater, with “stage sets” (i.e. movable walls, flexible bus controlled lightning and a variety of interaction devices and displays) that can quickly be configured to the specific needs of the researcher. The technology in the studio is based on digital audio and high definition video distribution, which can be routed internally for real time presentation and recorded for later analysis.

The Luleå Design observatory is also designed to replicate distributed work by dividing a local group into two groups located in two studios, forcing the group to use collaboration technologies (i.e. video conference, shared tools, etc.) to communicate and thus create an environment for complex distributed in-situ observation of design teams as it unfolds. Interaction in the DO can also be followed either from an observation bridge or be presented for a larger audience on a large screen (5x2 m) in an adjacent studio, see Figure 1.

Figure 2. The view from the observation bridge and the quad view in the adjacent studio.

4.3. Grenoble

The Design Observatory developed in Grenoble (MEXICO lab) aims to analyze both co-located and distance collaboration meetings. The equipment is based on two rooms, collaborative tools and video and audio recording equipment. The audio video recording equipment allows synchronous recording and four video and four audio sources directly from a camera or computer screen. Both rooms are connected to facilitate capture. An observation room with a beam splitter glass in between separates researchers from designers. Video conference equipment in the video conference room allows a complete recording of the exchange. This technical equipment was designed to capture face-to-face meeting and distance meetings, providing the capture of all mediated design activity, digital or non-digital (see Figure 3).

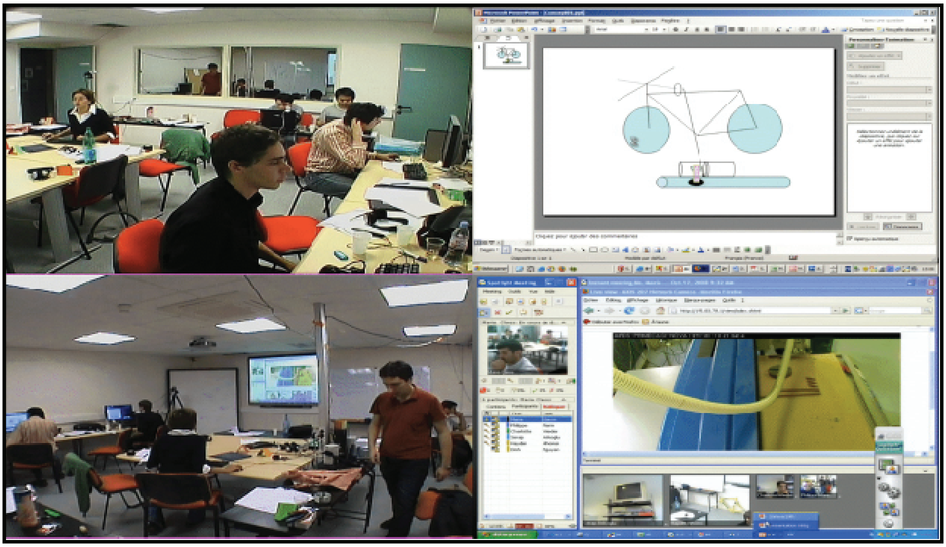

Figure 3. Capture of video and Computer interaction in the MEXICO lab.

The methodological approach is based on ethnomethodology and focuses on the designer's interactions. Experiments are based on the collaborative design situation model developed by Prudhomme et al. [12].

5 WHAT ARE THE LESSONS LEARNED FROM DESIGN OBSERVATION STUDIES?

In the last 10 years, several design observation studies were conducted by the research groups (Bath, Grenoble, Luleå and Stanford); Table 2 shows a summary of selected studies.

Table 2 – summary of selected design observation studies.

Study	Research focus	Type of study	Group size	Stage of design	Where	Speed and iteration	Reflections
Hägglunds Drives Study [13]	Communication in distributed teams	Eth., Video single camera, SG, SL	1-2 consultants 1-3 (main site)	Detailed design with focus on optimization.	Team room at main site and consultants office	Six month study	Screen capture and storage of system logs simplifies analysis.
Sirius/ ME310 projects DTI [14, 15, 16] and Nösphere [17, 18]	Creative sessions and prototyping	Eth., Video 1-2 cameras, SL	Two global teams, each team 4 + 4 students	From planning to functional prototype	Team spaces (LTU/Stanford). Both local and distributed meetings	Two nine-month studies	Large amount of data. Difficulties of capturing distribute teams (what happened vs. what could be seen).
Creative spaces	Impact of place and space in creative stages	VO multiple cameras Protocol analysis	Four students per group	Brainstorm and creative sessions in general.	LTU DO	15 min experiment x 8 groups	Insights on the importance of iteration in the design of the experiment.
Luleå Experiment	Exploring research methodology for design observation	VO, multiple cameras, protocol analysis	One test group, 3 X 4-6 students	Brainstorming and creative sessions in general.	LTU DO	One week research iteration	In-depth reflections on research methodology as well as synergies between participants.
Grenoble Distributed design model [19, 20]	Emergence of solutions in collaborative and role of sketches	VO Two cameras	Four researchers	Conceptual design	Grenoble DO	Two hour meetings	Necessity to capture process of objects and sketches of construction
Grenoble and French labs network [21]	Explore the possibility to record a 4 point distant meeting	Eth.	Four distant students	Detailed design	Grenoble DO (and three remote sites)	Four weekly meetings of two hours	Methodology and requirements for recording distributed meetings
Grenoble COSMOCE project [22, 23]	Observe and model the argumentative process	Eth.	Three local students /Global design team eight professio-nals	Detailed design	Grenoble DO /Meeting room of the company	1 h of activity (students)/ 2 h (professio-nals)	Two studies that compare with observations made in DO (students) and industry (professionals) Experiment methodology based on design situation model.
Creative stimulation in conceptual design. [24]	Creative idea generation	Observational study, protocol analysis	8 per group with roughly 20 groups total	Conceptual design	Crown packaging, innovation department	Two years in total. Each session was two hours.	Full viewing of the session from a static camera. Changing tape. Importance of sound quality.
Emotional Design Team Dynamics	Emotional expression of individual on the team during disagreement discussion	VO, emotion coding	Three to four per group	Not applicable (disagreement could arise at any stage).	Stanford DO	55 min per team, 12 teams	Study pioneered observation of real team activity in a controlled setting, prior studies involved contrived tasks. The video cameras were focused on individual close-ups to observe emotion.
Video Library study [25]	Use of Video Library for information reuse	VO, library logs, questionnaires	Three to four per group	Conceptual design	Stanford DO, design project studio	Study conducted over two quarters	The video library was used much more in the lab than in the project studio. This emphasized the shift in context between lab and studio.
Pair programming study [26]	Testing the advantage pair programming.	VO, computer screen capture	Two per group vs. one in controlled condition	Software design	Stanford DO	Study conducted over a few weeks	This was the first time professional software coders were hired for a DO study.
Real-time instrumentation pilot	To prototype real-time process feedback to design team	VO, real-time video analysis, projection of results to the design team.	Three in a team	Conceptual design	Stanford DO	One prototype conducted	It is feasible to give real-time feedback to design teams. However, the benefit of the feedback depends on providing an evaluation baseline to the team.
Type of study: Eth. – Ethnographic study, VO – Video observation, SC – Screen capturing of computers, SL – Storage of system logs (e.g. tools used, metrics)							

The lessons learnt from the usage can be categorized into the following key areas:

5.1 Capturing

The capturing systems have improved radically during the last 10 years. Today it is possible to capture several stream of high definition video and audio with very high quality at a relative low cost. Some general conclusions regarding capturing are presented below

Importance of audio

A common denominator is the importance of audio quality. Several of the ethnographic studies had insufficient audio quality for quick transcription or even understanding what is communicated when several people are speaking simultaneously. The ideal setup is a dedicated microphone for each participant and one with all sources mixed together. Using only separate channels sets high demands on exact synchronization of audio in the analysis.

Ease of use

In several projects it was found that the ease of use of the capturing system is important, using tape based recording has the advantage as it can be used as back up copy, but needs to be digitized and transcoded for further analysis. The computer based recording system used has had several problems of reliability. Also the process from recording to analysis should be as streamlined as possible.

Distributed projects

Several projects were distributed projects, where teams were located at two different sites. Often, the video captured only the local collaboration (including the video conference). From the quality of data collected in these studies, we can infer the importance to at least capture local work and the media used for communication so that comparisons of *what happened* (local site) and *what could be seen* (from the remote site) can be done in the analysis [8]. The LTU design observatory was also designed to overcome some of these difficulties by replicating remote collaboration. To further simplify capture and storage of these complex design sessions (capturing several locations, multiple media streams, conferencing and sensor data) a framework for data collection of distributed collaborative design research is under development [8].

Capturing events and computer interaction

Video and audio create the baseline for capturing the design session, but they do not capture the interactions with computers and technology in detail. In a modern design environment, computers and technology are greatly used to find information, communicate, review and evaluate existing design solutions and create new data. Two basic approaches exist – store the computer interactions as video or storing events.

The usage of screen recording (screen capture using hardware or software) provides the researcher with complementary empirical data from the interaction with computers. In the Hägglunds Drives study [13] a simple form of screen capture was used, greatly simplifying the analysis. In all three design observatories described above this can be achieved by storing the computer screen as video. Today, several screen recording programs exist, such as *Camtasia* or *ScreenFlow*, where both screen interactions, audio and video, are easily captured. Some programs for screen capture also have the possibility to store the events (e.g "user interacts with computer and writes 'www.iced09.org' in explorer"). By storing these types of events the analysis process can be simplified. The approach to store events was used in the *iLoft* project [6] by using a global timestamp all events can be presented on a timeline. Similar programs are often used in Computer Science and Human Computer Interaction, where video, computer interactions and events are captured, one example is the *d.tools* [27] suite for design, test and analysis of computer hardware and software.

One of the main issues is to capture both synchronous and asynchronous activity. Design activity generally involves personal reflection and collective elaboration. The two sequences are heavily connected and the analysis of a complex design activity needs to keep track of both. A second point is to capture all intermediary objects used by the designers and built into the context of their design activity. The intermediary objects can be digital mock ups, physical objects, papers, white board, etc. Moreover, to capture the final object we need to capture the construction process of the object synchronized with verbalizations and other interactions of the group. This is a problem in many existing protocols, which do not capture these elements.

5.2 Analyzing

From the analysis viewpoint the studies above highlights two areas; how to quickly find relevant sequences and the robustness of the coding scheme.

Usage of bookmark, field notes or system logs to find relevant sequences

Although a limited amount of meetings was captured in many of the ethnographic studies, an enormous amount of data was captured; hence, the usage of field notes in conjunction with the video capture is essential. A detailed analysis of the complete material is impossible, since it is very time-consuming, with 1 hour of video recording often taking up to 20 hours to analyze. The field notes can be used as bookmarks to find interesting events that later can be analyzed in detail using video analysis and transcriptions of relevant passages. In the DTI study [14], some quantitative data were collected (number of instant messages sent, SMS and e-mails). Here, an interesting measure was not the amount of messages exchanged, but the rate of change (i.e. a large increase of messages sent) was a good indication that something unusual had happened.

Creating a robust coding scheme

Another challenge is to build a robust coding scheme that can support the analysis of multiple ethnographic studies. If we develop an ethnomethodological approach, we assume that each design situation is specific and that actors build rules of interaction during the action process. In this context, it is difficult to compare design situations, even if the tasks are the same. In our approach we try to analyze different types of situations to improve the analysis tools of the design situation, with the goal to create a robust coding scheme to ensure the coding is repeatable (i.e. it could be learned and used by a number of coders, which in turn should be able to repeat the same coding of the video).

5.3 Technology and environment

Many of the in situ studies were done in existing team rooms or meeting rooms, rendering position of the cameras difficult and a more complex setup with several cameras and microphones impossible. Here, the DO gives much more freedom to explore different setups with short iteration cycles. The technological infrastructure in the DO should not limit the user and the researchers by imposing a specific technology to be used – it should support the researcher with some basic functionality for capturing different types of media. At the same time the researcher should have the freedom to rearrange the physical layout in the room so that different types of scenarios can be designed, e.g. how to capture audio, video and other media. In some scenarios the users are allowed to adjust and adapt the environment to their changing needs, where the experiment setup may restrict this freedom in other research experiments (evaluation of technology, tools and physical environment).

Even though the in vitro experiments in the DO gives the researcher a higher level of researcher flexibility and control, there is still a need for the in vivo studies at company sites and in existing team rooms. To been able to capture the design collaboration in real industry project the development of mobile, easy to use DO is important. These mobile DO shall be quick and effortless to deploy, and still have the possibility to capture necessary data.

5.4 Teams

When summarizing the research above, the focus is clearly on small design teams (4-8 persons) early in the design process. Several experiments have shown several interesting advantages in using a pre-existing design team in a controlled experiment compared to a team consolidated only for the experiment. A study of pre-existing teams provides an observation of design activity that is motivated by real-world concerns and not by the researcher. This affects the motivation of the designers and the subsequent emotional engagement, trust and social dynamics within the team.

When using student projects, it is important to reflect over roles and responsibilities. In the DTI project [14] and the Nösphere [17], the researchers were also coaches for the projects, which in retrospective was not the optimal approach. One part of our job as teachers is to influence our students. However, when the researcher intervenes in the design process the intervention is often interpreted as positive, since it is comes from the teaching team (regarded as an expert). This is most apparent in projects where the researchers are involved in the teaching team or as coaches. The role of being a researcher into design while being part of the teaching team is a difficult path to follow at best.

If these dual roles cannot be avoided, to retain scientific rigor, the researcher has to carefully reflect on these implications and how this could influence the results.

Feedback

An interesting issue was to give quick feedback to the design team studied. In the Luleå experiment the teams involved received feedback (based on a quick analysis by the researchers) on how to change their behavior for better team communication and design performance. The team members considered this feedback very valuable. If the analysis and feedback could be done even faster, this type of feedback could be used to introduce interventions based on the interactions between the design teams.

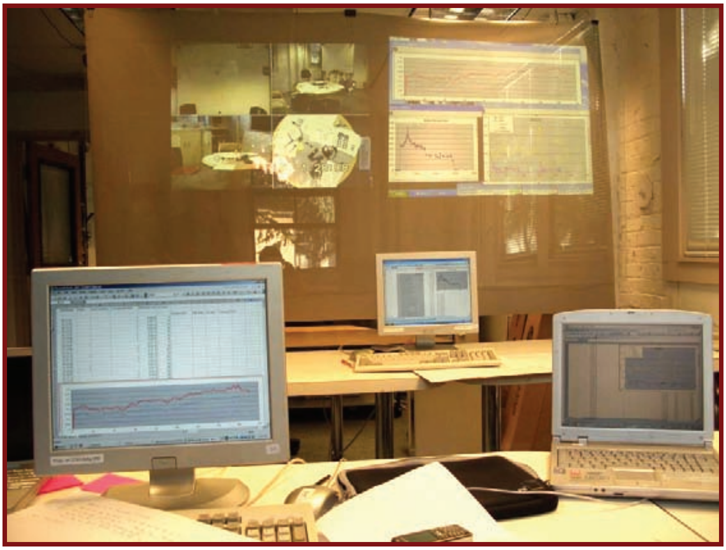

Figure 3. Real-time coding of design activity. The graph on the screen was displayed to the design team in real-time.

The Real-time instrumentation pilot study prototyped the feasibility of giving real-time process feedback to a design team (see Figure 3).

While the team was engaged in design activity, the video of the activity was coded by a group of researchers for parameters such as questions asked and ideas blocked versus amplified. The results of the real-time coding were displayed graphically to the design team while they were designing. The prototype showed the setup to be technically feasible. However, the biggest shortcoming was the inability to benchmark the feedback given to the team in terms of good or bad performance.

5.5 Measures

Measures in a DO connect the design activity through an analysis (where design patterns are recognized) to some kind of measurable criteria. The design process is based on social interactions between humans and is considered non-repeatable, providing particular challenges for measurement [28]. There is a large number of variables that influence the outcome of a design study or experiment.

Design may be described as consisting of three parts, **Product**, **Process** and **People**. These three concepts are intertwined and span the design activities. The measures of design activity often focus on the outcome of the process, i.e. the Product, and not the Process, i.e. method or the actual activities of design, or the interaction between the People, which also includes the resources or competences. As quoted from Robert McNamara (former US Secretary of Defense), *"We have to find a way of making the important measurable, instead of making the measurable important"*.

When deciding on a measurement for the design study, it is important to reflect on these three concepts. It may be easy to measure design in terms of outcome, e.g. the Product, though insights provided from a study that only measures the design performance based on the outcome overlooks a huge part of the design activity. Issues concerning Process or People are in some cases where most is gained since these aspects also provide insights into how design performance may be improved. Hence, reflection on the measurements and how they influence the results are essential.

5.5 Experiment design

When the researcher chooses to create an experiment, the robustness of the experiment must be considered. How can we create an experiment where the external influences can be assessed and where the results can be used to infer generic findings? [9]. In the Luleå Experiment the same design task was used for several teams, whereas the approach to solve the design problem by each team was very different. When reflecting over the results the researchers found that small differences in the presentation of the design task by the researchers substantially influenced the students methods and approach to solving the design problem. To come up with a robust experiment design, researchers need to rapidly test the research design (i.e. quickly examine several iterations of experiments, evaluation, and redesign of the experiment). This is also true regarding instrumentation setup, placement of cameras, microphones and sensors. Can we capture the necessary information for our experiment?

In this experimental design philosophy the final design will emerge over time and the researcher will learn by creating 'prototypes' that are refined in each design iteration. Each iteration gives the researcher more knowledge that can be used to create a more robust experiment.

6 IMPLICATIONS FOR DESIGN OBSERVATORY RESEARCH

By reflecting over the research in design observatories, some questions stated in paragraph 2 can be answered:

- **What kind of research does a DO lead you to do***?* There are two kinds of research that a design observatory leads us to do. The first is a purely descriptive research. The intention here is to understand what's happening when designers design. It is ethnographic in its nature and is arguably best done in a natural setting – the design studio, the company, etc. However, there are certain observation constraints in a natural setting that a design observatory helps the researcher to overcome. For example, emotion coding requires a close-up video of each participant at all times. This might be considered too intrusive in a natural setting. While it is true that there is a context bias in laboratory studies, their validity lies in the fact that the findings do not claim to generalize to the natural setting, but rather further our understanding into a particular aspect of design in greater detail.
  The second kind of research that a design observatory leads us to do is so-called 'probing' research. Here, we are not interested in what designers naturally do, but what would they do during a particular intervention, a probe. The response to the probe furthers our understanding of the design activity. As mentioned earlier, the design observatory was designed as an instrument to probe design activity and see how it responds.
- **What do you miss?** We miss the longitudinal aspect of designing when using a design observatory. Currently, we conduct studies in which we study in detail a slice of design activity in all its complexity of the moment. The design observatory, as currently designed, is not suited for long-term studies of design teams.
- **What question can you frame?** The Design Observatory is not the best tool to answer general descriptive questions. It is good for questions that probe deeper into the mechanism of the design phenomenon being studied.
- **What limitations and assumptions are tied to the DO?** The Design Observatory is created from a design epistemological [29] background. The underlying assumption is that designing is a complex phenomenon that cannot be understood completely by structured analysis. Rather, we are better able to understand designing and enhance design performance by adopting a probing approach, which attempts to probe the problem space with possible solutions and simultaneously refine the solution and the problem understanding.

The implications based on the reflections and lessons learned presented above can be summarized:

- To create robust experiments the design observatory must support an **iterative research approach**, whose final design of the experiment builds upon several iterations where the experiment setup, question and coding scheme are refined. This approach demands high flexibility from the design observatory so that the researcher can go through several iterations in a very short time span.

- The importance of **creating a robust coding scheme** that can be learned and used by different coders on different types of studies. When a robust coding schema has been developed the analysis process can be automated or simplified by machine coding.
- The need for a more **complete capture of data** (video, audio, interactions, etc.) where analyses can be done in real time.

It is argued that future design observatories must support a more 'active' role, where some measures can be analyzed in real time. Such an environment would afford faster analysis and new types of experiments whose interventions can be made based on interactions in the environment. The Design Observatory will provide the researcher with systems that simplify data collection and analysis; the vision is a design observatory that supports real time feedback (instrumentation). This would arguably allow a greater range and number of experiments, as sophisticated interventions could be made rapidly, thus supporting the idea of agile design research.

A future DO can also be used to monitor a team over a longer period of time, where the researcher can create usable measures from the instrumentations and, if a certain threshold is reached, a more sophisticated capture can be started. By using this approach, a whole project could be monitored at a lower level of capture and more interesting phases can be monitored in detail.

When creating the future design observatory, issues of invasiveness and privacy are even more important – if everything is recorded and all interactions can be replicated. How can this information be used? Who has access to the data? How long is the data stored? These are challenges that must be dealt with before design observatories can be implemented in industry.

REFERENCES

[1] Carrizosa K., Eris O., Milne A., and Mabogunje A. Building the Design Observatory: a Core Instrument for Design Research, *Proceedings of International Design Conference - Design 2002*, Dubrovnik, May 14 - 17, 2002.

[2] Eris O. *Perceiving, Comprehending, and Measuring Design Activity through the Questions Asked while Designing*. Ph. D. Thesis, Stanford University, 2002.

[3] Bergner D. *Dialog Process for Generating Decision Alternatives*. Ph. D. Thesis, 2006, Stanford University.

[4] Larsson A., Törlind P., Bergström M., Löfstrand M., Karlsson L. Design for Versatility: The Changing Face of Workspaces for Collaborative Design, *International Conference on Engineering Design (ICED 05)*, August 15-18 2005, Melbourne, Australia.

[5] Tang J., *Toward and Understanding of the Use of Shared Workspaces by Design Teams,* Ph.D. Dissertation, Stanford University, 1989.

[6] Milne A. and Winograd T. The iLoft project: a technologically advanced collaborative design workspace as research instrument, *International Conference on Engineering Design (ICED03*), 2003, Stockholm, August 19-21.

[7] Eris, O., Mabogunje A., Jung M., Leifer L., Khandelwal S and Hutterer P. An Exploration of Design Information Capture and Reuse in Text and Video Media. *International Conference on Engineering Design (ICED 05),* August 15-18 2005, Melbourne, Australia.

[8] Törlind P. A Framework for Data Collection of Collaborative Design Research, *International Conference on Engineering (ICED 07),* 2007, Paris, France, August 28-31.

[9] Hicks BJ., Culley SJ., McAlpine HC. and McMahon CA. The Fundamentals of an Intelligent Design Laboratory for Researching the Impact of Tools, Teams and Technologies on Information use and Design Performance, *International Conference on Engineering (ICED 07)*, 2007, Paris, France, August 28-31.

[10] http://www.amiproject.org/, visited 2009-01-15.

[11] Randall D., Harper R., and Rouncefield, M. *Fieldwork for Design - Theory and Practice.* Series: Computer Supported Cooperative Work, 2007.

[12] Prudhomme G., Pourroy F and Lund K. An empirical study of engineering knowledge dynamics in a design situation, *Journal of Design Research*, 2007, v 6, No. 3, pp. 333-358.

[13] Törlind P., Distributed Engineering via Broadband - a Case Study, *International Conference on Engineering Design (ICED 03),* Stockholm, August 19-21, 2003.

[14] Törlind P. and Larsson, A. Supporting Informal Communication in Distributed Engineering Design Teams, *Annals of 2002 International CIRP Design Seminar*, Hong Kong, 2002.

[15] Larsson A., Törlind P., Mabogunje A. and Milne A. Distributed Design Teams: Embedded One-on-One Conversations in One-to-Many, *Common Ground: Proceedings of the Design Research Society International Conference at Brunel University*, Staffordshire University Press, 2002, pp. 604-614.
[16] Larsson A. Making Sense of Collaboration: The Challenge of Thinking Together in Global Design Teams, *In Proceedings of GROUP 2003*, Sanibel Island, FL, USA, November 9-12, 2003.
[17] Bergström M & Törlind P. Examining creative collaboration in distributed and co-located design teams, *International Conference on Engineering (ICED 07)*, 2007, Paris, France, August 28-31.
[18] Bergström M & Ericson Å Prototyping – a way to think together, *International Conference on Research into Design - ICoRD'09*, Bangalore, India. 7- 09. January 2009.
[19] Blanco E., Garro O., et al. Intermediary object in the context of distributed design. *CESA Computational Engineering in systems applications,* 1996, IEEE-SMC, Lille.
[20] Blanco E. Rough Drafts. Revealing and mediating design. Everyday engineering. *An ethnography of design and innovation*. Ed. D. Vinck. 2003, Cambridge MA, MIT press, 181-201.
[21] Ruiz-Dominguez, G. R. and Boujut J. F. A study of cognitive synchronisation in distant mediated design through design artefacts, *Journal of Design Research* , 2008, 7(2): 136-152.
[22] Prudhomme, G., Pourroy F. et al. An empirical study of engineering knowledge dynamics in a design situation. *Journal of Design Research*, 2007, 6(3): 333-358.
[23] Chartier, J., Prudhomme G. et al. An activity model as a tool for analysing communication in engineering design. *International Design Conference 2006*, Dubrovnik, 2006).
[24] Howard, TJ., Culley SJ et al. Creative stimulation in conceptual design: An analysis of industrial case studies. *ASME 2008 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference IDETC/CIE 2008*, Brooklyn, New York, USA
[25] Jung M., Mabogunje A., Sonalkar, N., Eris, O and Leifer, L. Design Knowledge Coaching - A Conceptual Framework to Guide Practice and Research. *International Conference on Engineering (ICED 07)*, 2007, Paris, France, August 28-31.
[26] Chong, J., et al. Pair programming: When and how it works. *in 17th Annual Workshop of the Psychology of programming interest group*, 2005, Brighton, UK: University of Sussex.
[27] Hartmann B., Klemmer S.R., Bernstein, M., Abdulla L., Burr B., Robinson-Mosher A., Gee J. Reflective physical prototyping through integrated design, test, and analysis. *Proceedings of UIST 2006*, October 2006.
[28] O'Donnell F.J. and Duffy A.H.B. *Design Performance*, Springer, 2005.
[29] N. Cross, Designerly Ways of Knowing: Design Discipline Versus Design Science, *Design Issues*, vol. 17, pp. 49-55, 2001.

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