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BUILDING THE DESIGN OBSERVATORY: A CORE INSTRUMENT FOR DESIGN RESEARCH

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1. Introduction

For the past fifteen years researchers at the Center for Design Research at Stanford University have focused on two fundamental questions: what are designers doing, thinking, and experiencing when they do design and how can we improve their performance? One research methodology that has been effective in helping answer these questions is the "observe-analyse-intervene" method pioneered by John Tang [Tang 1989]. This iterative approach emphasises the development of interventions as a way to perturb a system and test underlying assumptions.

Illustrated in figure 1, a design activity is observed and recorded in the observation phase. In the next phase, the new data is analysed and interpreted. In the third phase, this interpretation informs the design of new tools and methods that will impact the behaviour observed in the initial design activity. The cycle is then repeated. Each iteration deepens our understanding of the design activity, resulting in a refinement or replacement of the tools and methods that were earlier introduced.

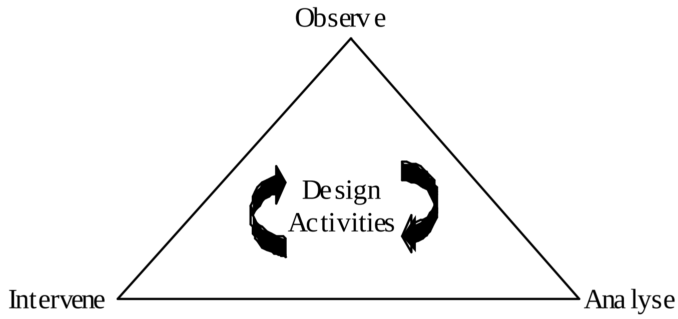

Figure 1. The Observe-Analyse-Intervene methodology, through its intervention step, allows a complex system to be perturbed and reveal hidden assumptions

To accomplish the observe-analyse portion of this methodology we have collected analogue video and audio data of the design activity. The collection of video and audio data of designers is a practice used by many researchers as evidenced by the number of contributions to the second Delft Workshop, 'Research in Design Thinking II - Analysing Design Activity', held in 1994 [Cross 1996].

Using video and audio data capture for observations has a number of advantages: we create a permanent record of the activity which can be replayed and reinterpreted; we produce data on the process that allow us to observe the evolution of an idea or a situation; we have access to behaviours and interactions that could have been missed by observers; and finally, we are able to reduce observer bias and better corroborate our results.

Video and audio-based observations also have significant limitations. Procedural difficulties include the assembly of multiple cameras, the capture of tapes for each camera view desired, the reliance on either the camera microphone or an intrusive desktop microphone for audio, and the disassembly of the entire set-up at the end of the exercise. The analysis, which involves viewing a number of different tapes asynchronously and either dubbing the audio to a tape or listening while viewing the video, is time consuming. The data, captured in analogue format, must be accessed sequentially, further increasing the time necessary for analysis. This reduces the number of experiments that can be run. We sought to overcome these limitations by creating a facility that would improve data collection and analysis procedures associated with in-situ observations of designers.

2. Designing a Facility

We treated the planning of this facility as a design exercise: we identified a customer, assessed needs, developed a set of requirements, identified resources, projected a timeline, generated alternatives, and explored existing solutions.

The primary customers were identified as the researchers who would be using this facility to collect and analyse data. These researchers formed the core of the design team. One of the first issues that we addressed was the timeline of the project. We felt it was important to have a very short development period and set the first important milestone, to start collecting data using this facility, at three months. We felt a rapid prototyping cycle was important because it allowed us to quickly test our design and make necessary modifications. The next issue was how much money we had to spend. The centre director made a budget of US$10,000 available. It was felt that having a bigger budget would result in a facility that could not easily be replicated by other researchers. The last preliminary decision was that the name of the facility would be the Design Observatory.

There were a number of requirements that the facility needed to meet. The most important was that the researchers should be able to use this facility to collect the data necessary to satisfactorily conduct their research. Each of the researchers has a particular focal area and different analysis methods. Our research interests cover the areas of design cognition, design communication, social aspects of design, and distributed team design [Eris 1999, Carrizosa 2000, Mabogunje 2001, and Milne 2001]. Our research includes the analysis of qualitative and quantitative data. Quantitative techniques require precision and repeatability of observation for identification of specific data points. Qualitative techniques require a wide spectrum of observation for capturing multiple aspects of activity. The facility would have to support both techniques.

The goal of our first phase of development was to provide a core functionality that served the needs of all researchers. It was understood that each researcher had needs, beyond this core functionality, which would have to be addressed later. This meant that we would have to build a certain level of flexibility into the facility to accommodate these additional needs.

Another requirement was that audio and specific video data needed to be captured. All researchers needed multiple video views of the design activity. It was important for us to capture frontal views of each participant to observe their gestures and the manipulation of artefacts, an overhead view of the work surface to observe artefact building and sketching activity, and a view of any space that the team would use to catalogue and organise their design process to observe documentation. We also needed to capture audio of the design activity.

We defined success to be the creation of a facility that captured design activity and maintained the advantages of video and audio data while improving on the disadvantages. Building a permanent facility could eliminate the procedural difficulties. The analysis difficulties could be improved upon by capturing data digitally into one file and analysing data digitally. Meeting this requirement adds a technological layer to the observe-analyse-intervene research methodology described previously. Using digital technology to collect data in a design setting was not a new approach, however, using it to analyse data was. The main benefits of digital data analysis are portability and customised indexing, and the related benefits are data sharing, which can lead to collective interpretation, and cross referencing, which can lead to the capture of the implicit elements of design activity. [Yen 2000].

The outcome of the design process was: that the researchers would build a permanent facility that supported design activity; that four video views and audio data of the design activity would be captured and recorded digitally into one file; that the building of this facility would be accomplished in three months; and that the price of implementing the core functionality would be under US$10,000.

3. Implementing the Core Functionality

3.1 Physical infrastructure

A primary concern was establishing a physical space to facilitate team design activity. We felt it was necessary to provide two elements, a horizontal surface for the design team to work at and a vertical surface where the design team could document their activity. To control costs, we chose to build both of these elements.

Since the standard team size in most of our experiments is three members, we felt a square table would discourage teamwork and lead to individuals working in alternating pairs. A small round table (1.5 m diameter) was selected as the most appropriate horizontal surface because it provided a work area large enough for individual and group activity yet small enough so that individuals did not feel isolated from each other. A round table also allowed us to equally space team members around the perimeter.

We decided to build a certain amount of flexibility into the vertical element because we wanted to experiment with different surfaces to aid the team in their documentation. A frame was built from floor to ceiling along one wall (3.6 m long) on which could be mounted three 1.2 meter sheets of facing. The current facing is two sheets of whiteboard material on which to write with erasable marker and one sheet of corkboard on which to pin sheets of paper.

3.2 Data capture

Our next concern was to collect design team activity data. We chose to purchase analogue capture equipment because it is relatively inexpensive compared to digital capture equipment. We installed four cameras to record video data. One camera is mounted on the ceiling directly over the table to document activity on the work surface. A second camera is pointed at the whiteboard/corkboard wall to capture documentation. The third and fourth cameras are positioned on opposite sides of the table to record frontal views of the team members. To capture audio data we mounted an omnidirectional boundary microphone on the ceiling directly over the table. A picture of the physical infrastructure and the data capture equipment of the Design Observatory is shown in figure 2.

Figure 2. Physical layout of the Design Observatory showing, from left to right, the whiteboard/corkboard wall, participant camera, table, whiteboard camera, and participant camera. Table camera and microphone in ceiling at top of figure

3.3 Data digitisation and recording

A final concern was to transform the captured data from analogue to digital format and record the data. The cables carrying the output signals from the cameras and microphone run up into a space above the cosmetic ceiling, through a wall, and down into the adjoining room where our computers are situated. The microphone output goes through an audio digitizer that transforms the signal from analogue to digital. The digital signal is then fed into the audio computer station where it can be saved in .wav format. This audio signal is also sent to the video computer station to be combined with the video. The camera outputs go into a video-mixing device that combines the four camera views into one view with four quadrants, shown in figure 3. This combined signal is sent to the video capture card of the video computer station and converted from analogue to digital format. The digital video is then combined with the digital audio and saved in an .avi file.

Figure 3. Quad view output from video-mixing equipment

3.4 Cost

We had limited resources to implement the core functionality of the Design Observatory. From a budget of US$10,000, we had to buy two computers, two monitors, four cameras, one microphone, audio digitising hardware and software, video mixing hardware, video digitising hardware and software, assorted cables, lumber, building hardware, and painting supplies. As a result of extensive comparison-shopping and the fabrication of a majority of the physical infrastructure our total expenditure to realise the core functionality was less than US$7500.

4. Expanding the Functionality

By definition, the core functionality was a necessary requirement for all of the researchers involved. But each researcher also had needs beyond this functionality. The Design Observatory was built with the flexibility to add capabilities on top of, or in addition to, the core functionality. The following are some of the capabilities that have either already been implemented or are being developed for future implementation.

4.1 Individual audio capture

Limitations were observed with the captured audio. A single audio signal captured from a group of individuals bounds the types of analysis that can be performed. Also, while the single audio signal provides high quality capture of sound it does not allow us to completely record individual speech. Individuals often talk at the same time and it is difficult to decipher what is being said. To resolve these problems we have purchased wireless headset microphones with built-in transmitters to serve as additional audio capture devices. Because the transmitters are built into the headsets there are no cables to inhibit movement. These microphones allow us to capture digital audio files for each individual. The signals can be mixed into one audio signal and sent to the video computer station to be combined with the video signal so we still have the complete video/audio capture of the session. With individual audio signals we now have access to every utterance from each team member. We can also automatically process the digital data and pull out time stamps of individual utterances. Future plans include processing these files using automatic transcription software and combining the text into one file using the time stamps to digitally capture the dialogue in text format.

4.2 Electronic whiteboard capture

Early problems with the quality of data captured from the whiteboard wall have been observed. To capture the entire surface with the camera we have to zoom so far out that the detail of what is on the surface is lost. Uneven lighting over the surface of the whiteboard wall means that pen activity recorded by the camera has varying shades of visibility. To resolve these problems we have installed hardware and software that digitally captures pen strokes on the whiteboard. This can be saved as a picture file or printed out at the end of a session to serve as a record. A potential use of this technology is to send the information directly to the video-mixing device to replace the video signal currently provided by the camera.

4.3 ReCall indexing of data

There is an opportunity to use a multimedia indexing, searching, and retrieval tool to improve the accessibility of our data. An application named ReCall, developed by a previous researcher at our centre named Sam Yen, takes audio, video, and sketches captured during a design activity and saves them into a file. This file can be accessed over the Internet using a Java applet. A user selects a section of a sketch and is shown the audio and video that was captured when that portion of the sketch was created, providing the user with a better contextual understanding. We are investigating using ReCall to index the signals from the cameras, microphones, and electronic whiteboard capture hardware in the Design Observatory. A potential use of this technology is to index instances that inform research questions for easy future access.

4.4 Miscellaneous functionality

We are investigating a number of other capabilities that will improve the overall functionality of the Design Observatory, allow us to observe designers with higher granularity, or better support distributed team design activity. We would like to install a projector so that people can use the room to give presentations. The output from the projector could also be sent to the video-mixing device to be combined with camera views and audio signals so that a high quality record of the presentation is captured. We are interested in acquiring helmets that record electrical activity in the brain. The information captured from the helmets could be used in conjunction with video and audio data to provide a richer picture of the design activity. And finally, we would like to install a videoconferencing system.

5. Reflecting on Results

We began building the core functionality in January 2001 and the first data was collected a month later. In the past year of using the Design Observatory we have seen an increase in the amount of data that has been collected and analysed, an increase in the quality of the data collected, and a decrease in the amount of time spent in analysis. In addition, the room facilitates the capture and analysis of both qualitative and quantitative data, which was a key requirement of all involved researchers.

The facility addresses some of the significant limitations of using video and audio-based observations. We have eliminated the errors involved with continually setting up and taking down equipment. The time necessary to prepare for an experiment has been drastically reduced; and there is no data lost due to researcher set-up error. The data is digitally stored so we do not have to worry about keeping track of large numbers of analogue tapes. Analysis time has decreased because we are only looking at one video file with multiple views instead of many different videotapes with one view.

There are also a number of unexpected things that have been observed since the creation of the Design Observatory. Because the room has only one entrance there is no distraction to participants engaged in experiments caused by through traffic. The room, due in part to the capture capabilities, has proven to be a quality meeting space. Our research group now regularly meets in the room and a number of other researchers at the centre have expressed interest in using the space.

6. Conclusion

The Design Observatory fulfils all of the requirements we identified during the initial design phase. The cost to build the facility is modest and each of us plans on building one of our own after we move on from Stanford. The flexibility built into the room allows each researcher to add equipment necessary to their own data collection while still maintaining the core flexibility necessary for other researchers. The use of digital data for analysis and the permanence of the equipment have improved our efficiency. The use of quality cameras and microphones has improved our effectiveness. The Design Observatory has become a core instrument for our design research.

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