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A Framework and an Environment for Collaborative Analysis of User Experience

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Pervasive technologies, such as shared interactive surfaces and mobile devices, are beginning to be used to support a diversity of collaborative user experiences. Compared with fixed PC applications, however, they are more difficult to evaluate. Of importance, it requires understanding the context of use through capturing and analyzing different types of data (e.g., conversations, gestures, movements) and re-representing them at different levels of abstraction. This can make the analysis complex and unwieldy, requiring teams of analysts to manage it. A new approach to managing the complexity of collaborative analysis is presented, where an integrated physical and conceptual space have been co-designed to allow design teams to readily share and transfer their interpretations of data through preserving the contextual information. A case study is described showing how a collaborative analysis approach enabled small groups of designers to work together to interpret and further analyze a variety of data.

1. INTRODUCTION

Pervasive technologies, such as shared interactive surfaces and mobile devices, are beginning to be used to support a diversity of collaborative user experiences. New methods of passing and sharing information have been developed that allow information to be transferred between computers and devices, such as from a laptop to an interactive tabletop screen (Ben-Joseph, Ishii, Underkoffler, Piper, & Yeung, 2001; Shen. Lesh, Vernier, Forlines, & Frost, 2002) and to a large public display (Guimbretière, Stone, & Winograd, 2001; Klemmer, Newman, Farrell, Bilezikjian, & Landay, 2001). Physical and tangible interfaces are also being used for connecting the physical world to the digital world (Lange, Jones, & Meyers,

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1998). There is much scope for supporting new ways of collaborative working and interacting with information.

However, pervasive technologies present new challenges for designers. In particular, they are more difficult to evaluate compared with fixed PC applications. More aspects need to be considered than measuring the effectiveness of a single user's interactions with a graphical user interface. It involves examining how co-located people interact with each other, how they move around a physical space, and how they coordinate their interactions with the various shared. Of importance, it requires understanding the context of use through capturing and analyzing different types of data (e.g., conversations, gestures, movements, technology interactions) and being able to re-represent these at different levels of abstraction. However, the analysis itself can become complex and unwieldy, requiring teams of analysts to undertake and manage it.

The aim of our research is to provide an analytic approach that is easy to use and manage by groups of designers and researchers when assessing the benefits of pervasive technologies in the context of their use. Our focus is on the collaborative and social aspects of people's activities when using pervasive technologies, including how human activities affect or are influenced by other people. Designing such collaborative systems requires a good understanding of human activities in context, not only the human–technology interaction but also the human-to-human interaction associated with the collaboration being supported. Of paramount importance is an understanding of the dynamics and complexity of the physical and social world itself, where people actually live, and where the systems are embedded in the physical environment (Norman, 1999; Weiser, 1993). How can this be achieved?

There have been a number of theoretical frameworks developed aimed at helping designers understand the collaborative use of technologies. For example, activity theory has been promoted in human–computer interaction (HCI) and Computer-Supported Cooperative Work, taking into account the motives that drive human activities (e.g., Bardram, 1998; Kaptelinin & Nardi, 1997). Essentially, it provides an analytical framework comprising orienting concepts to interpret people's activities and their motivations at different levels of their actions (Kuutti, 1996). Numerous variants of the original theory have been proposed by researchers to make it more applicable to specific work and educational contexts (see Rogers, in press, for a review). However, few of the approaches have transformed the theory into usable design methods that have demonstrably been used in design practice for the analysis of user experience. This is partially because activity theory is steeped in a socio-historical background, making it difficult to apply it in a design process without having a good understanding of its underpinning.

Ethnomethodology is another theoretical approach that has been promoted for understanding the context of group work (Dourish & Button, 1998; Suchman, 1987). This approach emphasizes the everyday methods by which people manage and organize their everyday actions and interactions. It uses ethnographically generated materials and focuses primarily on the analysis of the practical issue of social order, providing meaningful accounts and detailed analysis of work practices in their social contexts. However, similar to activity theory, it requires the

analyst to be trained in the philosophy and background of ethnomethodology, which makes it also less amenable to designers.

Hence, there appears to be a large gap between what design teams need in their work practice and what the theories and frameworks have to offer (Rogers, 2004). Furthermore, most require large overheads in terms of the time, effort, and skill to learn and use with any competence. Our research seeks to fill this gap by developing an analytic approach, based on relevant theory, that is easy to learn and use by design teams when evaluating the design and use of pervasive technologies intended to support co-located people.

A central question is, How can we help analysts make sense and integrate disparate sources of data that are collected? Although there exist a number of conceptual frameworks and software tools aimed at recording and coding video and logged data, they have been primarily targeted at individual use. In contrast, we have developed a collaborative approach that allows members of a design team to analyze the various data sources together and discuss and represent their interpretations of these in a format that is easily communicated and readily picked up by others. In addition, we consider how the shared physical environment needs to be appropriately designed when using the analytic framework, to enable different team members to coordinate their analysis activities and easily understand how to conduct the analysis. We emphasize the importance of configuring the physical space for doing analysis because most design teams work in a customized physical environment, such as a design studio, which helps them share their ideas, learn from others, and enhance creativity (Goldschmidt & Tatsa, 2005; Guimbretière et al., 2001).

Our analytic framework is designed to help conceptualize group activities in relation to contextual factors. It has been structured to guide the recording of empirical data and the capturing of the context of the work situation. It has a number of core elements that emphasize the types of context and interactions that take place. The physical environment has been designed specifically to support the sharing of physical materials and data sources, comprising a shared table, adjacent whiteboards, a large video display, and sets of physical cards placed in containers on the table for sorting and categorizing concepts. To demonstrate the effectiveness of our framework plus environment approach, we present an in-depth case study, first showing how a number of groups used it to analyze video data from a previous user study (that they had not had any involvement in), and second, how a number of other groups used those group's analyses to re-represent them in diagrammatic form. The rationale behind our study design was to determine how effective the approach was in supporting the use of other's data sources and analyses.

2. RELATED WORK

Many of the current methods and tools for understanding user experience can be categorized in the following three ways: (a) computer-supported video analysis tools that can be used to tag and classify data elements (Fisher & Sanderson, 1996; Lewis, Mateas, Palmiter, & Lynch, 1996; MacKay, 1989; Noldus Information

Technology, 2005); (b) theoretical or prescriptive model-based methods for formal analysis of user tasks and actions (Diaper & Stanton, 2003; van der Veer & van Welie, 2000); and (c) informal methods for collaborative analysis or synthesis of user study data such as Contextual Design (Beyer & Holtzblatt, 1997) and Video Card Game (Buur & Soendergaard, 2000).

Exploratory Sequential Data Analysis (EDSA; Fisher & Sanderson, 1996) is a well-known example of a computer-supported video analysis tool for user research that provides an environment to analyze different aspects of HCI, especially for sequential data such as conversation, interaction, and cognitive tasks. It emphasizes the concept of visualizing the collected data, which also has been promoted by the exploratory data analysis developers (Tukey, 1977), and identifies eight elements that are visually expressed to capture general patterns of the sequential data. The tools for ESDA, however, have been designed primarily for individual work. This is true for many other video software coding and analysis tools.

One approach, however, that has extended ESDA for joint analysis is the Collaborative Video Analysis tool (Cockburn & Dale, 1997). Specifically, it provides a computer-based application for collaboratively analyzing video data. Individual analysts use their own PC terminal for the analysis but can also see other's cursor movements through their screen when using the tool. Although it increases awareness of what the other person is doing when using the analytic tool, it is still primarily targeted at individual rather than collaborative use.

Buur and Soendergaard (2000) also developed a collaborative video analysis environment for user-centered design, called Video Card Game. In contrast to the software analysis tools, the method provides analysts with physical representations, such as physical cards similar to those utilized by the participatory design techniques (e.g., CARD; Muller, 2001). The method is informal and does not provide any structure or framework for supporting the recording or analysis of user experience data.

The methods and tools developed for this line of work have sought to help designers and analysts capture and describe the context of work. However, they fall short of supporting the transfer of intermediate outcomes across different teams and members involved in a design process. Being able to support the handing over of findings and the sharing of different interpretations is important to enable design teams to distribute their work among their members without overloading a certain individual.

3. THE FRAMEWORK AND PHYSICAL ENVIRONMENT FOR COLLABORATIVE ANALYSIS OF GROUP WORK

The goals of our research are to provide a framework that can help design teams capture and describe the context of group work when using pervasive technologies, to enable the outcome of using the framework to be readily picked up and interpreted by others in furthering the analysis, and to develop a physical environment for supporting cooperative analysis of group work.

3.1. Group Work Analysis Framework

The original Design Information Framework (DIF) was developed for archiving information created by various design activities such as user studies, concept development, prototyping, and evaluation (Lim, 2004; Lim & Sato, 2001). It provides a structure for defining design information elements in a generic format that can be consistently interpreted by different team members involved in a design project. The DIF framework was designed to be flexible and does not specify a fixed set of information elements. The selection of information elements can be influenced by any theoretical concepts or practical considerations that the designer is familiar with and wishes to use. For example, the Multiple Aspect Based Task Analysis defined the information elements using concepts from Kuutti's (1996) version of activity theory and coordination theory (Malone & Crowston, 1990) to create various task models of group work (Lim, 2004).

The DIF has been successfully used for creating scenarios that describe representative user experiences based on actual observations of use situations (Lim & Sato, 2006). In particular, it has helped in the description of the detailed context of use situations leading to the creation of scenarios. The Group Work Analysis Framework presented here is an extension of DIF. It is aimed at teams of designers working together in the analysis of group work with pervasive technologies. It provides the same information elements as those used in DIF for recording and organizing the data, but it instantiates these via various physical materials intended to enable teams to capture the details of a user study while allowing them to note and create patterns of the captured data. The physical materials were also designed to allow other team members to pick up and continue with an ongoing analysis.

To minimize the possible confusions that can arise when different designers try to represent and communicate aspects of the user experience, generic but clear-to-understand terms are incorporated into the group work analysis framework. These terms are *action*, *interaction,* and *object description*. We define *actions* as those carried out by users toward any product elements they interact with; *interactions* as the interactions among people, such as verbal conversation and gesture-based communication, when using a product during the interaction; and *object description* as the description of an object regarding its attributes and functions. These concepts are relatively easy to understand and allow analysts and designers to be able to consider the concepts of collaboration and cooperation through considering human-to-human interaction. For example, different types of interaction among people can be captured such as collaborative interactions, cooperative interactions, and communication-based interactions.

As shown in Table 1, each of these information elements is described in more detail in terms of information primitives. The information element, interaction, consists of five further primitives: a *subject-user,* which is the person who initiates an interaction; an *act,* which is the act of the interaction; an *object-user,* which is the person who received the signal from the subject-user; a *tool,* which is the artifact that is used to enable the interaction; and *time,* which indicates in which moment the interaction happens. The information element, action, consists of five further primitives: a *user,* which is the person who acts upon the object; an *act,* which is

Table 1: Group Work Analysis Framework

Information Elements (Analogous to DILs in DIF)	*Information Primitives (Analogous to DIPs in DIF)*
Interaction	subject-user, act, object-user, tool, time
Action	user, act, object, location, time
Object description	object, attributes, time

Note. DIL = Design Information Element; DIF = Design Information Framework; DIP = Design Information Primative.

the act of the action; an *object,* which is the object that is used by the user; a *location,* where the action happens; and *time,* which indicates in which moment the action happens. The information element, object description, consists of three further primitives: an *object,* which is the name of the object that has an important role in the situation; *attributes,* which are the description of attributes of the selected object; and *time,* which indicates in which moment the object presents itself.

3.2. Co-Located Collaborative Environment for Collaborative Analysis

The framework provides a mechanism to organize, archive, share, and analyze the collected user data. However, the framework by itself is not a sufficient condition for supporting collaborative analysis. Teams need to be able to share their interpretations of the data observed. In the real world, it is rarely the case that one person records and codes the entire data gathered from user studies. It is more common for a team of analysts to do this, where one person may hand over his or her analysis to another. Hence, the physical environment also needs to be designed to be conducive to teams of designers to be able to utilize the framework in a collaborative and distributed way.

It is important, therefore, to consider how best to design and arrange the physical space to support effective collaborative recording and analysis of archived video data. To guide the design of the environment, we drew upon Kirsh's model of the context of work that is based on the theoretical perspective of distributed cognition (see Kirsh, 1995, 2001). According to this approach, people frequently offload some of the cognitive effort involved in carrying out their tasks onto the environment (Hollan, Hutchins, & Kirsh, 2000). Examples include the placement of sticky notes and piles of books, files, and so on, in salient parts of the work environment, acting as reminders, through demanding our attention at opportune moments during our work. Kirsh provided three concepts to consider when designing the context of work:

1. *Entry points* that are cues or triggers for inviting people's attention to start to do something such as blinking signals from a voice mailing system, headlines in newspapers, and magazines positioned on a desk.
2. The *activity landscape* that helps people perceive how to use the materials provided in the environment. The arrangement of materials in an environment enables a different activity scope—for example, chairs aligned side by side in front of a table affords sitting at and working on materials (e.g., notebooks,

paper) placed on it, whereas a room with a whiteboard and no chairs affords people standing at it and drawing things and referring to them on the board.

3. *Coordinative mechanisms* that facilitate coordinative aspects of people's activities such as reminders, schedulers, and lists.

The notions helped us think about the design of our physical environment, focusing on how to make the various stages of the data analysis tasks explicit, easy to manage, and easy to switch between by both co-located distributed team members.

It is important to provide materials for doing the analysis with which design teams are familiar, such as physical artifacts. To this end, different-sized physical cards were used as the entry points for recording the designer's interpretations of the data. Two sizes were chosen to make it easy to see which one referred to which part of the framework. The large size referred to the top-level elements and the smaller size to the atomic primitive elements for each of the top-level items. Figure 1 shows examples of *interaction*. The form fill-in structure presented on both types of cards was intended to guide the analysts when entering user study data such as video analysis data. Color stickers were provided to enable the designers to annotate the type of information element. Number stickers were also provided for identifying each card's unique ID. The cards were laid out in physical containers positioned centrally on a shared table, providing easy access for all

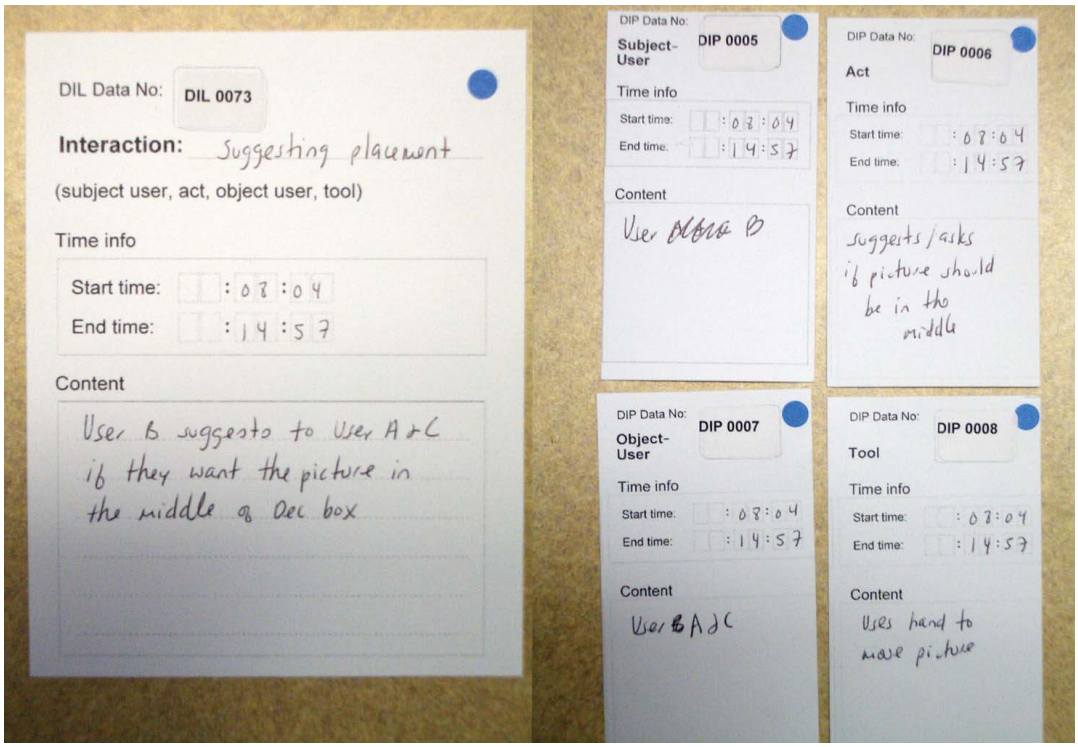

FIGURE 1 Examples of an Interaction card and its primitive cards produced by one group of the participants in our user studies.

group members. We chose to make this part of the analysis activity physical rather than using computer-based tools as it can support problem-solving activities more effectively (Maglio, Matlock, Raphaely, Chernicky, & Kirsh, 1999). In particular, it enables the materials to be easily to passed around, manipulated, and shared with others.

The three framework categories (action, interaction, and object description) were written on a whiteboard, again with the aim of guiding the analysts in appropriately placing their filled in cards. The idea was to allow the group members to structure and store the cards they had filled in. This part of the analysis was also designed as a physical activity, providing a tangible and visible activity landscape, allowing all the group members to easily add, access, and share the cards.

Another whiteboard was used to create the visual diagrams. A transparent film was added to allow the diagrams to be built up by different team members by overlaying their comments, using marker pens, on the diagrams previously created by others. For example, an information exchange flow between a group using an information system can be represented in one diagram, which is then overlaid by someone else's interpretation of the group members' roles and their influences on the pattern of system use. Again, the idea of representing this task in a physical form rather than digitally was to make it easy for all to add (and remove) their comments while being persistent for all to see in relation to the others.

The wall at the front of the room was designed as a shared viewing surface for the video clips. A large screen with a data projector, rather than individual PC screens, was used to project the video. A computer-supported video player was provided to allow the playing of two video clips simultaneously on the screen, so that two different views could be seen together. Our rationale for using this method of joint viewing on a large display was to support collaboration, enabling groups to discuss their ideas and opinions together.

The size of the room needs to be appropriate for small-sized groups to work together. It should not be too large so as to seem impersonal but also not too small to be uncomfortable for groups working closely together. Figure 2 shows the physical layout of our room, with a shared table, chairs, and wall surfaces used as key features of the activity landscape. The space was designed so that pairs could sit comfortably side by side and move easily to and between the two whiteboards to place their cards on or create their diagrams. The setup also designed to enable groups to switch easily between viewing the video clips, recording their analysis on the cards, ordering them on the whiteboard, or using them to create diagrams on the other whiteboard.

By creating a collection of physical entry points that were highly salient and distributing them throughout different parts of the room, we hoped to provide a physical space that would make it easy and effortless to know where to find information and use it to perform a particular analytic task. A key question is whether such a setup when used with the collaborative form of the analytic framework helps groups understand and interpret complex user experiences, such as those where groups of users are interacting with pervasive technologies.

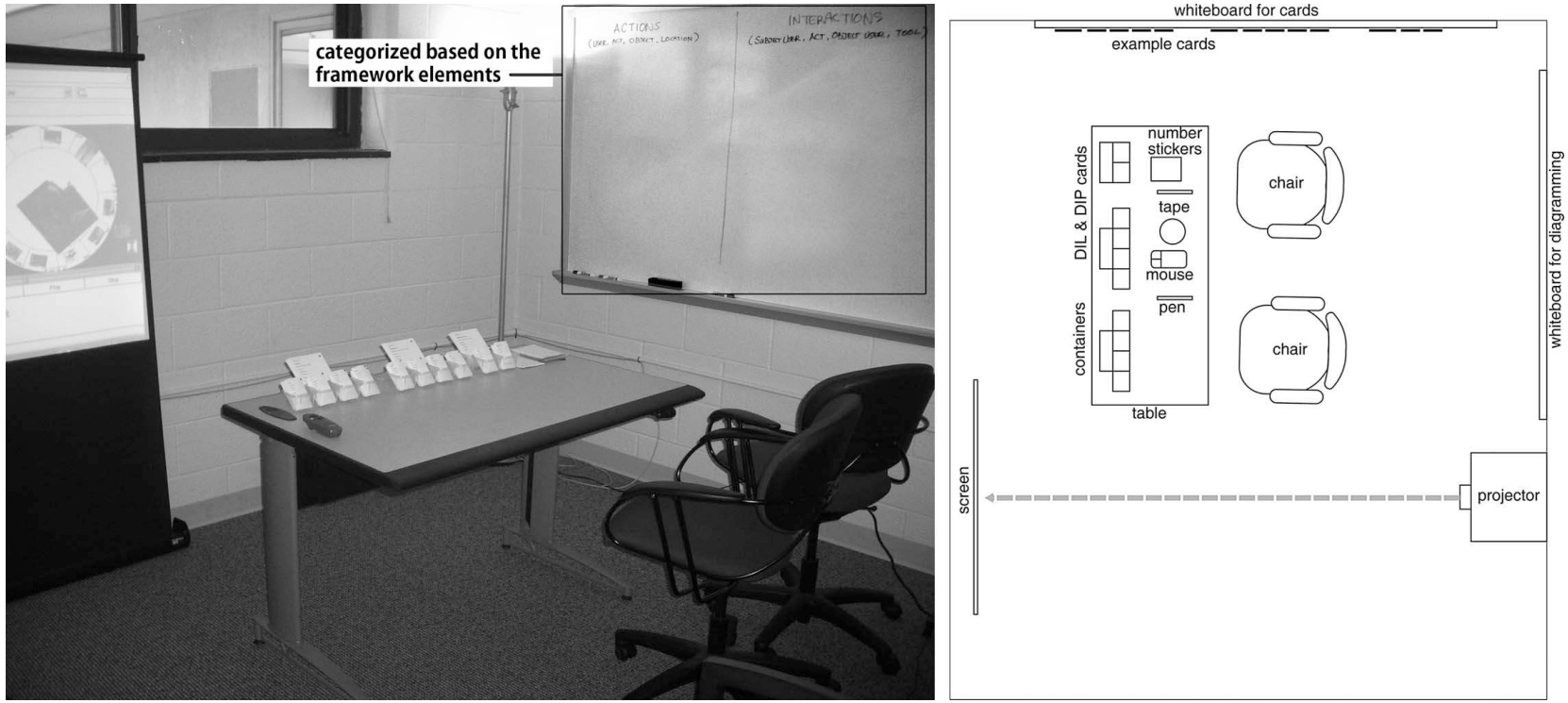

FIGURE 2 The environment design setup for the user studies.

4. CASE STUDY

We conducted a user study to see how small groups collaborated when using our framework in the physical environment. Groups of two were asked to analyze video clips taken from a previous study that investigated how collaborative working was affected when using a shared interactive tabletop (Rogers, Hazlewood, Blevis, & Lim, 2004). The video clips showed three people who know each other using a tabletop application designing a cover for a new calendar by selecting an appropriate image for each month. The problem space that Rogers et al. were interested in was face-to-face meetings where asymmetries in access to and the creation of information can arise. The aim of that research study was to determine whether interactive tabletops can help reduce such asymmetries in collaborative working by providing more equal and direct access to the digital information that is being created and discussed. The reason for using an existing corpus of data from that research was to see how groups would analyze and coordinate data sources and materials that had been handed over to them by others. In addition, this example effectively represents a group work situation of using a new pervasive technology.

Four groups were asked to perform one type of analysis, and another four groups a follow-on analysis. These were a *recording task*—recording and organizing user experience data using the framework—and a *diagramming task*—interpreting the user experience by creating visual diagrams using the data created from the first task. Many researchers have recognized the importance of visualizing patterns of user experience through different diagrams and models, such as contextual modeling (Beyer & Holtzblatt, 1997) and task analysis models (Diaper & Stanton, 2003). To accommodate the benefits from these approaches, the framework used for capturing user experience should guide designers to collect detailed elements of situational description as well as enable the visualization of the patterns of the captured data.

4.1. Design of the Study

Four groups of two participants took part in the recording task, and another four groups took part in the diagramming task. The participants were graduate HCI students who have experience in user study analysis. The groups were formed with students who know each other and had experience in working together in order to simulate the ordinary situation of design teamwork. Our intention in the case study is to explore problems and possibilities that can further inform us to refine our framework and environment.

The groups in the recording task condition were asked to view different segments of two video clips lasting 30 min uploaded onto the computer-based video player. Figure 3 shows a screen shot from the video clip of the group using the tabletop and one of the application running on it at that point in time. We deliberately asked the groups to view the different segments of the video clips in order to simulate one of the key aspects of design practice—teams change over time—and this requires transferring data from one team to another. In the real

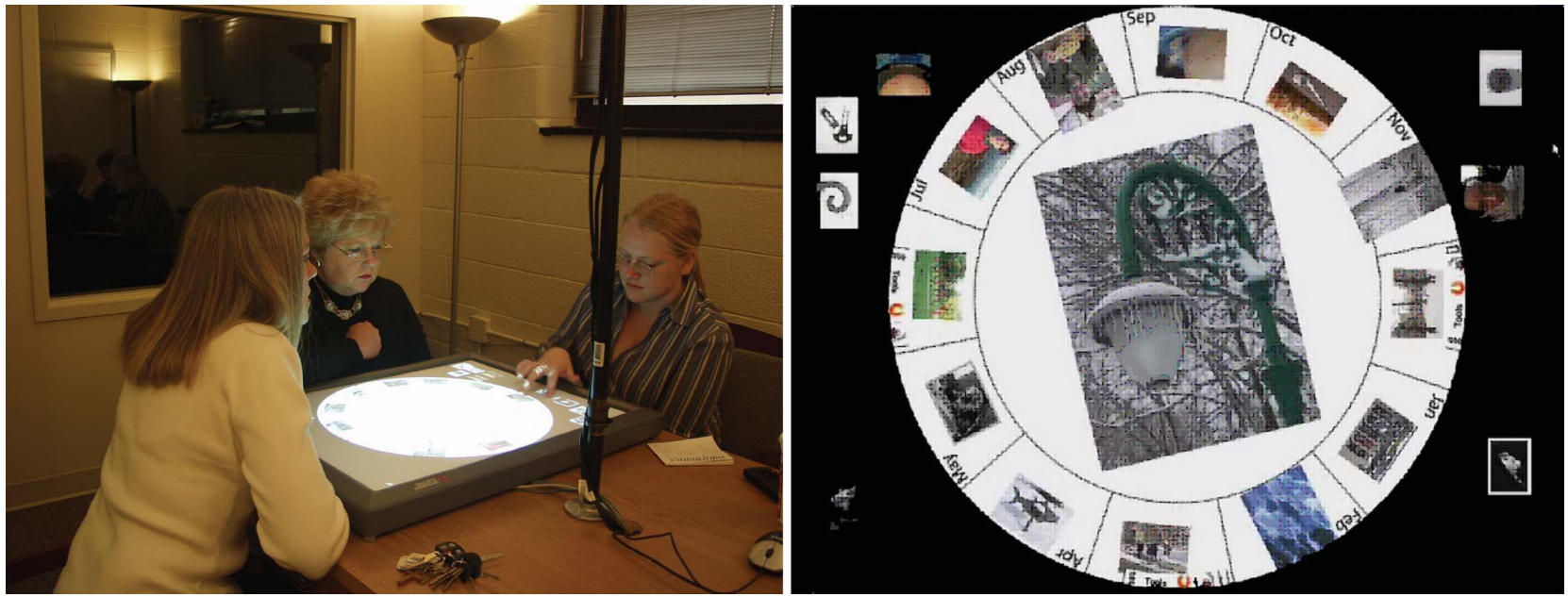

FIGURE 3 The video data provided to the participants for the analysis. On the left is a group using the tabletop to move images around. On the right is what appeared on the tabletop at that point.

world, it is not desirable for one person to record and code the entire data gathered from a field study. There is a need to divide up the work, and we wanted to emulate this.

Brief instructions and an explanation of the framework were given to the groups for each condition. The groups were told how the tabletop worked. They were informed of the goal of the user study they were analyzing (to investigate how groups collaborate when using it) and the goal of the study they were taking part in. For the groups in the recording task condition, they were shown how to use the different cards, where to place the cards, and how to view the video clips. The groups in the diagramming task condition were asked to create diagrams on the whiteboard by going over the different sources of user study data (the video clips and the framework-based cards created by the four groups that did the recording task).

Examples of the framework-based cards were provided for the groups in the recording task condition, and examples of the visual diagrams were provided for groups in the diagramming task condition. The groups in the diagram condition were asked to create diagrams in two different ways: create a diagram from scratch or create a diagram by annotating a previously created diagram. Two groups created new diagrams, and the other two groups added to the previous diagrams. The groups could decide for themselves what aspects to represent and how to create their diagrams. We were interested in how the groups interpreted and utilized the information on the framework-based cards created by the other groups during the recording task. The groups were also given the option of playing the video clips. We wanted to see whether they would need to use both the cards and the video clips to create their diagrams. We also wanted to know what they captured when creating the diagrams and how they used the elements in the framework for the diagram.

The groups in each condition were each given up to 1 hr to perform their task. To record the groups, we placed two cameras in the room. We coded their behaviors and what was said in each group. We also asked debriefing questions after each group finished the task. The following questions were asked of all groups regarding their task:

1. Did you understand easily how to use the materials provided to achieve the task? If not, what were the difficulties?
2. Did you experience any moment in which you feel you are not sure what to do? If yes, could you explain what made you feel that way? What made you confused?
3. Was the arrangement of materials in the setup of work effective to coordinate your work? For example, did you feel comfortable moving around the space to reach each material for your activity? Did you feel comfortable working with your other pair with this arrangement of the materials? If not, could you explain when you experienced the difficulty?
4. Which part of the materials you feel encouraged the sharing of your ideas with other members? For the groups that did the recording task, we asked one more question: "Did you understand easily what to fill out in each

index card? If not, what made it difficult?" For the groups that did the diagramming task, we asked one more question: "Was it easy to understand the information on the cards on the board? If not, what made it difficult?"

5. FINDINGS

The groups all agreed that conducting the analysis task as a group exercise was beneficial and helped them come to a shared understanding of the user experience. They also mentioned how the physical setup was easy to use and manage. In terms of the framework, we examined how the groups conducted the two different analysis tasks in terms of (a) ability to initiate analysis, (b) transferability of data and analysis across different teams, and (c) interpretability of the group work experience through the creation of diagrams. In terms of the environment, we looked at (a) coordination and their use of and movements in the physical space and (b) the roles they adopted.

5.1. Use of the Framework

The use of the framework was examined by looking at how the participants conducted the given tasks and from their comments.

Ability to initiate analysis. The framework provided the groups with a way of initiating their analysis of the user experience. For the groups in the recording task, the physical cards provided clear and constrained entry points helping them decide what to record for what they observed from the video clips. In particular, the points guided them in representing aspects of the collaborative activities observed in the video clips at a higher level of abstraction, in terms of the elements of interactions, actions, and object descriptions. The process of placing the cards they had filled in onto the whiteboard cards also helped them further understand what they had seen in the video clips.

The group members who worked on the recording task mentioned that the framework was effective for understanding the collaborative user experience portrayed in the video clips. They also said that using the physical cards with the elements written on them helped them to understand how to start to analyze the user information. The structured cards were considered preferable for writing down their analysis compared with using only blank notes. The groups indicated that the cards helped them understand better the patterns of individuals versus group activities shown in the video clips. They also said that it was easy to represent the patterns of the user experience using the top-level framework categories of interactions, actions, and object descriptions. Having the video material together with the two types of physical cards formatted in terms of the various elements of the framework enabled the participants to understand the user experience from different levels of detail.

The filled-in cards also provided a good starting point for the groups to create the diagrams in the diagramming task. In contrast, the previously created

diagrams were found to be more difficult to add ideas to than creating new ones. The integration was difficult because the participants had their own way of visualizing their interpretation through the diagrams.

Transferability of data and analysis across different teams. By transferability, we mean how well the data recorded on the framework-based cards could be effectively used by the other groups in the diagramming task. The groups in this condition used the data on the cards as the primary source for understanding the user experience of the group collaborating around the tabletop. All of the groups spent much time initially reviewing the cards. The information written on the cards helped them to see the context and overall patterns of actions, interactions, and objects in the user experiences. For example, in one group, one participant worked out the temporal and semantic relationships among interactions and actions by looking at the cards, enabling that participant to interpret the activities that had been recorded. Another participant mentioned that he did not even realize that there was a specific action when just looking at the video clips, but the cards actually helped him to see the details.

The groups subsequently viewed the video clips to confirm their interpretations. They commented how the videos helped them to see simultaneous happenings more easily, such as an action and an interaction that happen together. They also mentioned that the cards helped them to identify key components of the user experience that could have been missed if they had only viewed the videos. Table 2 shows the participants' activities and the reasons for checking and using the video data. Their reasons included the following: to be familiarized with the user data, to look for the corresponding points among the cards and the video clips, and to make sure if what they saw on the cards was correct. This suggests that the

Table 2: Each Group's Records of the Reasons for Accessing the Video Content While Conducting the Diagramming Task

Group	*Time*	*Observation—Reasons for Accessing the Video Content*
Group 1	0:17:14	to be familiarized to the user data
	0:30:30, 0:42:10	to look for the corresponding points among the cards and the video clips
	0:40:47	to make sure if what they saw on the cards was correct
	0:47:58, 0:52:58, 0:58:51	to check the group decision making action, which is the core idea of their diagram
	0:59:30	to check what they have just seen by playing it again
Group 2	0:20:35	to listen to it over doing other things. They do not actually pay attention to the videos.
	0:28:24	to look for the corresponding points among the cards and the video clips
	0:30:50, 0:32:08, 0:33:19, 0:34:34, 0:35:36, 0:40:43	to go through the video without audio to see the movement patterns
Group 3	0:30:23, 0:33:25	to be familiarized to the user data
Group 4	0:33:00	to be familiarized to the user data
	0:56:42	to make sure if what they saw on the cards was correct

videos were used by the group members for familiarizing themselves with the user experience rather than for doing the analysis for creating a diagram.

Interpretability of Group Work Experience. By interpretability of group work experience, we mean the effectiveness of participants' analyzing group work patterns utilizing the information on the framework-based cards and how this was represented in the diagrams. Groups 1 and 2 created diagrams from scratch, whereas Groups 3 and 4 created their diagrams using the previously created diagrams by the other two groups.

Figure 4 shows the diagrams created by Group 1. They visualized the group decision-making patterns while watching the video clips. Although the video clips were the primary resource for their decision of what to visualize, they identified the details of the structure of the group decision-making processes by looking at the information on the framework-based cards. These included the decision-making components of controller, proposer, proposal, approval, and action. When they were reviewing the cards under the interaction category on the whiteboard, they noticed that the information on the subject-user cards primarily contained the person who either proposed his or her ideas to the others around the tabletop or made the approval of the proposed ideas. When looking at the cards in the action category, the participants realized that many of the actions are the executions of their decisions. They also identified two types of approval, which are verbal and gesture. In contrast, Figure 5 shows Group 2's approach to creating a diagram who focused more on visualizing the flow of attention point changes on the tabletop interface. They used the cards to determine how the users interacted with the digital information presented the tabletop.

Figure 6 shows Group 3's diagram. They were provided with Group 1's diagram to base theirs on, and this influenced what they chose to represent. They discussed the group decision-making patterns that were defined by Group 1, clarifying the meaning of the terms, controller, proposer, and approval. In addition, they identified the flow of the group decision-making process. Their ideas were not very different from Group 1's diagram, but they made more detailed explanations. After deriving their initial ideas, they then looked at the video clips to confirm and check their subsequent ideas about the group's interactions and actions. Figure 7 shows Group 4's diagram; they were provided with Group 2's diagram. Based on the information from both the framework-based cards and the video clips, they came up with a list of the key types of negotiations that took place at the tabletop. These were agreement/disagreement, suggestion, action, and discussion. The group used the cards that lead them to focus on the negotiation that took place, which was not represented in Group 2's diagram. They then tried to visualize each person's state of negotiation at the tabletop, such as agreement/disagreement, suggestion, action, and discussion, along a time line in their diagram.

For both recording and diagramming conditions, it is clear that the group work analysis framework helped the groups understand and interpret the tabletop group work patterns, especially when they used the framework-based cards as their main source of the analysis. Diagrams that others had created were found to be more difficult from which to build further analysis.

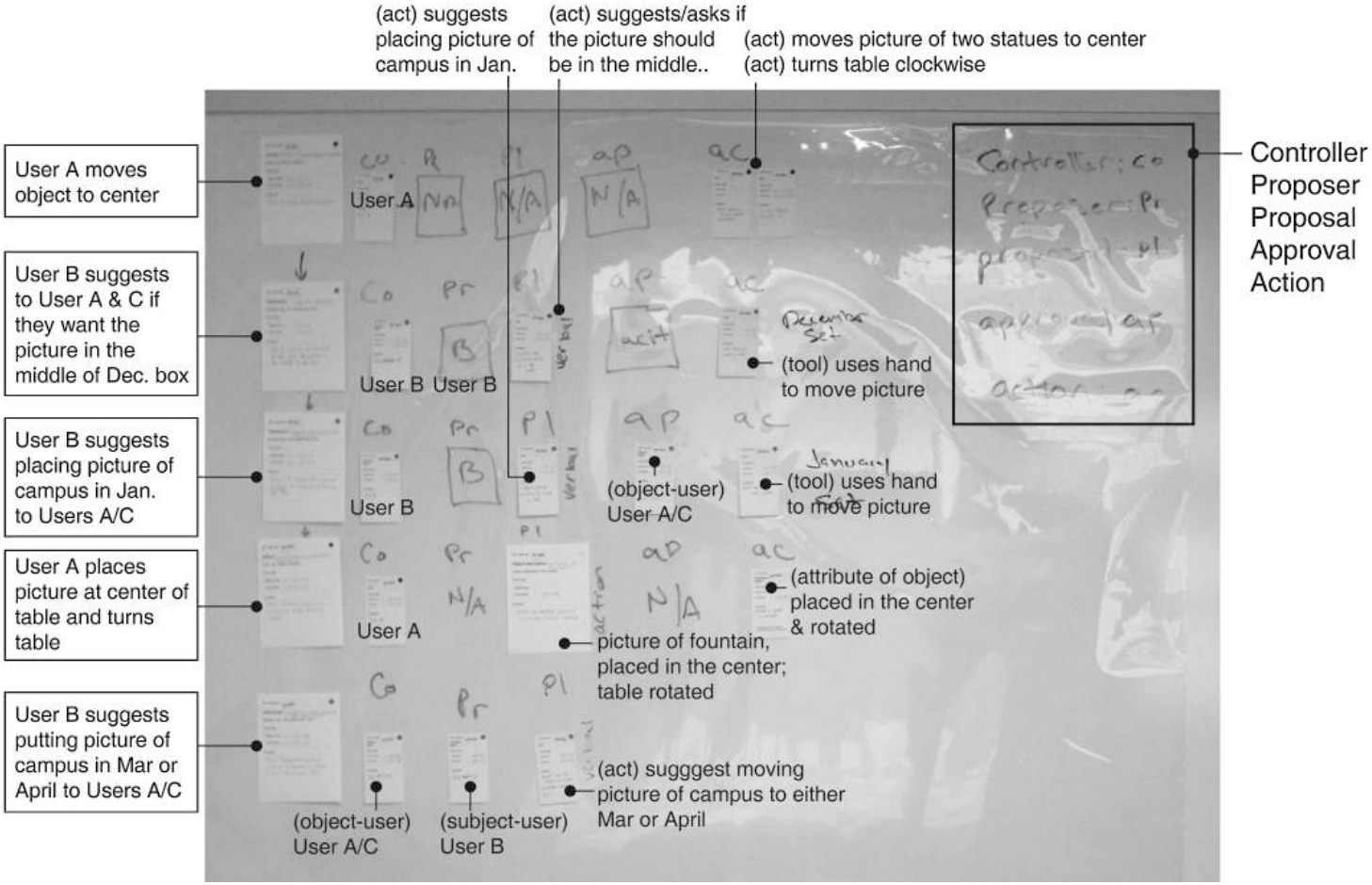

FIGURE 4 Group 1's diagram representing the group decision making pattern. The annotations are included to show what the group wrote down.

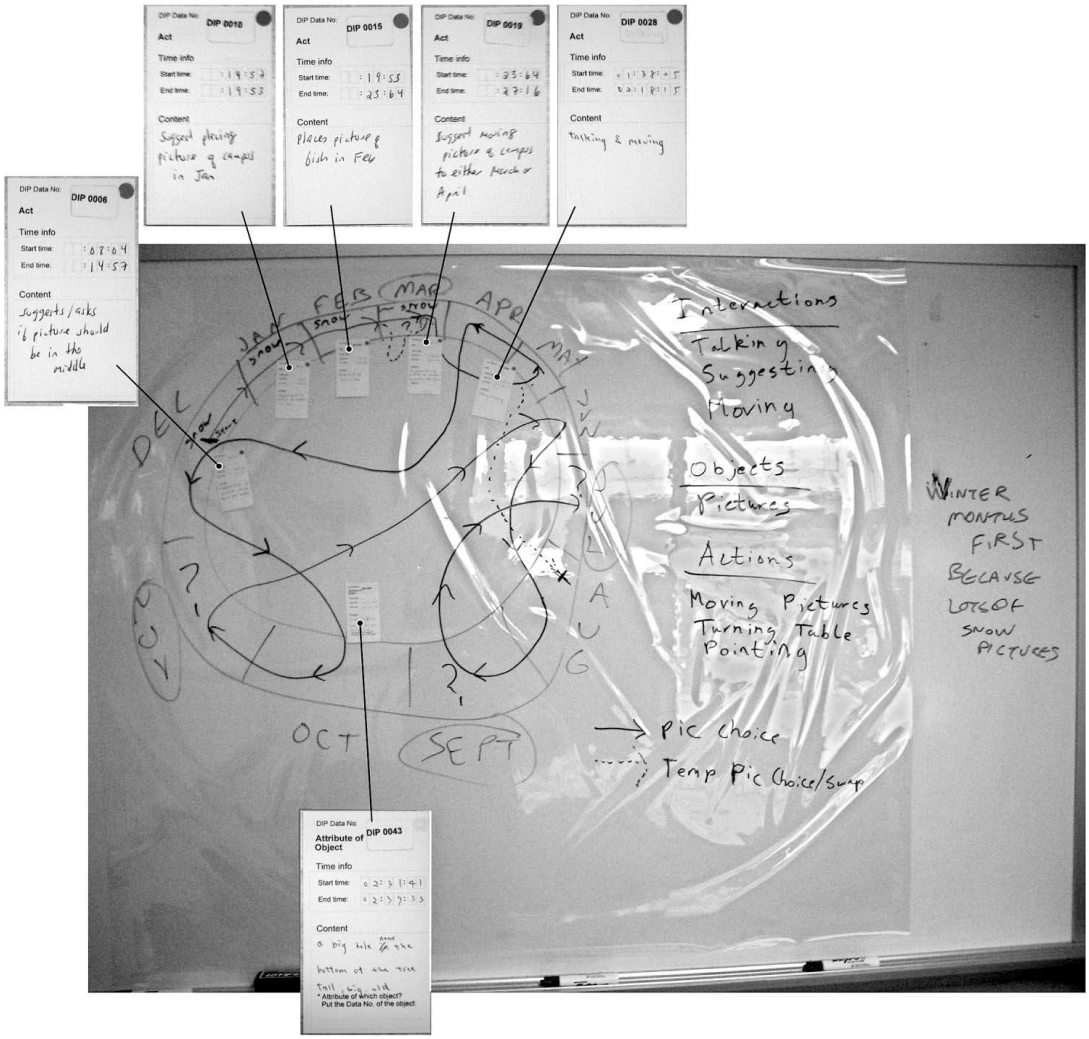

FIGURE 5 Group 2's diagram representing the pattern of the interaction between the users and the tabletop application interface elements throughout time.

5.2. Use of the Physical Space

The groups found the setup to be easy to learn and use and, of importance, remember what to do where and how to use the various materials and surfaces as a group.

Coordination, use of, and movement in the physical space. To understand the coordination of the work among the participants and their use of the physical space, we visualized their work patterns in terms of frequencies of physical movements or attention changes across different materials arranged in the space (Figures 8a and 9a) and amounts of time spent in different locations in the space (Figures 8b and 9b). In the recording task, all participants said that the arrangement encouraged them to coordinate their work. The seating also affected

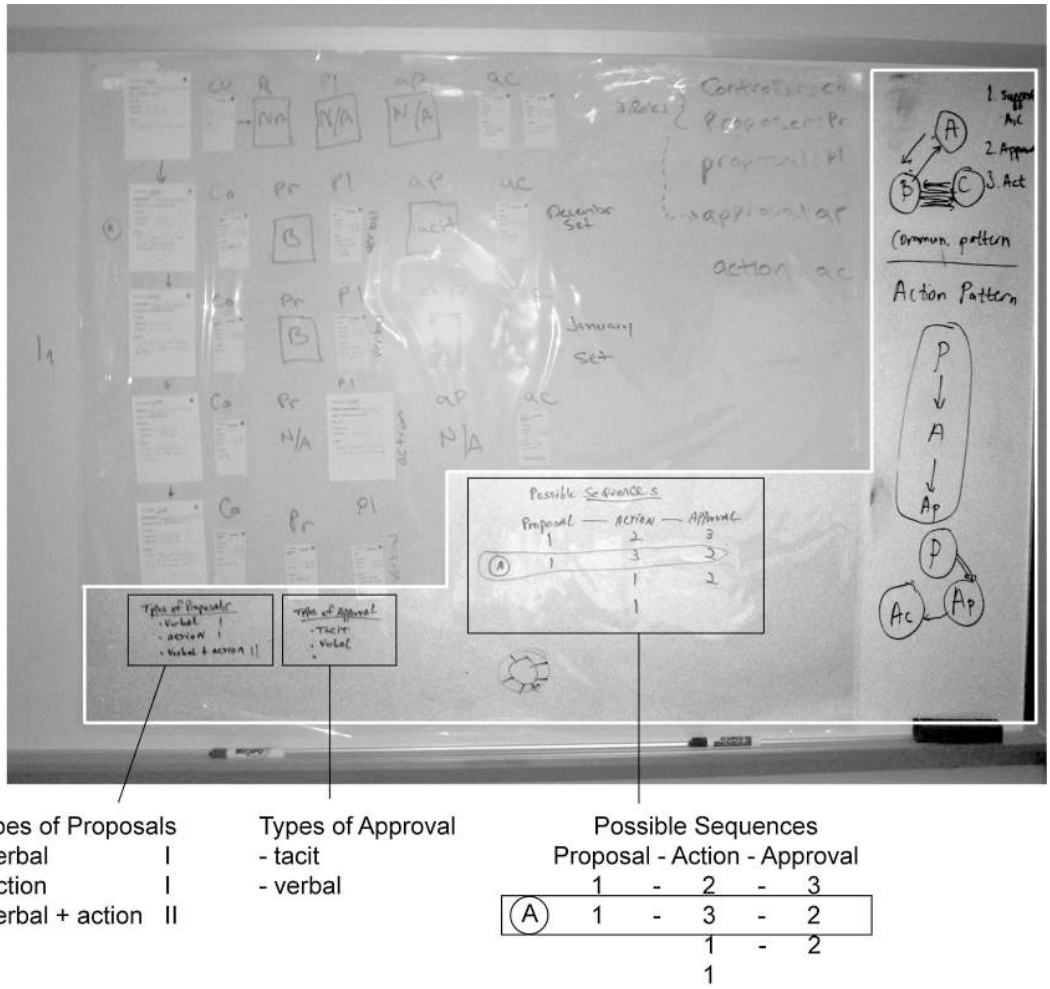

FIGURE 6 Group 3's diagram representing the mechanisms of the group decision making by integrating Group 1's diagram. The parts that are highlighted are created by Group 3. The annotations are included to show what the group wrote down.

the way they worked. The participants who were sitting in the chair on the right-hand side—which is indicated as U1 in Figure 8b—were more active in working on the whiteboard during the task than the participants who sat at the left side (U2). Participants in U2 were primarily sitting in the chair and working on the table. Two participants mentioned that they liked that they had to stand up and move around in front of the board. For the diagramming task, the participants needed to go back and forth between the whiteboards and the table quite often. When creating their diagram, two groups used paper to work on them at the table. Accessing to the video clips from the table was easier than working at the whiteboard. The participants spent relatively more time collaborating in the diagramming task than in the recording task.

Many decisions were made to represent ideas in the shared spaces (i.e., the whiteboards, the screen of the video clips and the table). The groups in the

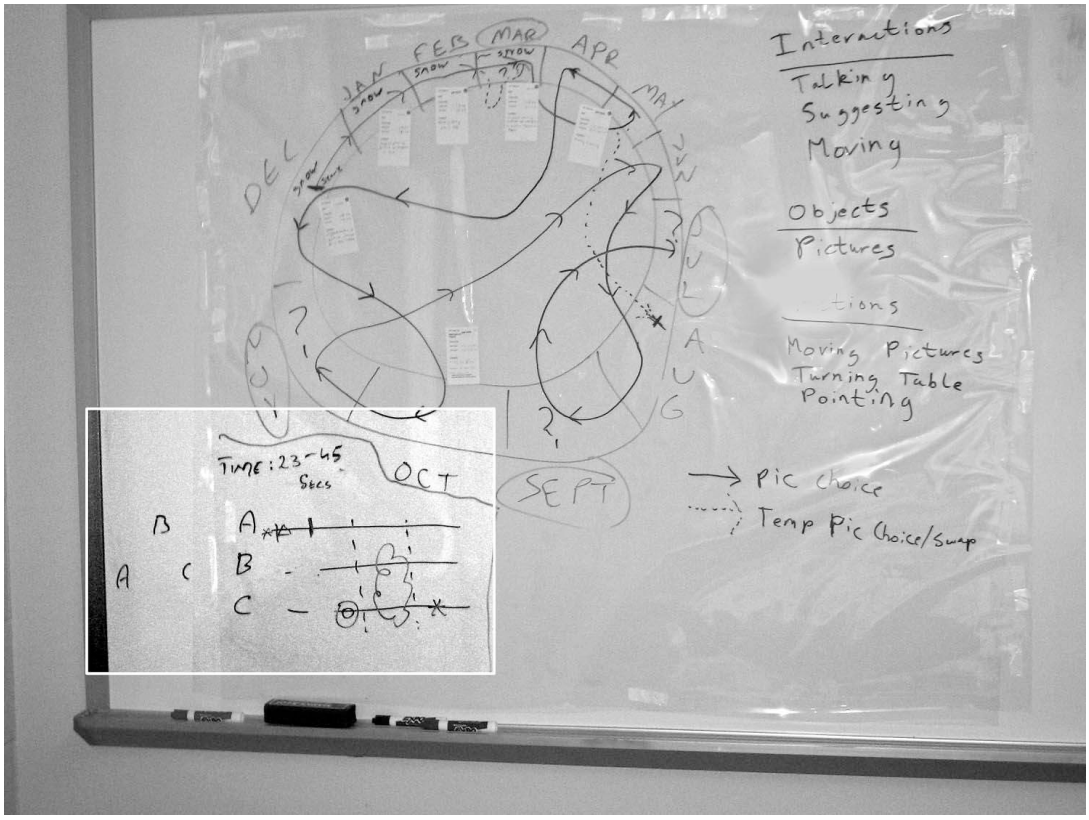

FIGURE 7 Group 4's diagram representing the patterns of negotiations by integrating Group 2's diagram. The parts that are highlighted are created by Group 4.

diagramming condition mentioned that the cards on the whiteboard encouraged them to share the information. They discussed the information by looking at the cards and reading the cards to the other. They also viewed the cards individually and later discussed what they read. When they viewed the video clips, they watched them together and discussed the scenes they had watched to try to build up a shared understanding of them. The groups also mentioned that drawing the diagrams on the board or on the paper encouraged them to share their ideas when creating the diagrams.

The input devices and materials (i.e., the cards, pens, mouse, and stickers) enabled the participants to coordinate their work by distributing the activities to each member of the group. The containers helped the participants share and pass each other the framework-based cards. They also helped them keep the cards for different information components without mixing them with other cards. The color codes helped them to separate the cards easily.

Roles adopted. The groups in the recording condition took on different roles. Typically, one became the observer of the video clips, whereas the other recorded the data on the cards. The groups encouraged each other to exchange their roles and to not feel that one person was dominating for a certain activity. However, the roles tended to stay fixed in most groups, although they encouraged

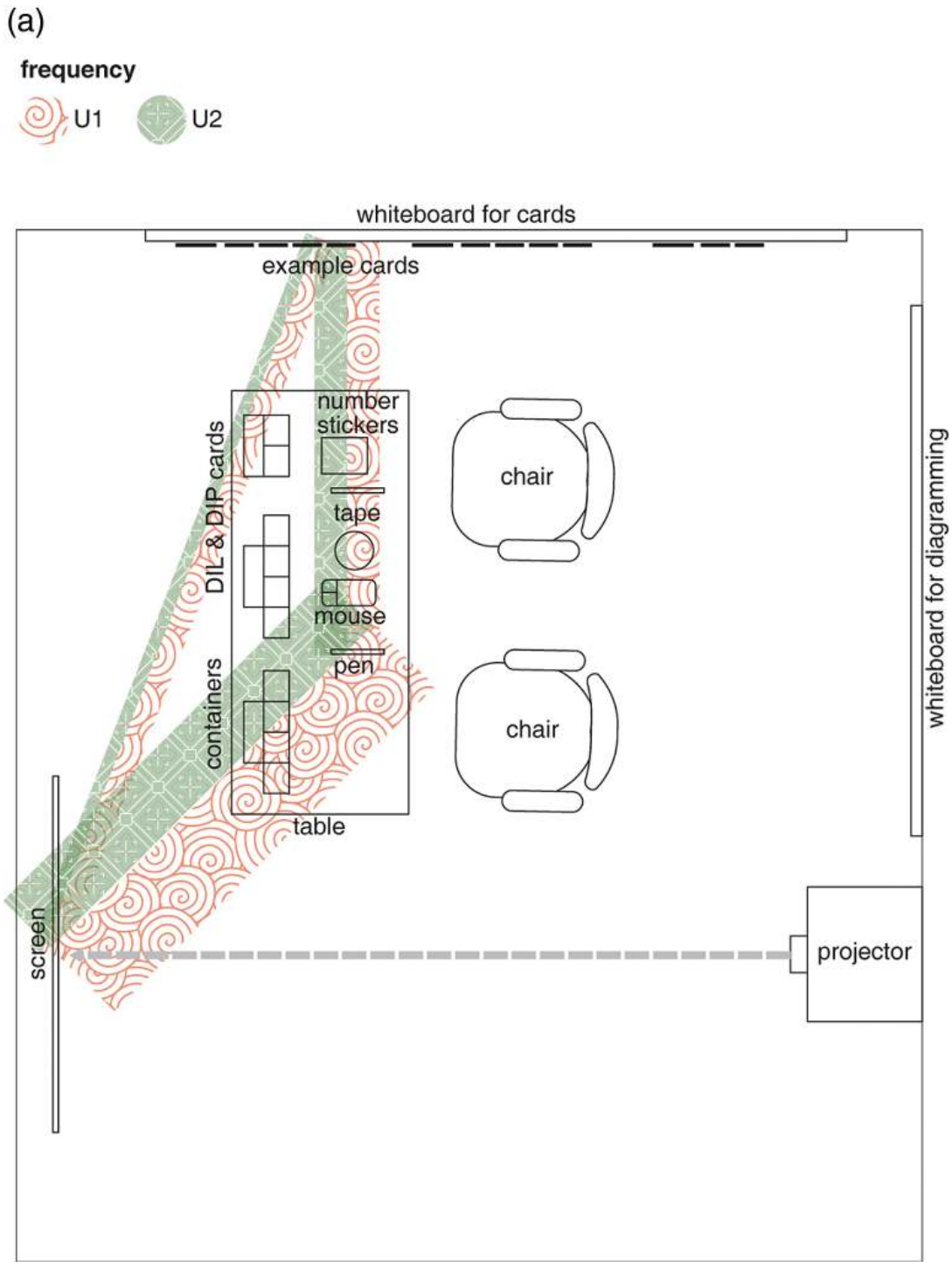

FIGURE 8 (a) Frequencies of each participant's attention changes and physical movements between places in the environment (average) for the recording task. The width of the bar is correlated to the frequency. (b) Amount of time spent by each participant in work for each place—both individual spending and the shared spending of the space for the recording task. All three types of spaces—shared, U1's, and U2's—are mutually exclusive. The diameter of each circle is correlated to the length of time.

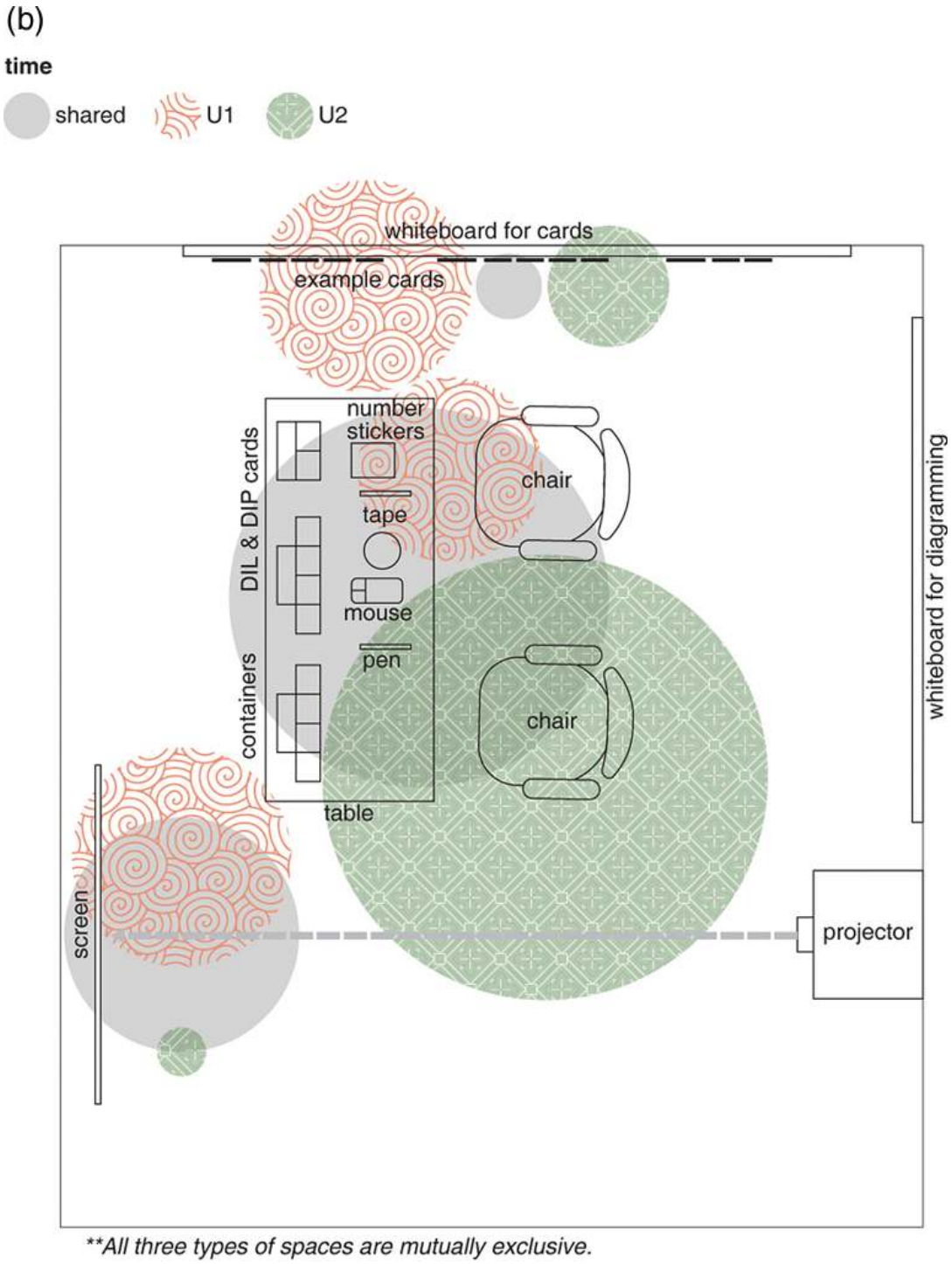

FIGURE 8 (Continued).

exchanges. They also sometimes told each other what to do to get a better understanding. The cards helped them coordinate their activities with each other. Likewise, the whiteboard used for placing the recorded cards on helped the groups discuss and confirm the information they captured and to interpret the

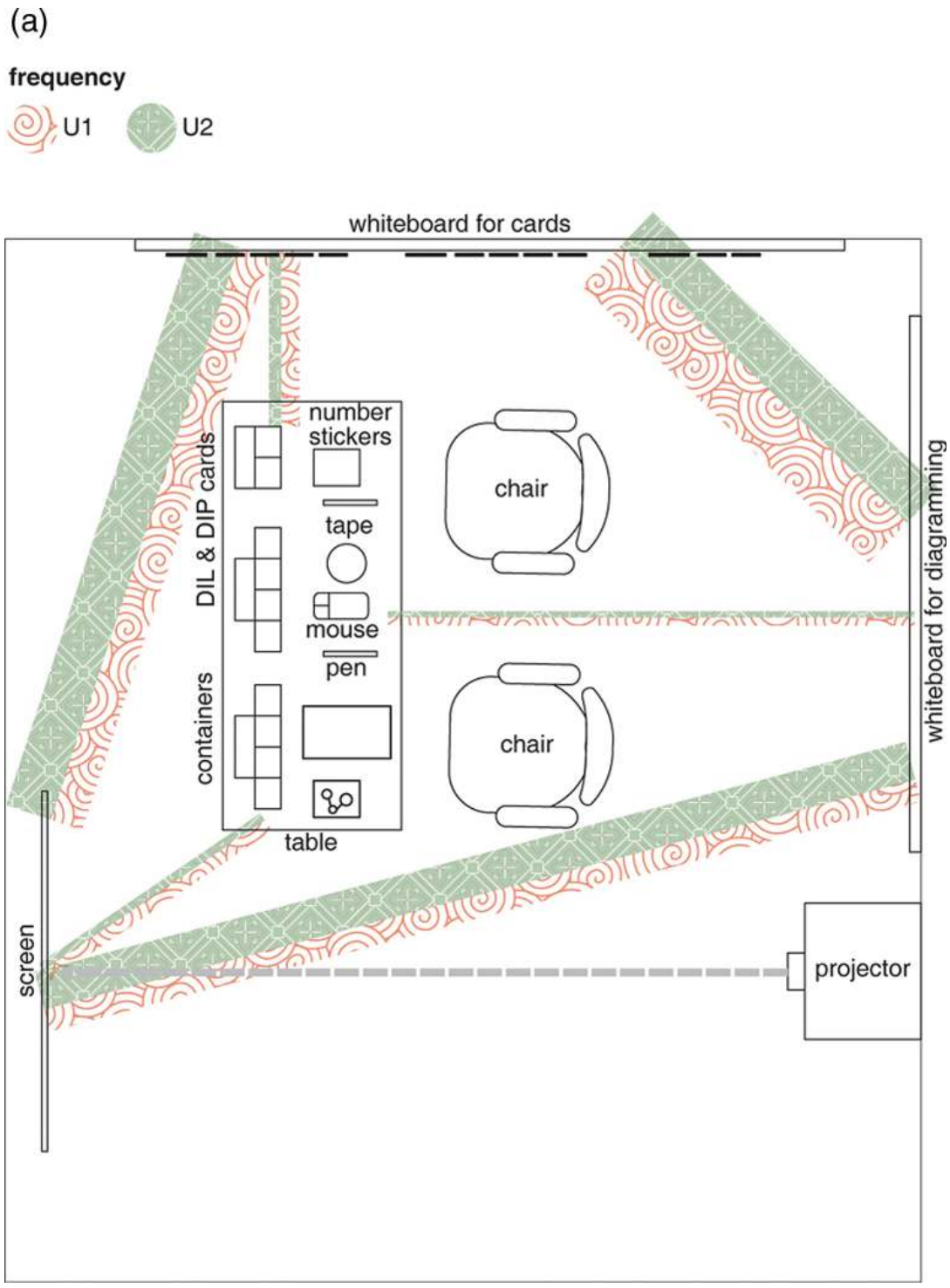

FIGURE 9 Frequencies of each participant's attention changes and physical movements between places in the environment (average) for the diagramming task. The width of the bar is correlated to the frequency. (b) Amount of time spent by each participant in work for each place—both individual spending and the shared spending of the space for the diagramming task. The diameter of each circle is correlated to the length of time.

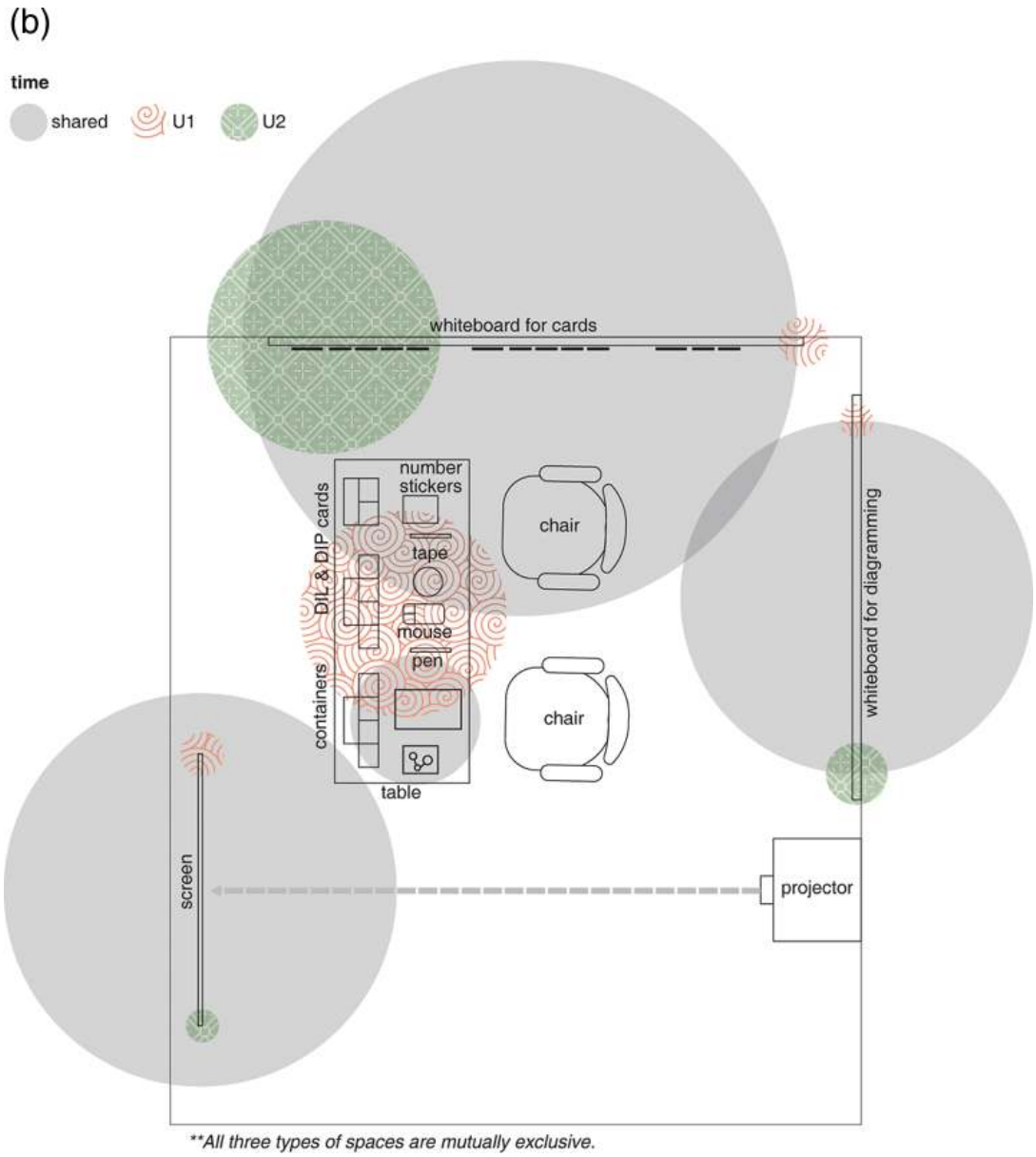

FIGURE 9 (Continued)

user experience together. In Figure 8b, we can see that most of the collaborations were involved when using the framework-based cards at the whiteboard and with the screen showing the video clips.

6. DISCUSSION AND CONCLUSIONS

Examining other designers or researchers' data is likely to increase as new technologies and use situations become more diverse and complex, in the sense of comprising multiple interconnected components and people. Providing the

means by which designers can orient toward a particular way of understanding data that others have collected, such as ethnographers, is also becoming recognized as important, especially for companies interested in developing new pervasive technologies aimed at groups of people in their work, home, and other environments. Our study showed that providing groups of analysts with a conducive physical environment to work in together with a guiding framework enabled them collaboratively to analyze data that had been captured from another user study. In particular, it enabled them to enter into the frame and understand how to analyze data they had not been involved in collecting, helping them in knowing what to look for and what information was important to highlight and represent. The framework was particularly helpful for identifying and detailing the collaborative and coordination aspects of the group study that they had to analyze. It also showed how the physical environment facilitated collaborative analysis for a complex setting—in this case, how a novel shared interactive tabletop was used by small groups during collaborative problem solving.

Our study showed how the participants used both the physical space and the framework in different ways, indicating that both were flexible. For example, Group 1 used the framework to focus on group decision-making flow, whereas Group 3 focused on the interactions between users for negotiation and discussion. Group 2 represented the group work as an interaction flow with the interface elements of the tabletop application while the others examined other features. This variability in what the groups chose to focus on in their analyses for the hourlong study shows how the framework was more facilitative than prescriptive, encouraging different ways of looking at the same data and analysis. The groups in the diagramming condition were also able to use the others' analyses as a starting point in creating their diagrams.

It is well known that the use of physical materials, such as cards, whiteboards, and sticky notes, are very effective for supporting brainstorming and other design tasks (Guimbretière et al., 2001; Klemmer et al., 2001). Similarly, our findings showed how such low-tech materials were effective at supporting collaborative analysis, making the mechanisms of coordination, sharing, and referencing easy to accomplish. The entry points provided in the recording task helped the participants to coordinate their work with each other, whereas the spaces provided in the diagramming task helped them to discuss and share their ideas with each other.

Some analysis tasks are likely to be suited to being computerized, such as archiving and recording time information. Digital representations could also be used to provide different views of framework-based data, such as category based or timeline based. The problem of automating these kinds of analytical activities, however, is that they will replace the highly visible and physical activities, such as filling in and placing cards on a board, with an action controlled by a single user, making it more difficult to reach the same level of shared understanding among the team. Future research needs to consider how best to mix physical and digital activities to ensure flexibility and efficiency when doing analysis but also to support the coordinative and collaborative needs of teams, to be able to switch roles; work with each other; and, of importance, be able to jump readily into a stage of the analysis and be able to know what to do.

In terms of designing an optimal physical environment to support collaborative analysis of user study data, we suggest the following guidelines:

- Provide entry points that can be sharable and collaboratively usable such as cards, whiteboards for placing the cards on, and a large screen for viewing video clips.
- Support sharing/brainstorming ideas and making group decisions by providing shared focal spaces such as whiteboards and a large screen for viewing videos.
- Support coordination of analysis tasks by setting up clearly structured tangible and distributable components such as framework-based cards, stickers, and controlling devices like a mouse and pens.
- Make the use of diagramming spaces flexible so that people can manipulate previously created diagrams together effectively.
- Provide a temporary space for working on diagrams.
- Arrange the spaces that are accessible comfortably in terms of browsing, comparing, and writing on.

In sum, providing a collaborative framework plus physical environment can help teams of designers enter into the frame of the setting and guide them in abstracting and understanding the important group work patterns of the user experience in relation to the new technologies. It can also help designers who have not been involved in the data collection readily orient toward specific interactions and different types of group work, such as group decision making, negotiation, and discussion.

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