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# Idea Management In a Shared Drawing Tool

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Abstract

The generation of design ideas in group discussion is a complex and dynamic process. Some design ideas are accepted; others are rejected; many others are modified and combined. The fluent expression of ideas and the ability to interact and build on representations created by others contributes significantly to the idea generation process. Computerized shared drawing tools support this fluency and interaction, but such tools need to aid not only the drawing process but also the management of design ideas during group interaction. This paper lays the groundwork for the design of the idea management portion of a shared drawing tool. It presents a taxonomy of group idea management activities, identifies user requirements in support of these behaviours, and illustrates how the user requirements are satisfied by features in CaveDraw, an experimental shared drawing system.

## 1. Introduction

Because modern technology is complex, it is unusual for an individual to tackle the design of a major project single-handedly. Often, a small team is gathered at the initial stage of the design process introducing problems of organization, coordination and communication. Sketches are an important coordination tool for the shared design process and group communication. This group communication can be faciliated by computerized shared drawing tools which permit simultaneous sketching by team members in different locations. Although these shared drawing tools are exceedingly useful, we believe that the management of multiple inputs remains a significant issue in their design.

Observational studies have identified several critical factors in the design of shared drawing tools. These factors are derived from analyzing and interpreting collaborative workspace activities. Tang and Leifer (1988) point out that different workspace activities occur with different work mediums (e.g., whiteboard, private notebooks), different tasks (e.g., mechanics, architecture), and different time-scale problems (e.g., multi-year versus two-week projects).

We believe that understanding the group process of creating and manipulating task artifacts — sketches in a shared workspace — will allow us to identify user requirements in a shared drawing tool. We focus solely on group behaviours as members manage and manipulate design ideas and ignore variables like cohesiveness and prior design training. Akin (1979) shows that the more imaginative design alternatives and major design conflicts are often recognized while staring at sketches. We believe that supporting group behaviour in manipulating the sketches plays a central role in fostering this creativity. We note that Grudin (1989) has pointed out that lack of understanding of group behaviour is one of the reasons for groupware failure.

In this paper we are concerned with the design of tools that support idea management. Although no direct evidence exists to demonstrate that idea management is an important consideration in the design of shared drawing tools, we suspect this is an important issue based on empirical evidence from studies of individual designers using design aids. Ullman, Stauffer and Dietterich (1987) noted that in an individual design session, designers tended to forget some of the ideas they formulated. Yeomans (1982) discovered similar recall failures. Ullman et al. (1987) also found that a team of designers often worked at different levels of abstraction in their design, making it difficult to integrate the final products.

We also examine studies of group design that did not have the use of shared drawing tools. Rouse and Boff (1987) note the following group design behaviour:

> If an outside observer were to characterize designers' behaviors, particularly for complex domains such as aircraft design, it is quite likely that such an observer would conclude that chaos is the most appropriate characterization of design teams at work.

They explain the chaos as arising from different design philosophies that designers bring to a design team. Scheidel and Crowell (1964) describe group decision making as an idea-in-the-making process wherein one member suggests an idea, another modifies it and a third changes its focus until the final agreed upon solution unfolds. This process of cooperative work in the building of a group decision becomes too complex as more participants are involved. None of the above studies indicate that the outcomes of a design are affected by lack of idea management and no studies have been done on its use in shared drawing tools. However, throughout Section 3, we provide evidence from the literature that strongly suggests that the idea management criteria we propose is valid.

Design ideas are much more than sketches. They also embody task context, conversational exchanges, gestures and the order in which all of these take place. When we use the term "design idea" we loosely refer to the sketches actually laid out on the drawing surface. Thus, we focus on the tasks of choosing, comparing, and integrating multiple design sketches. We use these tasks to classify those areas

that would benefit from design idea management tools. We propose a set of user requirements for the design of multi-user shared drawing tools and illustrate the requirements in the design of a prototype, CaveDraw. CaveDraw is a shared tool running within a multi-media environment at the University of Toronto (Mantei, Baecker, Sellen, Buxton, Milligan & Wellman, 1991).

## 2. The Approach

To develop our user requirements, we studied videotapes of drawing space activities collected by various researchers. We have also drawn on prior research in engineering design studies, group communication and social psychology. We focused primarily on the interactions between collaborators as they manipulate current and previous design ideas. Our research plan is illustrated in Figure 1.

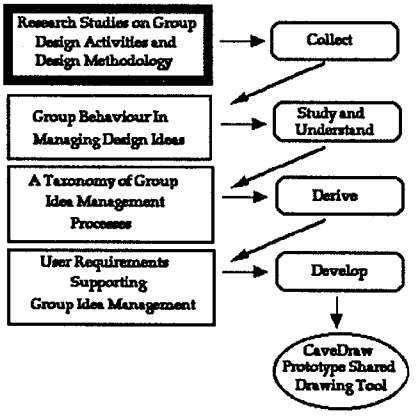


**Figure 1.** Research focus of this paper

Studying and understanding the scenarios of group behaviour in managing design ideas provides us with constraints on how a tool should be designed to support them. The scenarios presented in the taxonomy lead us to new insights into both shared drawing activity and user requirements for shared drawing tools.

## 3. A Taxonomy of Group Idea Management Processes

We present our analysis of the design study videos and previous research in the form of an idea management taxonomy. The taxonomy is primarily a listing of the more general levels of group interchanges and idea manipulation decisions made by group members. It is not exhaustive but covers the major behaviours we and others have observed in design activity.

**Agree and add on to the suggested idea:** A design idea is suggested. One or more collaborators make comments on the design either verbally or by sketching out the alternatives. Additional sketches are performed to further enhance the idea.

Tang (1989) observed this scenario in his studies; for example, one designer (S3) draws a representation of her design idea into the workspace, the other designer (S1) builds on the idea by adding keyhole slots. Tang (1989) points out

that this behaviour indicates that initial representations gradually evolve into distinct artifacts, often through modifications and additions made by others.

**Agree and subdivide the suggested idea:** A design idea is suggested. Participants agree on the idea as a start. They then proceed to break down the idea into sub-tasks or segments and work on them separately.

Breaking up a design idea into hierarchical sub-tasks is a general phenomenon seen in architectural and mechanical engineering design tasks. For instance, in the Office Design Project (Stults, 1988), the architects articulated a shared analysis of the client's needs, formed a concept (an overall design idea) in response to the needs, and summarized the issues (the sub-tasks) underlying the concept. Effective management requires that inter-relationships among solutions for each sub-task be laid out and saved by the group before the group commences work on the sub-tasks (Otto, Riley & Erdman, 1988).

**Modify the suggested idea:** A design idea is suggested. One or more participants modifies the idea by editing the sketches of the idea or by presenting additional related sketches. Participants may not be notified by others before their sketch is changed.

This scenario occurs in studies using Commune, a three-person shared drawing tool (Minneman & Bly, 1991). One of the participants erases one of the other participant's sketches without requesting prior permission for this action. We observed this in a private viewing of a Xerox PARC design session recorded on videotape. Such behaviour is also observed by Tang (1989). He points out that the change usually addresses a verbal criticism and such criticism often compromises the design idea. In studies of idea development in a small group meeting, Scheidel and Crowell (1964) describe how one idea is progressively remodified in group interaction until the group achieves agreement.

**Modify, but preserve the suggested idea:** A design idea is suggested, and participants suggest modifications that are distinct from the original idea. These changes can be removed if they don't appear to work.

Although we did not find this behaviour mentioned in the literature, we extrapolate its occurrence from our studies on shared writing (Posner, Baecker & Mantei, 1991). Both ForComment™ (Opper, 1988) and Word 4.0™ (Microsoft Corporation, 1989) permit this type of annotation in a document without the annotation affecting the original text. In the Office Design Project (Stults, 1988), one of the architects is observed to lay tracing paper on top of his tv monitor. Using another architect's sketch displayed on this monitor, he then proceeds to add his own idea on the tracing paper. The original sketch is preserved while the other architects comment on the new suggestion.

**Scratch and restart:** A design idea is suggested. One or more participants comment on the idea, and the originator admits that there is a problem with the design idea. The idea is discarded and the group searches for another design solution.

Tang (1989) calls this scenario "Admit Problem". He describes it as one of the negotiating patterns in encouraging the group to accept an idea. He notes that this

event often encourages others to help resolve the problem and share in developing the idea, but that some groups also use the admitted problem to reject the idea. In fact, the more ideas that members contribute, the more ideas the group will reject (Fisher, 1974). Fisher also points out that the period of idea testing during the conflict phase, involves the rejection of many idea proposals.

**Suspend and wait:** A design idea is suggested, and one or more participants make comments on the idea. Because the group is unsure about the suggested idea or because the idea is rejected out of hand, the discussion about it is dropped. The suggested idea can be forgotten or later reconsidered in an unrelated context (Tang, 1989).

In Fisher's (1970) study of decision modification processes in small groups, he observes group members introducing a particular decision proposal, discussing it for a length of time, dropping it in favour of another decision proposal and then, re-introducing it later during the group deliberations.

**Agree and wait:** A design idea is suggested and is well received. The group moves on to the next sub-task on the requirement list to complete the design. The suggested idea is put on hold until all design solutions for the overall design are gathered.

Once a global design idea is agreed upon by participants, it is further broken down into design sub-tasks, as mentioned in "Agree and subdivide the suggested idea". This scenario is shown in the MacViz-A design studies (Tang, 1989) when the participants listed their ideas, one after the other, on the shared workspace. The accepted idea was noted and the group moved on to solving the next design issue.

**Compare and consolidate:** Multiple design ideas for fulfilling the design requirement are suggested. The group compares and criticizes the solutions, and then consolidates them into one accepted version. In the consolidation process, several design solutions are aborted or modified at the same time.

Fisher (1974) notes from his studies that

> Group members usually focus their attention on various proposals during their interactions and choose from among those alternative proposals the ones which they will accept or reject. The sum of the proposals accepted constitutes the productivity of the group.

This type of activity has been observed to occur iteratively whenever a new design alternative arises during the design process.

**Deprivatize design idea:** After a design idea is generated, it is sometimes transferred from an individual workspace to a shared workspace.

In studies conducted by Tang and Leifer (1988), one participant was observed to begin drawing privately, producing a graphical object. Other participants noticed the object and began working on it. Tang and Leifer (1988) point out that the migration of this object from a private to a public object illustrates the dual public/private nature of the workspace.

We have identified nine distinct design sharing and modification processes that have been observed in group design. Naturally, the design process has additional complexities and subleties that we have failed to capture. Nevertheless, we believe that we have identified some of the primary behaviour patterns that groups apply

in managing their design ideas. We need to incorporate capabilities to support these patterns in shared drawing tools so that they become facile and fluent enough to support this process of developing ideas.

## 4. A Brief Overview of CaveDraw

Before we use the group idea management taxonomy to generate user requirements, we provide a brief overview of the shared drawing tool under development, CaveDraw. We describe the tool at this point in the paper because we will use examples from CaveDraw to demonstrate the application of the user requirements we have generated.

CaveDraw is a shared drawing package running on Macintosh II workstations. It supports multiple users drawing at the same time. Users working on their workstations, connected through an ethernet, can view and modify shared drawings in their window. Each workstation runs its own version of CaveDraw and communicates with other workstations via a communications manager running on a Sun 3/60 workstation.

CaveDraw differs from other shared drawing software in its support of "transparent layers." A layer is created when a user requests and names a drawing surface. All users can sketch on the layer. Once a workspace is exhausted on the layer, a new layer can be requested. The work on the previous layer dims to a light colour so as not to interfere with the drawing on the new layer. Each participant can create, hide and select any layer. As layers are superimposed on each other, participants can select their own individual layers to work on while drawing activity continues by other participants on other layers. Participants can copy or cut any portion of a sketch on one layer to a desired location on another layer. Sharing a common view of the sketch activity is not automatic in CaveDraw as it is in other shared drawing tools. However, participants in CaveDraw can synchronize their views with another participant.

CaveDraw supports line, rectangle, oval, polygon, text, and freehand (pencil & marker) drawing tools. Users can select and erase drawing segments and can use different coloured markers to identify their own work. CaveDraw shares sketching activities but supports gesture weakly. A coloured telepointer is used for gesturing but its two-dimensionality will never capture the richness of human gestures. CaveDraw is now implemented and is undergoing user testing.

## 5. User Requirements Drawn From The Group Idea Management Taxonomy

In Section 3, we summarized nine idea manipulation behaviours observed in groups working on design solutions. We now propose user requirements for the design of a shared drawing tool. This tool helps designers manage their design ideas. To build these requirements, we combine the nine idea management behaviours with five critical factors that have been shown to affect group design. As before, our evidence for the importance of these factors comes from prior research on shared drawing environments and from reviews of videotapes of

shared drawing activities. Once we have discussed user requirements, we present CaveDraw's solutions to these requirements. We also review the solutions for these requirements in other shared drawing systems and discuss their relative merits.

We focus on five critical factors that support group idea management processes. They are *Work Allocation, Design Integration, Design Ownership, Design Recall* and *Space Sharing. Work Allocation* refers to the split between individual and group work. In group design, participants often work on different parts of the same design. They therefore need a personal design space that can later be *Integrated* into the group's workspace. Conflict can arise in group design sessions if one person's idea is co-opted or erased by another. Thus, *Ownership* becomes an important issue. Drawing space evaporates rapidly as ideas are sketched and discarded. Yet, it is important not to eradicate an idea which could be useful in another context. If *Recall* is hindered by the organisation of a design space, prior ideas can be lost. Finally, group *Sharing of Workspace* can limit the amount of space available and thus, the number of design ideas generated.

## 5.1 User Requirements Supporting Work Allocation

Table I lists the user requirements for the work allocation factor. The "Agree and subdivide the suggested idea" scenario generates two requirements: Requirement (1.1); to allow participants to select individual segments of the design to work on simultaneously, and Requirement (1.2); to provide mechanisms by which each participant can be kept aware of what the other participants are doing.

| Taxonomy Scenarios | User Requirements |
|---|---|
| "Agree and subdivide the suggested idea" | (1.1) Participants can select individual segments of the design to work on simultaneously.<br>(1.2) Participants are aware of the design activities of others while working on their segment of the design. |
| "Modify the suggested idea" | (1.3) Participants are able to select and modify all previous design ideas. |

**Table I.** User Requirements Supporting Work Allocation

We believe that offering participants the choice to work on individual design segments simultaneously not only expands the design space for them, but also enhances creativity and reduces the processing time of the design task. Thus, they can select segments that are relevant to their expertise and work with lower communication overhead. Existing instantiations of shared workspaces do not permit group participants to retreat and work on a portion of the drawing without changing the workspace for the rest of the design group. In Commune (Minneman & Bly, 1991), a selection by one participant to move to a previous page of design work causes the screens of all participants to be changed to the previous page.

In a design task, the inter-relationship among design ideas can affect the outcome of the overall design. Ullman, Stauffer and Dietterich (1987) observe that different designers' ideas are sometimes developed at different levels of abstraction. If members in the group were constantly aware of each other's design processes, negotiation and adjustment to an agreed upon standard level of

abstraction could go on continuously. Participants could still work on their personal design but would be more likely to make it fit into the greater whole. Requirement (1.2) therefore requests this awareness capability.

The "Modify the suggested idea" scenario generates a third user requirement (1.3); to permit participants to select and modify all previous designs on an individual basis. Manipulating a suggested design idea plays an important role in the design process. In the engineering design world, designers attempt one solution, move on to a second, then a third, etc. With multiple participants, a large number of solution paths are created (Pahl & Beitz, 1984). The group is likely to skip a thorough investigation of prior solutions in the interest of group efficiency, but the ability to access this work on an individual basis can bring up good ideas that would otherwise have been discarded.

We use shared transparent layers in CaveDraw to implement the user work allocation requirements into the design. Their specific relationship to the design requirements is shown in Table II.

| User Requirements | CaveDraw's Design Solutions |
|---|---|
| (1.1) Participants can select individual segments of the design to work on simultaneously. | Participants draw out their design ideas on shared transparent layers. Drawings on the selected topmost layers are the only ones that appear in a brighter colour. |
| (1.2) Participants are aware of the design activities of others while working on their segment of the design. | The layers are superimposed on each other so that a participant can see other drawing activities taking place in a light grey colour.Participants can synchronize their view with the other participants, also they can find out who is viewing or working on each layer. |
| (1.3) Participants are able to select and modify all previous design ideas. | Participants can select, create and hide the display of any layer on their screen. |

**Table II.** CaveDraw Design Features Supporting Work Allocation

Each CaveDraw participant can create one or more shared layers. The layers are stacked together and design sketches on the current working layer are displayed in a prominent colour. All the underlying layers are dimmed to a light grey colour. Sketches drawn by others are visible but not intrusive. Figure 2 presents an example of the overlapping layered approach in CaveDraw. In Figure 2a, Designer A is sketching out her idea of a floorplan. The work of Designer B is visible but not prominent on the layer below her layer. Figure 2b shows her co-worker's screen with his layer on top of her layer. He is adding to her work, but on a different layer.

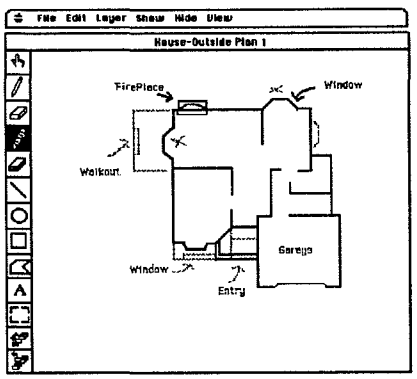


**Figure 2a.** Designer A chooses to work on the first layer where she put her idea

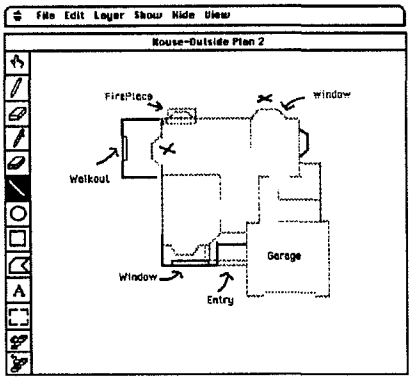


**Figure 2b.** Designer B chooses another layer to add to Designer A's idea

When participants work separately on different subset of layers, awareness of others' work becomes an essential part of coordinating the collaboration. In CaveDraw, participants can join or view any other participants' work through the View menu. This menu allows participants to view all the selected layers, the top layer or any of the dimmed layers of another participant. Also, participants are able to restore their own view after browsing through another participant's layers or working with another participant. Furthermore, they can find out who is working on each particular layer when they select a layer through the Show menu. Each menu item gives the name of the layer as well as the name of the other participants who are viewing it.

## 5.2 User Requirements Supporting Design Integration

Table III lists the user requirements that support the critical factor, Design Integration. Requirement (2.1); to allow participants to compare and consolidate modifications to different portions of the original design, while still being able to throw away undesirable changes, is a direct result of the "Compare and consolidate" activity. It is not possible to compare complex design alternatives unless they are equally visible. Group design sessions often involve large amounts of white paper pinned to walls or the use of a large whiteboard for this purpose. Space limitations and the immobility of drawn designs prevent easy comparison of distant designs. Commune requires paging through previous designs and bringing them up one at a time. VideoWhiteboard (Tang & Minneman, 1991) provides a whiteboard sized shared videospace allowing multiple designs to be viewed at the same time, but designs are still immovable. In Ishii's (1990) Teamworkstation, designs can be overlaid and thus, compared, but the technology limits the number of overlays that can be compared in this fashion. Boardnoter in Colab (Stefik, Foster, Bobrow, Kahn, Lanning & Suchman, 1987) supports the reduction of design alternatives into miniature stamp sheets. The stampsheets can be expanded into a full view, but screen space soon exhausts the number of expanded stampsheets that can be viewed at one time.

Consolidating designs is even less easy. Separate designs have to be redrawn and re-merged into a new design requiring a duplication of effort.

Teamworkstation allows participants to overlay video images of separate drawings but the adjustments require fine tuning using video controls. The consolidated design becomes the video sequence stored on videotape.

| Taxonomy Scenarios | User Requirements |
|---|---|
| "Compare and consolidate" | (2.1) Participants can,with little overhead, compare and consolidate modifications to different portions of the original design but still throw out undesirable changes. |
| "Modify but preserve the suggested idea" | (2.2) Participants can compare different modifications to a design idea at the same time without disturbing the original idea or having to view multiple displays. |
| "Agree and subdivide the suggested idea" | (2.3) Participants can, with little effort, view both the overall design and its subunits in addition to the design subunit they are working on. |

**Table III.** User Requirements Supporting Design Integration

The "Modify, but preserve the suggested idea" scenario creates Requirement (2.2); to allow participants to compare modifications to a design idea without disturbing the original. In a group design session, participants may have an agreed upon basis for their design, but may be trying out additional ideas to correct some aspect of the design. For example, they may want to design the lighting connections in the trunk of a new car, while retaining the trunk cavity layout design. If they drew over the trunk cavity design on the whiteboard and did not like the design idea, they would need to redraw the trunk cavity.

Requirement (2.3); to allow participants to view both the overall design and all its subunits, is drawn from the "Agree and subdivide the suggested idea" scenario. As participants create their solutions, they move further away from their original plan. Suchman and Trigg (1986) point out that participants relate their ideas to prior ones or to the problem at hand. If the original plan is not viewable from time to time, participants relate their current problem to the most recently solved problem. This eventually places designs far enough away from the overall design that integration could be very difficult. If multiple designers work individually without refering to the overall plan, their designs are unlikely to fit together.

The CaveDraw layer approach allows a form of design integration although it, too, has limitations. Table IV lists the CaveDraw design features that support the user requirements of Design Integration.

| User Requirements | CaveDraw's Design Solutions |
|---|---|
| (2.1) Participants can,with little overhead, compare and consolidate modifications to different portions of the original design but still throw out undesirable changes | Allows the participants to draw alternate design ideas on different layers and superimpose the layers or subsets of the layers in any order selected by the participants. Also allows saving of any of these combinations. |
| (2.2) Participants can compare different modifications to a design idea at the same time without disturbing the original idea or having to view multiple displays. | Same approach as (2.1). In addition, participants can work on their own layer while the other participants are performing a comparison. |
| (2.3) Participants can, with little effort, view both the overall design and its subunits in addition to the design subunit they are working on. | Allows each participant to bring up a sublayer showing the connection of all subunits while working on one of the subunits in the previous layer. |

**Table IV.** CaveDraw Features Supporting Design Integration

To support comparison and consolidation activities, CaveDraw permits participants to select a subset of layers to be displayed on their screen. The designs in this subset can be compared and, if desired, consolidated into one design on one layer. Design ideas can be discarded by removing the layer on which they are drawn. Any layer can be brought to the topmost position (brighter colour) by "mouse-clicking" on a pixel located in the layer. Layers below the topmost layer are still visible for the comparison task.

If an overview of the design plan is available, participants can maintain the overview as one of the visible layers on their display. They can refer to it from time to time by bringing it to the topmost layer or simply by looking at it through the other designs showing in the other layers.

Although CaveDraw supports some of the characteristics of Design Integration, it leads to what we call "layer overload." At some point, too many designs with too many different patterns will overlap each other in the layered design space. It will be difficult for users to disambiguate the lines of one layer from that of the other. A feature paralleling Furnas's (1986) fisheye views approach of looking at a design overview would be more useful for this function.

### 5.3 User Requirements Supporting Design Ownership

Ideas have creators and thus, owners. Any time a sketch is modified by other participants in the group, ownership preservation becomes an issue. The design scenarios, "Add on to," "Modify," and "Deprivatize," represent different ways in which an existing idea can be co-opted by the group. Table V lists user requirements that preserve ownership: Requirement (3.1); to allow participants to declare any portion of a sketch as private and therefore, undeletable, and Requirement (3.2); to allow participants to see who is working on what design.

| Taxonomy Scenarios | User Requirements |
|---|---|
| "Agree and add on to the suggested idea", "Modify the suggested idea", and "Deprivatize design idea" | (3.1) Participants can declare any portion of a sketch as private and not subject to deletion by others.<br>(3.2) Participants can identify, with no additional interaction sequences, who is working on any specific design sketch. |

**Table V.** User Requirements Supporting Design Ownership

Social norms are expected to keep others from erasing our work, but this does not always work. For instance, one dominant participant using Commune was observed to erase the other person's sketches without prior permission. Conflict resolution studies using the University of Minnesota's Group Decision Support System found that asocial acts of removing another participant's ideas were common and disturbed the group process (Poole, Holmes & DeSanctis, 1988).

Ownership prevents undesired deletion of design ideas, but sometimes deletion or permission to copy is desired. If Requirement 3.1 is met, then Requirement 3.2 needs to be in place to identify the owner of the design. Identified owners can then be asked if deletion or duplication is acceptable. Individuals in a design group may also have status. For example, it may not be obvious to other participants that a particularly complex design idea is a good solution, but if it is known that the

person who created the idea has a reputation as an extremely successful designer, then evaluation of the design will be more positive. It is also important to know who designed what in a design process to get a measure of the individual contributions of the group members and of their design focus.

Ownership is not a supported concept in most shared drawing tools (e.g., Commune (Bly & Minneman, 1990), GroupSketch (Greenberg & Bohnet, 1991) and BoardNoter (Stefik et al, 1987)). VideoDraw (Tang & Minneman, 1990) uses polarizing filters to fuse two separately drawn video images together making ownership inherent in the technology.

Table VI lists CaveDraw's design solutions for the ownership concerns. CaveDraw supports ownership through the use of colour. Each participant in CaveDraw is assigned a colour that is not currently in use. Participants have two basic drawing tools, a pencil and a coloured marker. If they draw with the pencil, all lines are black and the design they create can be changed by any participant. If they draw with the coloured marker, all lines are in the assigned colour and cannot be erased, only copied. When a user selects the pencil, all associated tools, e.g., "draw circle," generate public drawings. A marker selection makes all tool usage private. Moreover, the use of the public and private markers can distinguish between a tentative and definite idea (Suchman & Trigg, 1986).

| User Requirements | CaveDraw's Design Solutions |
|---|---|
| (3.1) Participants can declare any portion of a sketch as private and not subject to deletion by others. | Allows participants to declare public or personal work by selecting respectively public or personal drawing tools. Work drawn with a personal set of tools cannot be erased by others. Participants are allowed to convert their work from private to public and vice versa through available editing functions. |
| (3.2) Participants can identify with no additional interaction sequences who is working on any specific design sketch. | Identifies each participant's work or ownership of a design by a specific colour. |

**Table VI.** CaveDraw Features Supporting Design Ownership

Although CaveDraw supports design ownership, its support has some drawbacks. Designers can "sign" their work but the decision to make a particular design private needs to be made at tool selection time. In a creative design session, participants will not always know ahead of time that a particular design is significant. If they choose to personalize all their work, they may quit the design session before it is over, leaving behind a set of undeletable sketches. CaveDraw allows participants to make their design public or private through special cut and paste tools. Also, all their private marks on the shared layers will become public if they quit the design session before it is over. Ownership is only discernible at the topmost layer where colours are displayed. Since lower layers are in light grey, the colouring cue for the other participants' work in those layers is lost.

## 5.4 User Requirement Supporting Design Recall

In the "Agree and wait" and "Suspend and wait" scenarios, a group defers work on a design and returns to it later. Many other design events occur during the waiting period causing the group to forget the suspended design. Ullman et al. (1987)

found that designers often forgot prior design ideas and Agogino, Cagan and Molezzi (1988) observed design teams covering the same ground and redoing the same design ideas. We call this problem "Design Recall". Coupled with the design suspension behaviour, it generates Requirement (4.1) in Table VII; to allow participants to review prior design ideas with minimum effort.

| Taxonomy Scenarios | User Requirement |
|---|---|
| "Agree and wait" and "Suspend and wait" | (4.1) Participants can review prior design ideas with minimum effort. |

**Table VII.** User Requirement Supporting Design Recall

A large drawing space can support design recall because we have more prior designs visible at once. VideoWhiteBoard takes this approach by projecting a video image of shared drawing spaces on an entire whiteboard-like screen. Leaving the design idea on the video whiteboard has the disadvantage of taking up valuable drawing space. Commune allows users to flip through pages of prior designs, but we believe that users are unlikely to take the time for a serial search. BoardNoter allows users to both have sufficient drawing space and view prior designs by miniaturizing the design ideas. Users cannot view the underlying design idea in the miniature icons and may have to open each one up to recall what they represent.

CaveDraw again relies on its transparent layers to aid users in recalling prior design activity. Table VIII lists the manipulation capabilities that permit access to designs that have been drawn earlier in the design session. The access we refer to is cognitive access, not computer access. We use the layers and the relative ease with which they can be brought up on the display to make participants aware of these prior designs.

| User Requirement | CaveDraw's Design Solution |
|---|---|
| (4.1) Participants can review prior design ideas with minimum effort. | Allows participants to directly select the viewed layers that capture prior design ideas with one mouse click on the dimmed layers.<br>Also allows participants to select layers that have been put away through the pulldown menu. |

**Table VIII.** CaveDraw Features Supporting Design Recall

Design layers which are already on the display but underneath the working layer are in the drawing space where the user can see their dimmed image. They can be brought to the top by a mouse click on a line of the design drawn on that layer. If a layer is not on the display, it can be recalled by its name. A user is required to give each layer a name when it is created. This name is put in a pulldown menu for selecting layers and putting them back on the display. The names in the pulldown menu help the user recall a previously stored design.

CaveDraw's solution does not scale up well. First, since all layers underneath are dimmed, it is difficult to determine if two dimmed lines belong to a particular layer or to two different layers. Second, when too many layers exist in the pulldown menu, it becomes hard to scan the name list or to discriminate between similar names.

### 5.5 User Requirement Supporting Space Sharing

Suchman and Trigg (1986) point out that participants in a design session often hold different views when interpreting and evaluating a design idea. Misunderstandings are corrected by sketching on a shared drawing surface. Tang (1989) notes that the design process is enhanced if designers can share a common view of the workspace and have a sense of proximity with the ongoing drawing process. VideoWhiteBoard is a good example of this space sharing. The technology permits two users to draw in the same space and have the same view of the design. Table IX lists the user requirement that provides this space sharing. Requirement (5.1); to allow participants to work in their own space yet virtually share the space with other participants.

| Taxonomy Scenarios | User Requirement |
|---|---|
| "Agree and add on to the suggested idea", "Scratch and restart","Modify the suggested idea", etc. | (5.1) Participants can work in their own space yet virtually share the space with other participants. |

**Table IX.** User Requirement Supporting Space Sharing

GroupSketch, TeamWorkstation and Commune all support shared workspace, but the amount of space is relatively small and quickly fills up with drawings. CaveDraw supports a common view of the work and gives each participant adequate sketching area. Table X lists the features that give this dual capability.

| User Requirement | CaveDraw's Design Solutions |
|---|---|
| (5.1) Participants can work in their own space yet virtually share the space with other participants | Allows participants to generate as many layers of drawing surface as they need.<br>Allows participants to select a personal set of layers to work with while retaining elements common with others. |

**Table X.** CaveDraw Features Supporting Space Sharing

Individual layers in CaveDraw can be created, selected, merged with other layers, hidden and cleared. The superimposed visual effect gives each participant a view of the other participants' work. Yet, when a particular drawing is completed, the drawer doesn't run out of drawing space. The drawing is put away and replaced by a blank layer. The drawing space is still constrained because it is on a standard Mac II screen rather than a larger whiteboard.

## 6. Summary

Tasks carried out by groups can rapidly become overwhelming because of the complexity of the interactions and the amount of information that is generated. We have focused on group design tasks in this paper and mapped a set of group idea management processes against five critical factors that affect group design. The results of this mapping generated a list of design criteria. The list focuses on the task of managing multiple design ideas in shared drawing tools. CaveDraw's solutions demonstrate one software approach for accomplishing the design requirements that have been laid out. Its unique design feature is the use of shared transparent layers to extend the shared workspace. CaveDraw couples this with the

use of colour to identify the work of individual participants. The application of these features supports idea management but with limitations especially in terms of drawing complexity. We also discuss the limitations and advantages of other shared drawing packages, most of which have not been designed with idea management in mind. As with most design recommendations, the final proof lies in user testing the next stage in creating CaveDraw.

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