VIDEO COLLABORATORY - ASYNCHRONOUS COLLABORATION AROUND WEB-BASED VIDEOS

by

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ABSTRACT

VIKASH KUMAR SINGH. Video Collaboratory - Asynchronous collaboration around web-based videos. (Under the direction of DR. CELINE LATULIPE)

Most Internet users consume video in some form or another. However, despite the huge amount of content available on various video sites, typical interactions with the videos are limited to posting and viewing. Overall, online video artifacts are still treated as a simple finished product for individual passive consumption with limited interaction techniques. Video as a medium has huge potential to be used for communication and collaboration but people still mainly use multiple separate tools such as YouTube combined with email for their video-centered collaboration tasks. A tool that can support collaboration among group members while working around videos will need specific design affordances and novel interaction techniques. However, research in video interaction techniques has mainly focused on improving interaction with video for passive consumption and not for active group collaboration.

In this dissertation, I have studied the current state of video-centered collaboration and have surveyed features and problems of various video-centered collaboration tools. I have employed a 'research through design' approach of ideation, design and critique to develop a new video-centered collaboration system called the Video Collaboratory with various novel interaction techniques. The Video Collaboratory includes techniques such as integrated annotations in multiple modalities, a segment selector, contextual navigation, color-coding for group members and video looping in slow motion. These novel techniques allow users to navigate, select, mark and annotate

specific segments of a video using multiple modalities that makes the collaboration efficient, immersive and powerful. I have evaluated the Video Collaboratory through formative and summative studies and in this thesis I elaborate on these results.

The Video Collaboratory has proven to be instrumental in collaborating around video when working in a group. Based on the results of my studies and experiments, I have presented a set of guidelines for designing affordances for video-centered asynchronous collaboration tools and I have discussed some future research avenues.

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CHAPTER 1: INTRODUCTION

1.1 Collaboration and Collaborative Tools

Collaboration is a process where two or more individuals work together on a non-routine task to realize a shared goal [56]. While working together, these individuals will use various communication and coordination resources to assist with the completion of a common goal. These resources are generally some type of collaborative tool to enhance the interactive task completion process. The most simple example of a collaborative tool could be paper which is commonly used to share ideas by writing and drawing. In computing systems, a collaborative tool is generally something that has features specially designed to facilitate work that involves more than one person. Thanks to the rapid growth of the Internet and web infrastructure, collaborative groups now have available to them a vast selection of collaborative tools as shown in Table 1.

1.2 Synchronous vs Asynchronous Collaboration

In the classic CSCW time-space matrix, all collaborative tools can be categorized as synchronous or asynchronous [26]. Synchronous tools facilitate the process of individuals working together on a project in the same workspace at the same time (e.g., conference call) whereas asynchronous tools facilitate collaboration over longer time frames, where each member of a team may contribute at different times (e.g., email).

Table 1: Collaborative systems

Tool	**Examples**	**Features**	**Collaboration**
Email	Gmail, Windows Live Hotmail	Share documents. Schedule meetings. Threaded discussions. Coordinate events.	Asynchronous
Scheduling systems and Calendaring	Microsoft Exchange, Google Calendar	Schedule events and meetings	Asynchronous
Content-sharing tools	Photo sharing tools such as Flickr and Picasa, video sharing services like YouTube and Vimeo	Share media contents. Support conversation among members.	Asynchronous
Group interaction tools	Discussion forums such as phpBB, websites like reddit, blogging tools like Blogspot, Wordpress etc.	Share media contents. Support conversation among members.	Asynchronous
Conferencing tools	Chat rooms, instant messaging, video conferencing tools such as Skype, WebEx, GoToMeeting, TeamSpot	Synchronous meeting for distant members. Share documents and whiteboards. Audio and video streaming.	Synchronous
Authoring tools	Wikipedia, Google Docs	Document editing. Trackbacks and track changes. Version control.	Both
Special systems	Moodle for education, Microsoft Sharepoint for workplace	Document editing. Document sharing. Access control.	Both

To expand, synchronous activities include chat sessions, whiteboard drawings, and other group activity work while shared calendars and discussion forums are examples of asynchronous collaboration (Figure 1).

Both synchronous and asynchronous collaborative tools have their advantages and drawbacks. One of the key advantages of synchronous collaboration is the facilitation of real-time interaction that allows people to send and receive information right away

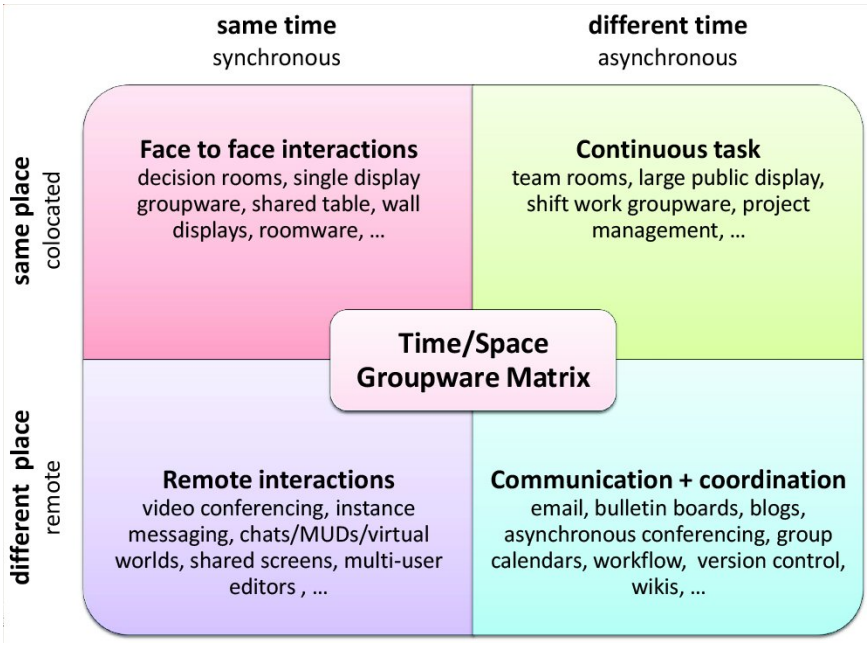

Figure 1: CSCW time-space groupware matrix.[1]

which promotes timely responses. The other advantage of synchronous collaboration is its resemblance to natural conversations such as face-to-face conversations or discussions through telephone. The drawback of synchronous collaboration is its rigidity with respect to time. All the parties involved in a synchronous collaboration must be ready and willing to collaborate at a predetermined, specific time. This could be helpful in many situations, but might not work well in cases where participants like to think over what they want to communicate [2], or when scheduling or time-zone differences make synchronous communication difficult.

The advantage of asynchronous collaboration is its flexibility. Collaborating participants can receive project communication and updates when it is most convenient for them. They can then take time to digest the information and put it in proper context and perspective. Once complete, they can then provide their contributions.

[1] https://en.wikipedia.org/wiki/Computer-supported cooperative work

This type of collaboration is generally helpful in learning and creative activities [2].

1.3 Video-centered Collaboration

Video-centered collaboration can occur in either a synchronous or asynchronous fashion. Pea et al. have categorized video-based collaboration into three different types, depending on how video as a medium is being used [49]. The first category involves collaborative work that requires simultaneous virtual presence of the collaborators and there are many existing video systems that support video-based conferencing to achieve that. The list of such systems ranges from Skype[2] and FaceTime[3] video on personal computers to dedicated room-based videoconferencing systems such as GoToMeeting[4]. In these cases the collaboration occurs synchronously and video itself is a medium to facilitate the communication. It closely resembles face-to-face conversation and has become a popular choice for distributed groups for online meetings.

The second genre of video related collaboration is video creation. Here the goal of collaboration is to create a video as final output. Group members in this category collaborate with each other to produce, edit and enhance the raw footage of video into a polished final product. This kind of collaboration could happen synchronously as well as asynchronously. WeVideo[5] is an example of a web-based tool that supports synchronous and asynchronous video editing within a group, whereas other examples include MediaSilo[6] that supports asynchronous viewing and commenting. Adobe Cre-

[2]http://www.skype.com
[3]https://www.apple.com/mac/facetime/
[4]http://www.gotomeeting.com
[5]http://www.wevideo.com
[6]https://www.mediasilo.com

ative Cloud[7] offers some popular software for video editing that allows team members to asynchronously collaborate on a video editing project. The output of such collaboration is a video which is then consumed by other people through various video distribution services such as YouTube[8] and Vimeo[9].

The third genre of video-related collaboration is when video is an artifact around which work must be done, rather than an end product. Here video acts as a central artifact and the collaboration happens around the content of the video. The discussion between an instructor and her students about a video explaining a cellular process through animation is an example of such collaboration. In such cases the collaboration could be synchronous as well as asynchronous and the conversation among the collaborators is about the content in the video. Such conversation requires a different set of tools and interaction techniques than the video conferencing or video editing tools. For this kind of collaboration, where the discussion is about the content, we need an interaction-centric video infrastructure that will let people engage in deep and precise conversation about the content recorded in the video. However, because of the lack of good alternatives people currently depend on video services such as YouTube to facilitate such collaboration. In this dissertation, I focus primarily on researching the use of collaborative tools that support conversation around the content presented in a video and the affordances that facilitate such collaborations. Norman has defined affordance as the design aspect of an object which suggest how the object should be used; a visual clue to its function and use [44, 45]. In this dissertation, I

[7]http://www.adobe.com/products/premiere.html
[8]https://www.youtube.com
[9]https://www.vimeo.com

have used Norman's definition of affordance.

1.4 Problem Space

Most everyone online uses video in some form or another. People use video chatting to connect and talk to their family and friends. Sites such as YouTube, Facebook, and Vimeo have enabled extensive sharing of video content. However, despite the huge amount of content available on those sites, the typical interactions with the videos are limited to posting and viewing. Limited interactions such as commenting on the video or organizing playlists exist, but these interactions are mostly at a macro level and generally apply to the entire video. There is a general lack of interaction techniques for fine-grained video content analysis. Some sites like YouTube allow video owners to annotate their own video content with speech bubbles and hyperlinks, but this is essentially a refinement of video production and doesn't add anything to the collaborative aspect of the video interface.

The life cycle of a video typically involves the production, distribution and consumption stages. To make video as easy to converse with, mark up, edit and ideate around as text, it is important to design and test interaction techniques that create a rich environment to encourage collaboration around video artifacts. However, despite the significant enhancements in end-user interaction for video production (e.g., camcorders, video editing software) and video distribution (Youtube, Vimeo and countless other websites) there have been very few enhancements in video interaction techniques. The interactions in commonly used video interfaces are often limited to a timeline slider for direct video navigation, a play/pause toggle, a volume

control slider, and a fullscreen toggle. These limited interactions inhibit the process of video exploration and do not afford an active and collaborative user experience.

To date, there has been some research in the field of video interaction, which I discuss in detail in Chapter 2, but this has mostly focused on video navigation through the use of specialized scrubbers. Overall, online video artifacts are still treated as a simple finished product for individual, passive consumption. The current limitation in video interaction techniques for exploration and analysis is a significant interaction problem for end users who want to use these videos to facilitate a collaborative or creative work process. As a part of my dissertation, I have designed and developed a video-centered collaboration system called the Video Collaboratory. I have explained the motivation, design and development of this tool in detail in Chapter 3.

1.5 Thesis Statement

> The Video Collaboratory system, which has affordances for groups of users to privately navigate, select, mark and annotate specific segments of a video using multiple modalities, makes asynchronous collaboration around video more contextualized, immersive and powerful than the standard use of video distribution channels in addition to separate channels for discussion.

1.6 Research Methodology

I started my research by understanding the dance production process while closely working with choreographers and dancers as a part of a National Science Foundation project called Dance.Draw [33]. As a project member, I attended weekly dance

rehearsals that involved choreographers, dancers, technologists and researchers. I studied the dance production process and observed the use of various technologies by different stakeholders during this process. I noticed that the choreographers and dancers used video to communicate the errors and progress in learning and cleaning the dance. However, dependencies on the technologies such as VCR and TV wasted a lot of valuable time during this collaborative process. This ethnographic approach [40] of studying the choreographic development process helped me to understand the need for a video-centered collaborative system in this process. I grounded the exploration of collaborative systems around my ethnographical study that informed and inspired me to develop a video-centered collaborative system with various novel interaction techniques [59]. The continuously evolving challenges in the collaborative set up allowed me to develop the system through an iterative process. The tool has been used by various departments at UNC Charlotte for teaching in classroom and studio-based courses. This initial usage of the tool helped me to collect data from the users through interviews, focus groups, surveys and user interaction logs. The in-situ evaluation further helped me to understand the socio-technical impact of the tool in a collaborative set up such as dance [13]. Market research through a related National Science Foundation I-Corps project suggested that people use tools such as YouTube and email for their video-centered collaborative tasks. The use of such tools leads to disjointed discussions from video that result in errors and waste of time. The market research and the early usage data of the tool helped me to improve the design of the Video Collaboratory to provide better affordances for video-centered collaboration than the other available options. This "research through design" approach [66]

of ideation, design and critique of the tool was instrumental in framing my research questions and developing my hypotheses. The research through design approach allows a contribution in the form of learning that informs the development of other products (Figure 2). In my research, this methodology helped me to form some design guidelines for video-centered collaboration that could be used by researchers and HCI practitioners for the development of video-centered systems.

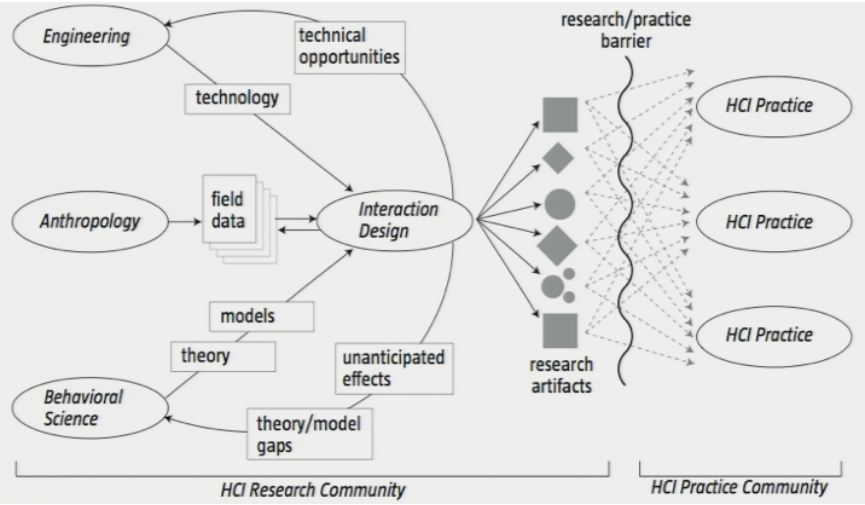

Figure 2: Research through design methodology[10]

1.7 Contributions

1. My first contribution is the design and development of the Video Collaboratory, a video-centered annotation system specifically designed with affordances for private group collaboration. The affordances include a login screen to make the collaboration private for group members, representation of collaborators' comments on the timeline, color-coding of group members' comments, and navigation of video through group members' comments to facilitate asynchronous

[10]From presentation slides - Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. Proceedings of CHI'07 - pp. 493-502

group collaboration around video documents.

2. My second contribution is an understanding of trade-offs and the socio-technical impacts of the introduction of this system in small collaborating groups.

3. My third contribution is a set of design guidelines based on my evaluations for creating affordances in asynchronous video collaboration tools.

1.8 Dissertation Organization

In Chapter 2, I provide an overview of research in the field of video, including user interfaces, video interaction techniques and a comparison of existing video annotation systems. It also provides a brief summary of the previous work done in the field of communication with video.

Chapter 3 is dedicated to an extensive discussion of the design, development, deployment and validation of the Video Collaboratory (formerly Choreographer's Notebook [59]). The system supports asynchronous collaboration around a video using multi-modal annotations. The tool includes various new interaction techniques to make video work easier and more contextualized.

In Chapter 4, I present the formative evaluation of how the tool has been used by various users in their work. The software has been used by more than 300 users in different domains and the views of some of the initial users on the usage of the system is presented in this section. This chapter also discusses the effect of the tool on the overall dynamics of a dance production and impact on active learning.

In Chapter 5, I describe a user study conducted to test my research hypotheses. In

this user study, I compared the efficiency and power of the Video Collaboratory tool with a popular video-centered system in a collaborative task. This chapter contains the methodology of the experiment, as well as results and findings.

In Chapter 6, I discuss the contribution of this research and present the overall findings. I also present a set of guidelines for developing asynchronous collaborative tools for video-centered systems. I conclude my dissertation with a discussion on the future research avenues made possible by this work.

CHAPTER 2: BACKGROUND

2.1 Collaborative Systems in Other Media

The explosion of the World Wide Web since the mid 1990s and recent ubiquity of Internet services with high bandwidth have received increasing attention from researchers. It has resulted in the development of many tools for producing and editing data on a shared network environment. The interest in such shared environments that support collaboration around various media such as text, image, audio and video has also seen a dramatic rise in recent years. Systems like Google Drive[11], Microsoft Web Apps[12] and Apache Wave[13] are some of the common examples of basic collaborative environments with shared content. These systems allow users to create and edit a multitude of content types such as rich text documents, spreadsheets, and multimedia documents.

Collaborative text editors allow simultaneous editing of a document. Some examples of collaborative editors include ShrEdit [17], Flexible JAMM [8], and Group Homework Tool (GHT) [31]. In a study of collaborative writing systems, Baecker et al. found that knowledge of the actions of collaborators is important for collaboration beside the mutual awareness between the collaborators [4]. Collaborative editing tools for writing documents are extremely common with the widespread availability

[11] https://drive.google.com
[12] http://office.microsoft.com
[13] http://incubator.apache.org/wave/

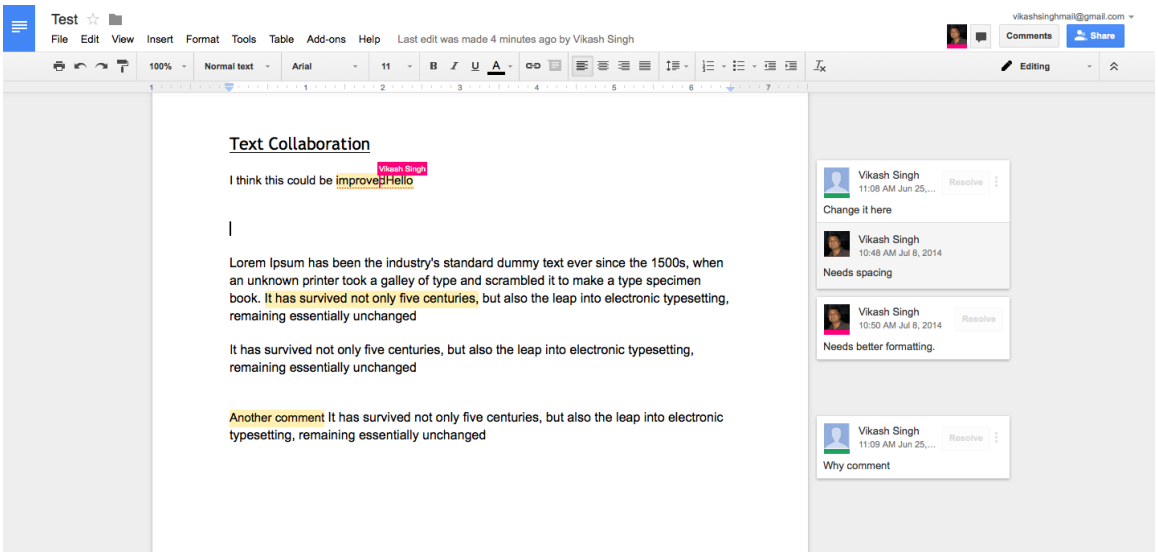

Figure 3: Design affordances in Google Docs

of web-based tools such as Google Docs[14]. Google Docs supports annotations, discussion, version control and provides a distraction-free environment for writing. The design includes a centrally positioned document with editing tools on the top. The owner of a document can invite other users to collaborate on the document and both synchronous and asynchronous collaboration is supported. When two or more users are editing a document in real-time, each of their cursors is color coded to reflect their respective positions in the document (Figure 3). Each user can add text annotations to the document. The annotated part in the document is highlighted and the related annotation appears on the right side of the document. Clicking on an annotation highlights the annotated text in the document. In the synchronous mode, two or more users can also talk to each other in a separate chat window.

Similar kinds of collaborative tools for creating and editing images are also avail-

[14]http://www.google.com/docs/about/

able. Notable examples include Google Drawing, Pics.io[15], Scriblink[16] and Pixlr[17]. Google Drawing allows users to collaborate on a virtual drawing board with a rich set of editing tools. Users can create various shapes and assign colors to these shapes. The shapes and scribbles on the canvas can be annotated with user's comments. Clicking on an annotation highlights the object associated with the comment. Google Drawing supports synchronous and asynchronous editing. Two or more people can create and edit a drawing in real-time. Google Drawing also supports real-time chat in a separate window and version control.

The design of Google Docs, Google Drawing and other similar collaborative environments share some basic design principles that make them very easy to work with. They are designed with affordances to make the experience of collaboration immersive and distraction-free. They are clearly structured and recognizable to users. All the needed options and materials remain visible to the user while they are working with the system. The menu items and thumbnails of all the collaborators on a project are displayed on top while all the annotations and discussions are visible on the right side of the screen (Figure 3). While collaborating, the users remain aware of the context they discuss with the help of color coded cursors and clickable annotations. The design keeps the user informed by providing good feedback on their actions and interpretations.

[15]http://pics.io/
[16]https://www.scriblink.com/
[17]http://pixlr.com/

2.2 Video-centered Collaborative Systems

The exponential rise in the past decade in video usage can be attributed to the wide availability of inexpensive video cameras and camera-equipped mobile phones, as well as higher bandwidth [49, 3]. Web-based video interfaces have become a common medium to deliver and consume videos. Notable examples are YouTube, Vimeo, news and sports sites such as CNN and ESPN. According to YouTube statistics, one hundred hours of video are uploaded to YouTube every minute[18]. Despite this increase in the creation and consumption of video, there has been a lack of tools to support video-centered collaboration.

Video has gained immense importance as a work artifact in many domains. Medical imagery, performing arts, education and sports analysis are some of the domains that depend heavily on videos for data analysis. As an artifact, a video can play a central and important role in collaborative work in all of these domains. The recorded videos can be used for asynchronous post-game analysis[19] or as a medium to provide instructions and critique as in the case of dance [59, 10]. Despite such need in various domains, video-centered collaborative systems are rare.

Most of the work on video collaboration has focused on synchronous distributed interaction where people collaborating are at different places at the same time. Commercial video conferencing systems such as Skype and Google Hangout are examples of synchronous interaction systems. These systems that support synchronous collaboration with video are good, but there could be many scenarios where video-centered

[18] http://www.youtube.com/yt/press/statistics.html
[19] http://www.hudl.com

collaboration might need asynchronous activities. However, because of the lack of such systems, people depend on tools that are not designed for collaborative purposes. To collaborate around video documents, people use tools like YouTube and Vimeo with the help of separate channels of communication supporting a video artifact. For example, the students on Massive Open Online Courses (MOOC) generally post their comments about video lectures in a separate forum or send an email to their instructors with their question. Video editors discuss the edits and corrections about a video through email. Such disjointed interaction creates confusion, wastes time and increases errors.

Nardi noted that collaboration using video as the main data artifact is a novel application which requires novel tools [42]. After almost two decades, Nardi's comment is still relevant as the research in developing tools for asynchronous collaboration around video documents with specific designed affordances has remained limited. Using video as an artifact for collaboration is an interesting idea but it is important to note that introduction of new technologies brings new design challenges for the development of a collaborative system.

In the next few paragraphs, I will first discuss the various video-based applications and their design affordances that support collaboration in one way or another. The majority of these systems support annotations on video in one or more modalities. Then, I will discuss some of the research that has happened in the field of specialized interaction techniques for video interaction. These specialized interaction techniques have been designed to provide better affordances to interact with a video. Finally, I will discuss some of the commercial applications that support video-based collab-

oration including various video-centered systems used by MOOCs. This literature review provides an overview of the different features in available video-based systems. The critical analysis of design features in these systems helped me to understand the current state of video-centered systems and guided me through the design process of the Video Collaboratory system that I developed. I discuss the Video Collaboratory system in detail in Chapter 3.

2.3 Related Systems

Digital annotations of a video are similar in concept to notes in the margin of a book. They are meta-data associated with the content of a video. These meta-data can take any form such as text, an image, a URL, audio and video. These meta-data or annotations can be anchored to a frame or segment on the timeline of a video. Though these annotations are anchored to the timeline of a video, they are generally stored in an external file. Annotations are a good platform for asynchronous collaboration as different users can remotely access and insert annotations for the same video content across multiple sessions separated in time.

Digital annotations of a video have the potential to provide immersive and contextualized support for creative and collaborative work. Many groups have explored the idea of using video annotation interfaces as a support tool to facilitate collaboration and communication among different stakeholders. Table 2 shows the design affordances available in different systems that support video-centered collaboration. Many interfaces have been developed in the past decade to support multimedia annotation in the form of text or digital ink or a combination of both. Distance learning

was one of the earliest domains to use video annotation interfaces. The Classroom 2000 project [1] and the Microsoft Research Annotation System [6] are two examples of tools that were developed for educational purposes. The design features in these two systems allowed students to record notes, questions and comments as they watched web-based lecture videos. The annotations were saved with video meta data to identify the time in the video where annotations were created. However, affordances for collaboration such as representation of collaborators' comments on timeline as as well as video navigation through annotations were missing. The annotation sharing was supported through email. Goularte et al. [22] developed a system that allowed annotation of MPEG-7 video files with sketch and voice modalities. The annotations were saved in a separate XML file and lacked direct integration of annotations with video. The system was mainly designed to review a captured video with annotations and didn't allow collaboration with other users.

The DIVER system was initially developed as a desktop application but has more recently been deployed as a web-based system. It allows users to attach text based annotations to the video and supports zooming in on different parts of a video frame [50]. The owner can annotate the video with text comments while others can only post comments on annotations and not on the video limiting the process of collaboration. VidWiki is an online system that helps people improve the quality of online videos. The tool is designed for the education domain and it allows users to improve handwriting, correct errors or translate text of educational videos [14].

CoVidA is a pen-based collaborative video annotation system which supports annotations in the form of digital ink on the video. The digital ink can be used for

drawing shapes or writing text on a video, which is saved in the form of XML [67]. TrACE is a media-playback environment that helps social learning among students and lets students request help from instructors through video annotations [16]. mStar is a software toolkit that supports creation of multi-user applications for streaming audio and video [48]. However, the applications designed using the mStar toolkit are best suited for e-meetings in the distance education domain. The toolkit focuses primarily on synchronous collaboration to enhance teamwork and is not meant for video analysis.

Most of the popular web-based or standalone video interfaces have a very specific set of controls. The common set of video interaction tools includes a video progress bar, a scrubbing handle on the video progress bar to manipulate video playback, a play/pause toggle button, a volume control slider, and a fullscreen view toggle button. The length of the video progress bar generally represents the duration of the video and a user can drag the handle or directly click on the progress bar to get the video playback to resume at the clicked position. These interactions work well for a casual user who is using video for passive entertainment purposes but for the people who want to use video for work, the interactions need to be more dynamic.

Previous work in digital video interactions has focused mainly on navigation through the use of specialized scrubbers [25, 53, 51], as well as segmentation and annotation [15]. Silver is a video-editing tool which displays an explicit 3-level view of the video timeline when the user zooms into a video segment [39]. The users can also add text annotations that span the segment. The Silver system is aimed at editing and rearranging video for the purposes of creating a final video artifact, and is not a

collaborative tool. SmartSkip [18] helps video viewers to skip video segments using the traditional TV remote and is aimed at video consumption and not collaboration. The system called LEAN uses a tabletPC and pressure-sensitive pen to navigate and control digital video. It uses simple pen gestures to allow users to do high speed scrubbing and create video segments which can be annotated [52]. Researchers have also investigated direct manipulation of video objects to interact with the video, resulting in some novel interaction techniques. DRAGON is a direct manipulation interface for interacting with video objects. The interface supports the dragging of video objects for frame-accurate, in-scene video navigation [27]. Goldman et al. developed a system in which different video objects are grouped together to allow for interactive manipulation. The system also supports annotations in the form of thought balloons, path arrows, and video hyperlinks to allow for interactive manipulation [20].

Using the crowd to extract useful information from a video has also been explored by many researchers. Glance is a video coding system that uses crowdsourcing to analyze a video. The system distributes and aggregates data from crowd workers and visualizes the result in real-time [32]. Kim et. al. have worked on video interaction techniques to augment a how-to video with data crowdsourced from other users. The collected data is visualized to represent high activity zones and collective navigational traces [29]. A similar system was later developed for educational videos on MOOCs [28]. EVA is a system that allows users to associate text comments with specific time segments in a video [64]. Exploration of the usage of multimedia for sports analysis has also seen some innovative research, including special interfaces for users to control video playback and switch camera angles by the press of a button [47, 46, 36, 7].

Some commercial applications also employ various domain specific video interaction techniques. The Reporter's Lab Video Notebook [20] is designed to support automatic transcription of news releases and related social media streams for jounalistic analysis, but does not support video segmentation. Other special purpose systems for usability analysis exist such as TechSmith Morae[21] and Mangold Interact[22], but they are not designed to support collaborative segment analysis and general purpose multi-modal annotation.

There are many commercially available video-based interfaces that support annotation in one form or another. YouTube[23] allows users to annotate videos they upload in the form of speech bubbles, notes, and captions. BubblePLY[24] is an application that allows user to annotate videos from other websites such as YouTube. Users can add text, a drawing, some pre-defined clipart, and video. They can edit and share their own annotated videos which are called bubbles. Videonot.es[25] is a web-based application to take notes on a video. The notes are synchronized with the different time stamp on the video. The video can be navigated by clicking on these notes. Viddler[26] is an online video platform which supports annotations in the form of clipart and video. Mozilla Popcorn Maker[27] is a web-based application developed for making it easy to enhance, remix and share web videos. It lets users import videos from other websites such as YouTube and modify them with the help of annotations

[20] http://www.reporterslab.org/video-notebook-beta/
[21] http://www.techsmith.com/morae.html
[22] http://www.mangold-international.com/
[23] http://www.youtube.com/
[24] https://www.facebook.com/bubbleplyapp
[25] http://www.videonot.es/
[26] http://www.viddler.com/
[27] https://popcorn.webmaker.org/

Table 2: Design features in existing video annotation systems.

Tool	Annotation modalities	Annotation markers on video timeline	Annotation overlaid on video	Navigation through annotations	Color coding for users	Annotate a frame or segment	Looped playback at various speed	Web-based	Private	Group Collaboration
YouTube	Text + Shapes (on self-uploaded video)	No	Yes	No	No	No	No	Yes	Need user settings	No
viddler	Text + Video	Yes	No	Yes	No	No	No	Yes	Yes	No
Vimeo	None	No	No	No	No	No	No	Yes	Need user settings	No
Popcorn Maker	Text + Shapes	Yes	No	No	No	Yes	No	Yes	No	No
Grockit	Text	No	No	Yes	No	No	No	Yes	No	No
VideoNot.es	Text	No	No	Yes	No	No	No	Yes	Yes	No
MRAS	Text	No	No	No	No	No	No	Yes	Yes	No
DIVER	Text + Shapes	No	No	Yes	No	Yes	No	Yes	Need user settings	No
coVidA	Text + Digital Ink	No	Yes	No	No	No	No	No	No	Yes
vidWiki	Text + Shapes	Yes	Yes	No	No	No	No	Yes	No	No
videoANT	Text	Yes	No	Yes	No	No	No	Yes	Yes	No
Mangold Interact	Text	No	No	No	No	Yes	Yes	No	NA	No
Techsmith Morae	Text	No	No	No	No	Yes	No	No	NA	Yes
Elan	Text	No	No	Yes	No	Yes	No	No	NA	No

in the form of text, sketch and URL. Although a powerful tool, remixes made using Mozilla Popcorn Maker platform are produced by a single user and not designed for collaborative activities. Grockit Answers[28] is a web application that supports text annotations on YouTube video. Users can ask a question or provide an answer to an existing question. These questions and answers appear in the context of video content.

In the education domain, though there are a number of education-specific video software platforms, none of them provide affordances for small-group interaction and collaboration. Kaltura[29] is a video hosting service that embeds in learning management systems such as Moodle and Blackboard, but this LMS plugin has no features for supporting collaborative discussion of the video content. Most of the popular web-based or standalone video interfaces used for education such as Coursera[30], edX[31] , and Udacity[32] have a general set of video controls. The Coursera video user interface, shown in Figure 4, provides video interaction features such as a video progress bar, a scrubbing handle on the video progress bar to manipulate video playback, a play/pause toggle, a volume control, a video speed control option and a full screen view toggle. Comments on videos are recorded in separate applications. The edX video user interface, shown in Figure 5 , includes a video player on the left and a panel on the right showing predefined video captions. These captions provide for video navigation: the captions are clickable and move the location of the video to a

[28]https://grockit.com/answers
[29]http://kaltura.com
[30]http://coursera.com
[31]http://edx.org
[32]http://udacity.com

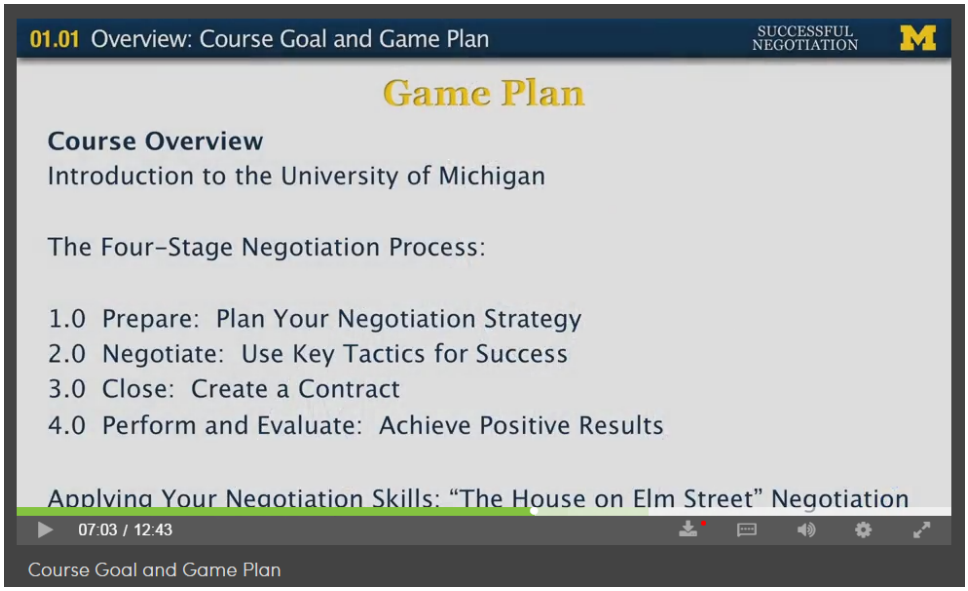

Figure 4: Coursera video user interface

specific time.

The typical video interactions allow watching video lectures but do not support a collaborative and engaging video experience. Some video applications in learning environments, such as those in Udacity and edPuzzle[33], allow instructors to embed interactive quizzes on the video timeline. The edPuzzle video interface includes editing techniques of cropping and trimming, specifically for the development of educational video lectures. Though questions and comments can be embedded in the lessons, there is no support for collaborative discussion. The edPuzzle user interface, shown in Figure 6, includes a video player and a side panel to show embedded quizzes at different points on the video. The points where quiz questions are embedded are indicated with a green marker on the timeline. When the video playback reaches the green marker, the video pauses and the quiz question appears on the side panel.

Udacity uses an embedded YouTube video player for its video content. A lecture is

[33]http://edpuzzle.com

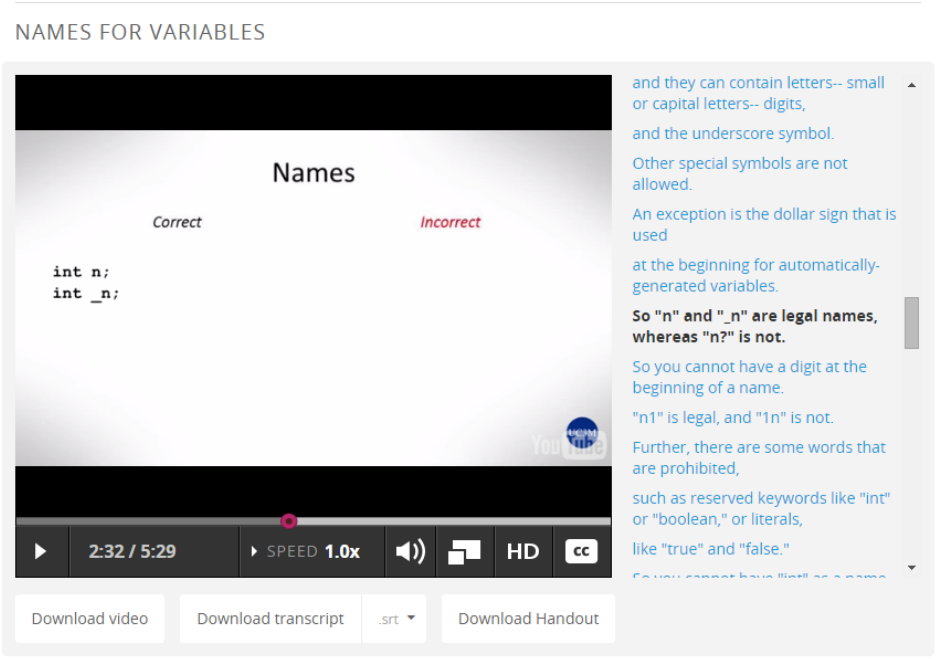

Figure 5: edX video user interface

broken down into smaller segments. The application allows the instructor to embed quizzes in one or more of these segments. The user interface, as shown in Figure 7, includes a color-coded bar on the top showing all the segments. The segments with quizzes are indicated with a dot on the segment while the current segment playing is shown in orange. The quiz questions are added by instructors at strategic points on the video and students are asked to complete the quiz before moving to the next sections of the video. The video can be navigated by clicking on these smaller segments. However, none of these video applications support direct video annotations or collaborative interaction with the videos. The process of embedding quizzes is done before student consumption of video content and although it adds some interactivity to the video, it does not support student-student or student-instructor collaboration.

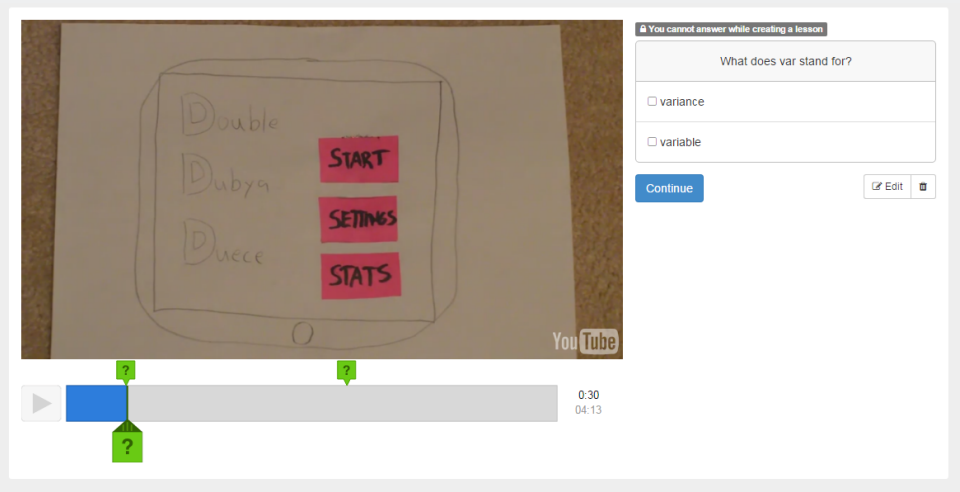

Figure 6: EdPuzzle video user interface

Figure 7: Udacity video user interface

GoReact[34] is designed primarily as a public speaking feedback tool where a video can be evaluated through a rating scale and evaluators can post comments on the video. However, the GoReact application lacks features such as automatic looping, sketching and speed control. The GoReact application, shown in Figure 8, includes a video player on the left and an annotation pane on the right. At the bottom of the video player, a panel includes a rating scale. The evaluator can add a rating on the video during playback or pause the video to insert a comment.

videoANT is a web-based video annotation application developed for e-learning [23] that allows annotations on the video in the form of text at different time points of the video. videoANT allows sharing of comments posted on the video with others through email and doesn't support multiple people collaborating and annotating around a single view of the video content. videoANT user interface, shown in Figure 9, includes a video scrubber on top, a video player on left and a comments panel on right. The videoANT supports text annotation: the annotations are added to the video timeline and the video can be navigated by clicking on these comments. For each comment, a marker is added on the timeline.

videoANT and GoReact allow video annotations in the form of text comments that are added to the video timeline and the video can be navigated through these comments. However, none of these applications have affordances to support multiple people collaborating on a video in the process of sense-making.

[34]http://goreact.com

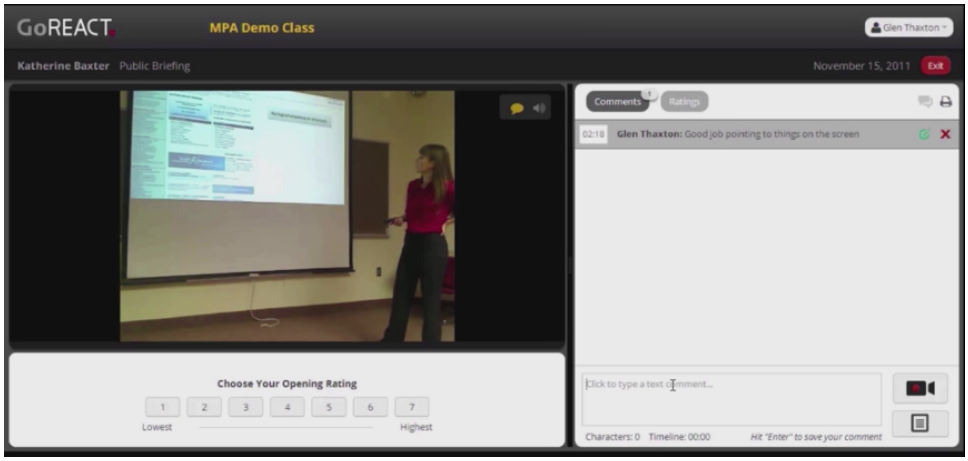

Figure 8: Goreact video user interface

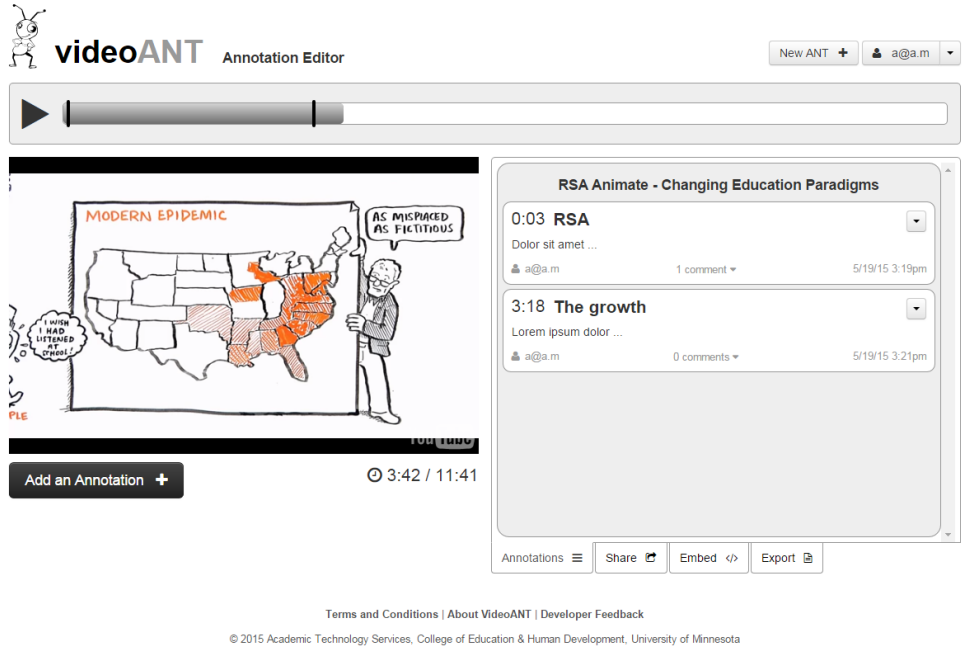

Figure 9: videoANT video user interface

2.4 Summary

The commercial systems that support video annotations such as YouTube, viddler, Popcorn Maker and VideoNot.es are good for annotating a video in different modalities but they lack various affordances that are needed for collaboration. None of these systems provide a platform where multiple group members can privately login and discuss and annotate a video. YouTube, viddler and VideoNot.es all support annotation on video only if the video belongs to the owner. No annotation is allowed on the video uploaded by other users. This limits the process of collaboration. Replying to a comment is an important feature for collaboration and YouTube and Vimeo allow its users to reply to each other's comments. In YouTube, the comments can be anchored to specific point on the video by specifying time stamp of the video in the comment. Clicking on the time stamp takes the user to that time on the video.

Different color-coding of each member's comments allows collaborators' to visually identify different member's comments from a list of comments reducing the time in searching comments. Text-based collaborative systems such as Google Docs have implemented the color-coding for collaborators. However, none of the video systems discussed in this chapter have any color-coding feature for their comments.

Navigating a video through posted comments can help collaborators to quickly find the context of comments in the video. Both viddler and VideoNot.es allow navigation of video through posted comments. However, both the tools are designed for individual authoring and not for collaborative tasks.

The analysis of existing applications presented in this chapter clearly suggests that

there is a need for video-centered collaborative applications that allow people to work around the content of a video with affordances specifically designed for video-centered collaboration. Affordances such as a login to make the collaboration private for group members, representation of collaborators' comments on timeline, color-coding of group members' comments, and navigation of video through group members' comments exist in some applications or other but they are not designed for collaboration and are mainly used for self authoring. Besides these affordances the design of tools for video-centered collaboration will need different ways to annotate and navigate the video content and should support asynchronous collaboration over Internet. Better control over video playback and other fine grained controls to interact with sections of a large video would also be helpful during collaboration. I have used the literature presented in this chapter as a foundation for my thesis statement and framing my research questions.

CHAPTER 3: VIDEO COLLABORATORY

The critical analysis of video-based applications in the previous chapter highlighted that many video-based systems used for collaborative tasks lacked features for group collaboration. Those that support collaboration lack design affordances that are necessary in a collaborative setup. In this chapter, I present the design and development of a web-based, asynchronous video collaboration system that was initially called the Choreographer's Notebook and later rebranded as the Video Collaboratory. The Video Collaboratory has been designed as a tool to connect group discussion threads directly with relevant points and segments within videos under discussion. The specially designed affordances provide a higher degree of discourse around a video artifact and remove the fragmentation between discussion and video content that occurs when videos are discussed in separate channels such as email.

The Choreographer's Notebook was initially designed to enable dancers and choreographers to improve communication and collaboration when they were not interacting face to face in a physical rehearsal space. The tool was later expanded to incorporate more features and is currently being used in domains other than performing arts. In this chapter, I will first discuss the motivation behind the development of the Choreographer's Notebook, then I will explain the design and various affordances of the tool and finally its transformation into the Video Collaboratory.

3.1 Motivation

Dance is a collaborative endeavor involving many people such as choreographers, dancers, designers, stage+lighting technicians and technologists [21]. Choreographers have used computing in various forms for composing and creating choreography [55, 12, 11]. Besides creating special tools for choreographic learning and composing [41, 24], various research groups have also explored the collaborative design of live-motion capture [38] and use of wearable sensors on dancers [34, 54]. While dancers and choreographers have traditionally used video for archival purposes, and occasionally for rehearsal review, most choreographers do not like to record all the rehearsals of a dance production. Dancers and choreographers favor an active life, but the increasing pervasiveness of computing devices has led them to use computers more extensively and with greater comfort. They are now very accustomed to video-based interfaces such as YouTube and Vimeo and some dancers even have their own digital video recorders for recording themselves in a studio during practice. Dancers and choreographers have access to many dance videos on dancetech.net[35] where users are comfortable with the idea of using video as an artifact.

The development of Choreographer's Notebook was inspired by the observation of various dance productions at UNC Charlotte. I had the opportunity to work with dancers and choreographers in a National Science Foundation funded interdisciplinary project called Dance.Draw and be a part of the dance production process for three years. I observed that the development of an academic choreographic work, including

[35] http://www.dance-tech.net

staged production, lasts for 3-4 months (14-16 weeks). Choreographic development is a very organic process and, though various stages in a dance production overlap with each other, it typically involves the following stages [59]:

- Choreographic Development: The first stage in a dance production process involves the development of choreographic concept. A choreographer, usually with the dancers, develops a choreographic vocabulary. At this stage, the choreographer tries to give shape to her vision by setting sequence and structure to the choreographic material. The choreographic development takes approximately 3-6 weeks depending on the choreographic material.

- Choreographic Learning: Once the choreography is set, dancers are taught the choreography. Dancers learn a few minutes of dance at a time and as they master more and more of the dance, they continue to rehearse what they have learned. If the dancers are learning an existing choreography, they take advantage of videos from a previous production to learn the choreographic work. If the choreography is new, it is typical for choreographers to record parts of rehearsal and review those parts at the end of a rehearsal session. The choreographic learning is generally the longest stage as the dancers learn new movements in this stage. It overlaps with the choreographic development and the choreographic cleaning stage and lasts for 6-8 weeks.

- Choreographic Cleaning: Once the dancers have learned all the material for a dance piece, the rehearsals turn to movement cleaning and detailing. The choreographer makes sure that each individual dancer is executing the dance

movements with specific nuances and dynamics. This stage of a dance production lasts 3-4 weeks and overlaps with the choreographic learning stage.

- Stage Readiness: In the week or two leading to the scheduled performances the dance moves from rehearsal space to the main stage for technical and dress rehearsals which include spacing, lighting, sound and costume. The choreographer gets a chance to see the dance on the stage and make appropriate adjustments based on space constraints and other technical factors. This stage of a dance production generally takes 1-2 weeks.

- Performance and Post-performance: It is rare for the production to change after the dress rehearsal and after the performances there is little or no activity related to the production.

A dance performance involves many people including dancers and technicians. They are often involved in more than one project at a time and hence gathering everyone together at the same time for a rehearsal becomes very challenging. It is evident that rehearsals play a very important role in the whole production process. I observed that the dancers and choreographers would meet two or three times a week for three to four hours during the choreographic development. These meetings took place in the rehearsal space: generally a dance studio equipped with a mirrored wall, a sprung marley floor and ballet barres. A dance studio plays a critical role in the overall dance production process as it is a specially designed space for the dance. In rehearsal meetings, the dancers rehearse the learned phrases and the choreographers would refine the learned phrases and teach new movements. Most university dance

programs have limited studio space which must be shared with multiple choreographers. For a commercial dance production/professional choreographic development, large private dance companies may own their rehearsal space while most small and mid-size companies rent space. Rehearsal spaces are generally limited in number within any city or town, and are expensive to rent. In the Manhattan area, a 1000 square foot dance studio, costs $50- $150 per hour[36]. A typical rehearsal usually lasts 7-8 hours a day and a professional production generally has rehearsals five days a week, starting weeks or months before the show is staged. Clearly, in both the academic and professional dance spheres, studio time is scarce and expensive and choreographers want to make the most productive use of this time. The scarcity of space and time is a prevalent concern that impacts the quality of a production in both the commercial and university dance environments.

It is important to judiciously utilize the space to make the best use of the rehearsal time. However, I observed numerous occasions during these scheduled dance rehearsals where dancers and choreographers would sit in a circle on the floor of the dance studio discussing aspects of the dance. They discussed their previous rehearsals and talked about improvements and corrections in their movements. Sometimes I also observed them pull out an old TV and VCR in order to assist them in their review of previous rehearsals. These discussions occur often and take anywhere from 15 minutes to a full hour. While this communication is important, I noted that a significant amount of studio time was spent in discussion rather than movement, which is not the most effective use of the specialized dance studio space.

[36]http://www.dance-manhattan.com/pricing_and_policies

So, what if choreographers could move some of the discussions taking place inside the studio to outside the studio? My advisor (Dr. Celine Latulipe) and I came up with the idea of an online platform called the Choreographer's Notebook that could be used for outside the studio communications and discussions. We noticed that the choreographers were sometimes recording the rehearsal to use the video as a medium to review the choreography and to explain the subtleties and nuances of movements to the dancers. The goal of Choreographer's Notebook was to create communication around the recorded rehearsal videos. We thought if these rehearsal videos could be made accessible to the dancers and choreographers outside the studio space and if these videos could be annotated through text comments and/or sketch comments (for spatial explanations), it would enable dancers and choreographers to communicate from outside the studio. The choreographers and dancers could use the Choreographer's Notebook to review, reflect and comment on their choreographic project, hence increasing communication and collaboration even if they are not interacting face-to-face in the physical rehearsal space. This mediation through technology was designed to free up more time in the studio for rehearsing the physical dancing. In the early production stages, this is likely to lead to more creative exploration. In later stages of a production, the Choreographer's Notebook could help with communicating, fine-tuning (cleaning) and positive reinforcement and allow more time in studio to embody movement details and to practice performance projection.

3.2 Design Goals and Requirements

The high level design goal was to create an online platform for small group collaborators such as choreographers and dancers where these collaborators could take a video and conduct anchored discussion around the video. Based on the analysis of existing text, image and video-based collaborative systems, it was clear that for a video-centered collaborative system for dance to be successful it must have design features to allow users to asynchronously and privately collaborate around a recorded video. Initial requirement gathering from dancers and choreographers helped me to decide on the initial list of features. The system must:

- Have access control such that rehearsal videos are only available to the participants of the dance production and are never publicly available.
- Allow comments from users on videos at their own time (asynchronous).
- Allow users to easily upload dance rehearsal videos where others can view them.
- Allow users to add, share, edit and delete comments on the uploaded videos.
- Allow multiple commenting modalities, including sketching to explain spatial relationships.
- Display annotations in context when comments are clicked.
- Integrate visual representations of annotations on the video timeline.

3.3 Design Concept and Prototypes

Based on these requirements, I started working on various design concepts for the application. The two column layout in DIVER system [50] and videoANT system (Figure 9) with video in left column and a place for annotations in right column seemed to be a good starting point. I created a wireframe showing the final design concept with various features (Figure 10). Later, I developed a high fidelity prototypes showing design features for collaboration (Figure 11). The color coding of comments was designed to allow collaborators easy identification of others' comments. Markers on the timeline were designed to afford collaborators the ability to visualize the activity density on the video timeline.

The application was developed in an iterative process. During the last five years, the application has gone through many iterations based on the continuous, valuable input of choreographers and dancers who used it for many different choreographic projects and dance productions. I am briefly going to talk about three major releases of this application, design rationale behind each release and then discuss some of the elements of the user interface. I will also describe some use case scenarios that informed the design of many features in the application.

3.3.1 Choreographer's Notebook v1

The first version of the Choreographer's Notebook (Figure 12) was released in Fall 2010. The application allowed multi-modal annotations (text and digital ink) on a linear video which turns the rehearsal video into an interactive teaching and collaboration tool. Based on the design requirements collected through interviews

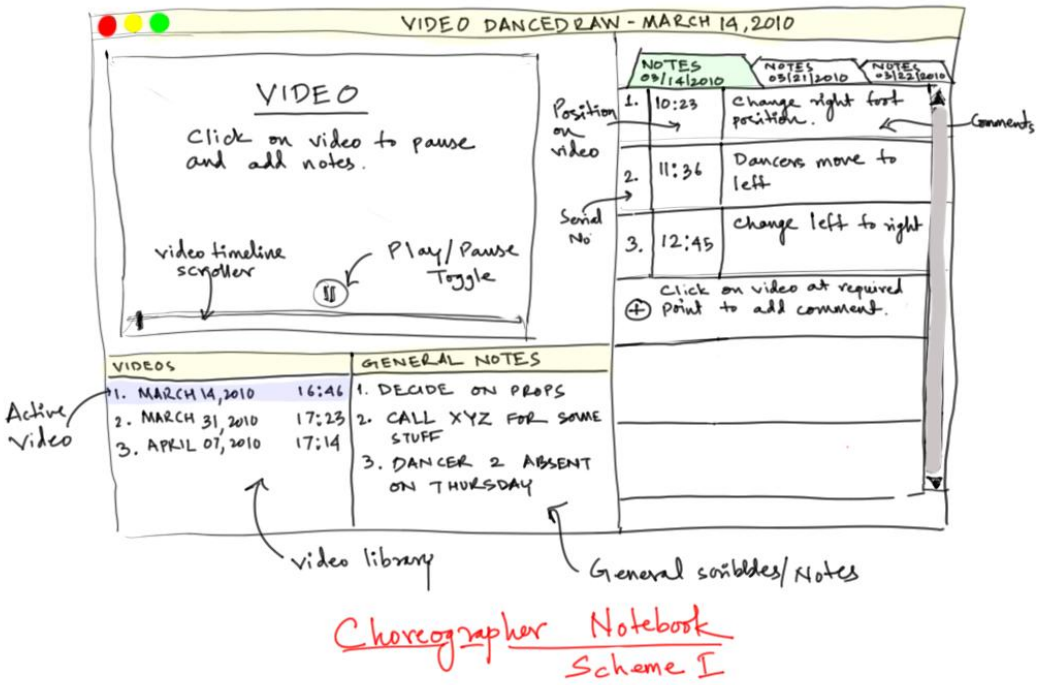

Figure 10: The wireframe sketch of the Choreographer's Notebook.

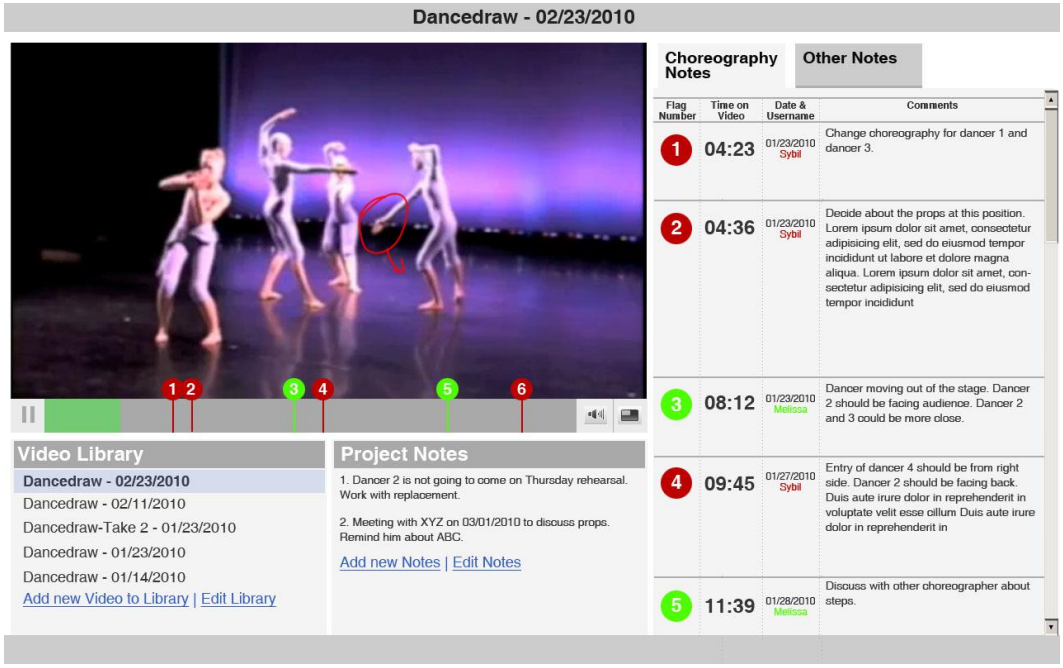

Figure 11: The high fidelity mockup of the Choreographer's Notebook system's main screen.

Table 3: Design requirements, affordances and signifiers for collaboration in the Choreographer's Notebook - v1.

Design requirements	**Affordances**	**Signifiers**
Access control	Login screen	Login form with username and password fields.
Easily identify the collaborators and their comments	Color-coding of user's comments	Each collaborator's name appears with different colors
Visual representations of annotations on the video timeline	Circle shaped markers on time line	Color-coded markers appear when comments are added
Display annotations in context when comments are clicked	Clickable comments and markers	On mouseover, the background color of comments changes

from choreographers and dancers I implemented various affordances with appropriate signifiers in the first version of the application (Table 3). The application supported visual indexing of annotations and a rich navigational set of controls for inserting and editing the annotations on the video. A choreographer could upload a rehearsal video and post comments in the form of text or digital sketches. Dancers could then use the comments posted by the choreographer to refine their movements at home, before they attend the next rehearsal. Further, they could add their own comments in response to the choreographer's input or that of a peer dancer.

This version was developed using the Adobe Flash framework and worked in all major browsers. Before the introduction of the Choreographer's Notebook, the choreographers and dancers were using video recording devices such as camcorders to record their rehearsal videos and watch these videos later in the studio on a TV. While designing the first version of the Choreographer's Notebook, it was important to support

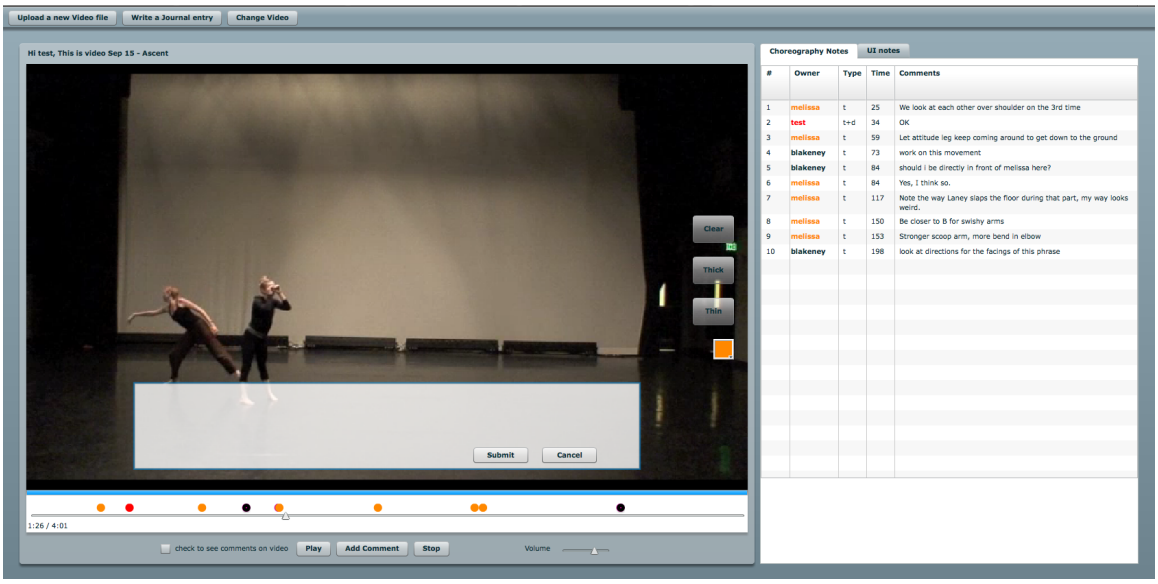

Figure 12: The first version of the Choreographer's Notebook that was used from 2010 to 2011.

the video uploads from camcorder to the designed application.

The first version of the Choreographer's Notebook was designed to support mp4 and flv video format. The videos from the camcorder were first encoded into mp4 format using iMovie software [37] and then uploaded to the application. After logging in, users could load videos, play them and insert annotations. This version supported the text and digital ink annotations and included a journal feature, allowing users to maintain a daily journal. The digital ink could be used with two different line widths and a variety of colors.

Because the first version of the Choreographer's Notebook was developed using Flash framework, there were many features in the application that were dependent on the tools available in the framework. One of the major trade-offs of using Flash for the application development was its inability to support mobile devices. Flash

[37] https://www.apple.com/mac/imovie/

Table 4: HTML5 video support in top 5 browsers.

Browser	**MP4 format**	**WebM format**	**Ogg format**
Internet Explorer 9+	Yes	No	No
Google Chrome 6+	Yes	Yes	Yes
Firefox 3.6+	Yes (v28+)	Yes	Yes
Safari 5+	Yes	No	No
Opera 10.6+	No	Yes	Yes

is not supported on most of the mobile devices including iPhone, iPad, smartphones and most tablets. To make this content available to users on mobile devices it was necessary to use programming environment that could make the content available on most of the devices. To address this issue I moved away from Flash in the next iteration of the application.

The initial feedback from the users was mixed. Although most users liked the ability to annotate different parts of the video and the ability to navigate video through posted comments, various glitches in the application proved frustrating. Many users reported a lack of consistency while adding annotations. Some reported that a comment didn't appear in the application immediately but was delayed until the next comment was inserted. The unavailability of the videos on mobile devices was also a concern.

3.3.2 Choreographer's Notebook v2

After careful analysis I chose to support 'mp4' video format for two main reasons. First, most video recording devices such as digital video recorders, iPhone and most smartphones support 'mp4' format. So it is possible from most of the devices to record a video which is saved in 'mp4' format to upload to the Choreographer's Notebook

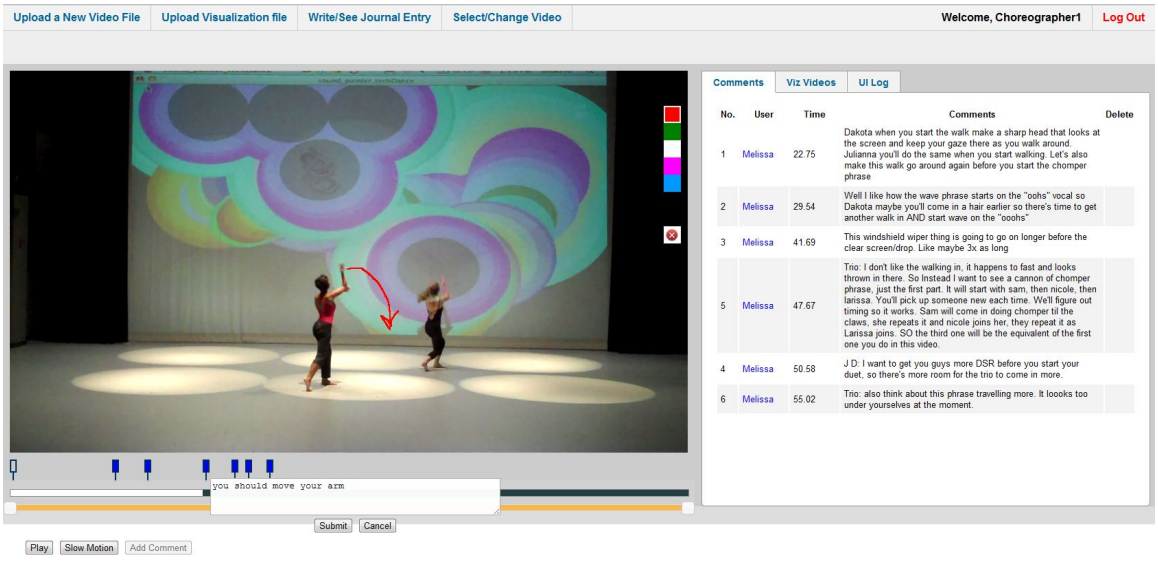

Figure 13: Second version of the Choreographer's Notebook that was used from 2011 to 2012.

without performing any extra step of video conversion. Second, 'mp4' video format is supported by 3 major browsers - Internet Explorer, Safari and Chrome. The three browsers include the default browsers for the two major operating system, Windows (browser Internet Explorer) and Mac OS (Safari). Later I observed that the video playback was 'choppy' in some instances while using Internet Explorer on Windows and hence Google Chrome (for Mac and Windows) was assigned as the default browser for this application. Google Chrome supports a smooth playback of mp4 video. Recent adoption of the H.264 codec by Mozilla community made the video playback possible on Firefox too.

Many significant changes were made in the second version of the application [58]. The application usage data was collected by observing dancers and choreographers use the system, An instrumentation model was implemented to collect and analyze

Table 5: Design requirements, affordances and signifiers for collaboration in the Choreographer's Notebook - v2.

Design requirements	**Affordances**	**Signifiers**
Access control	Login screen	Login form with username and password fields.
Easily identify the collaborators and their activities	Color-coding of user's comments	Each collaborator's name appears with different colors
Visual representations of annotations on the video timeline	**Rectangular marker on the time line**	Color-coded markers appear when comments are added
Display annotations in context when comments are clicked	Clickable comments and markers	On mouseover, the comment was highlighted
Ability to annotate a segment on a long video	**A segment selector**	**A scrubber with two handles**

users' low-level interactions with the system. After analyzing the usage data of the first version, I observed that the users never changed the thickness of the digital ink options. Whenever they used this feature they used the default thickness of the digital ink. In the second version, I removed the option of changing pen thickness and reduced the color palette to 6 colors.

The affordances for collaborations were retained in the second version of the Choreographer's Notebook. However, I improved some of the signifiers. The marker was re-designed as a pin with different colors signifying different collaborators. An early version of segment selector was also included. (Table 5).

The design of video browsing in the the Choreographer's Notebook-v1 was very primitive and didn't allow a user to easily find a video from a set of videos (Figure 14). I created a new user interface for video browsing from a list of uploaded videos. The

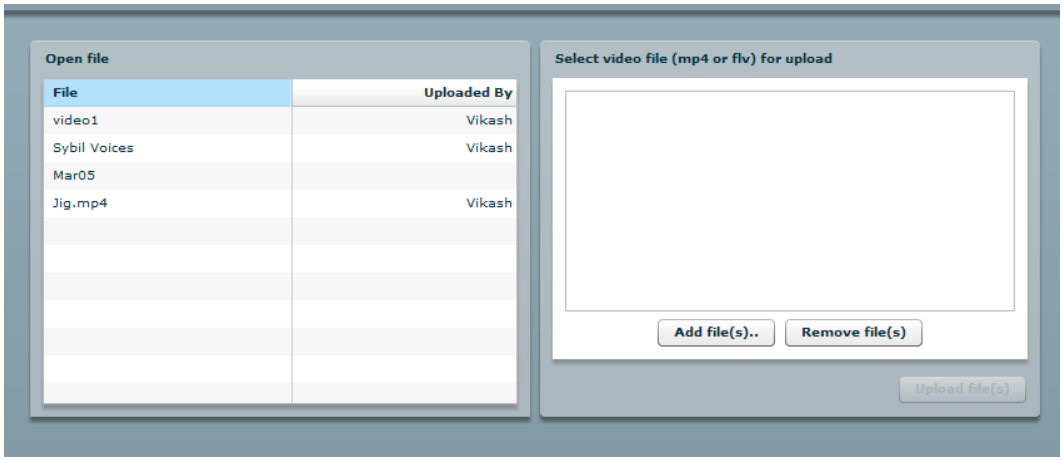

Figure 14: Video Upload - Choreographer's Notebook-v2

user interface provided a quick look into the video properties of a selected video (Figure 15). The tree structure for categorizing videos in different projects made the video browsing a little easier, but the user interface still didn't afford a preview of a selected video. The video preview support was added in the third version of the application.

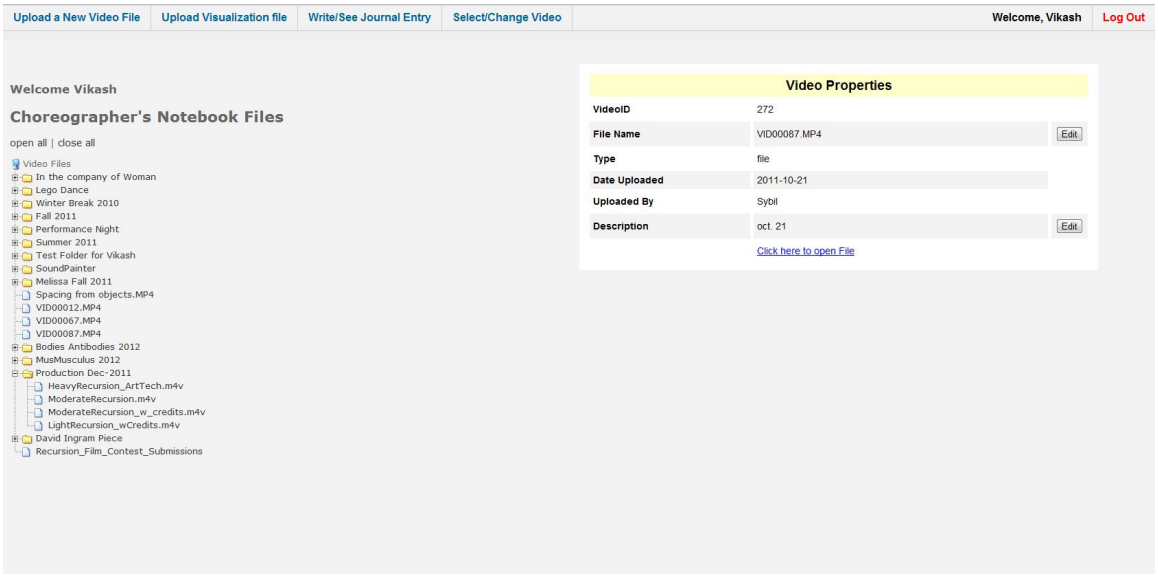

Figure 15: Selecting a video to open in the Choreographer's Notebook v2.

Table 6: Design requirements, affordances and signifiers for collaboration in the Choreographer's Notebook - v3.

Design requirements	**Affordances**	**Signifiers**
Access control	Login screen	Login form with username and password fields.
Easily identify the collaborators and their activities	Color-coding of user's comments	Each collaborator's name appears with different colors
Visual representations of annotations on the video timeline	Rectangle shaped markers with a pin on the time line	Color-coded markers appear when comments are added
Display annotations in context when comments are clicked	Clickable comments and markers	On mouseover, the comment gets a highlight
Ability to annotate a segment on a long video	A segment selector	A scrubber with two handles
Reply to a comment posted by another group member	**Threaded Commenting**	**A 'Reply' button at the end of each of comment**

3.3.3 The Video Collaboratory (Choreographer's Notebook v3)

The third version is the current version and (Figure 16) was released in Fall 2012. Some new features were added to the application such as comments preview and keyboard events. A few features were improved from the previous version. The comments were given a border color signifying different collaborators. The segment selector was improved with better handles. This version of the application was re-branded as the Video Collaboratory. The Video Collaboratory is a more general video-centered annotation system and is being used in domains other than dance. In the third version, the application was designed with a modular approach so that it could be used in various domains. The modular design approach allowed me to add and remove different functionalities required for different domains while keeping the

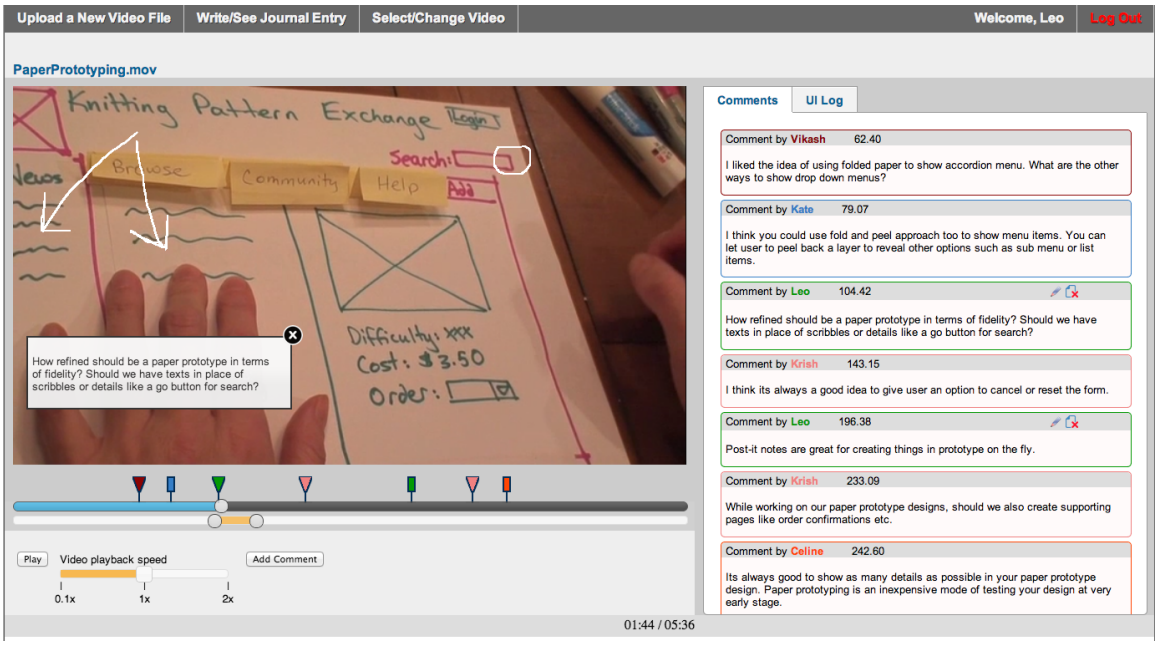

Figure 16: Current version of the application is the third version of the Choreographer's Notebook and is rebranded as the Video Collaboratory.

basic design the same across different domains. Later, threaded commenting was also added to the Video Collaboratory (Table 6).

3.4 User Interface

The web-based application is accessible through any Internet browser but currently it is best viewed in Google Chrome on Mac OS or Windows. When the web application is loaded, the user must first login (Figure: 17). After signing in, a user gets access to all the videos she has access to and can select one she wants to open. All the videos are arranged in a tree-like structure where each root node represents a project. When a project is clicked, it shows all the videos inside that project folder. The user can hover the cursor over any of the videos to get a preview of the video. Removing the cursor from the video thumbnail stops the video. The user can then click on any of the videos to load it to the main screen of the application (Figure: 18). The main

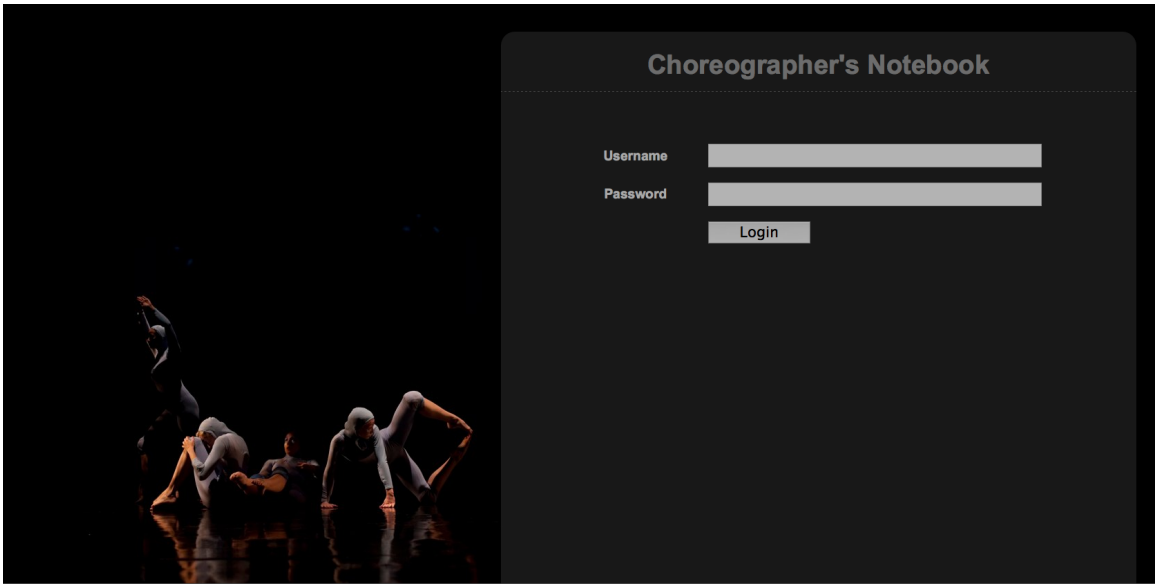

Figure 17: Login Screen of the current version of the application.

screen of the application is a two column layout. The first column contains the video panel and the second column contains the comments panel with all the comments posted on that video. The video controls are located in the first column below the video.

3.4.1 Major Features

Following are the design features that were implemented in the Video Collaboratory. Some of these features are available in other existing systems while some were specifically designed for video-centered collaboration are unique to the Video Collaboratory.

- Multi-modal annotations: Users can create timestamped text and sketch annotations. (Available in systems like viddler, DIVER, vidWiki)

- Access control: It is a private system and needs username and password to log in. Access control is important for collaboration as it restricts the availability

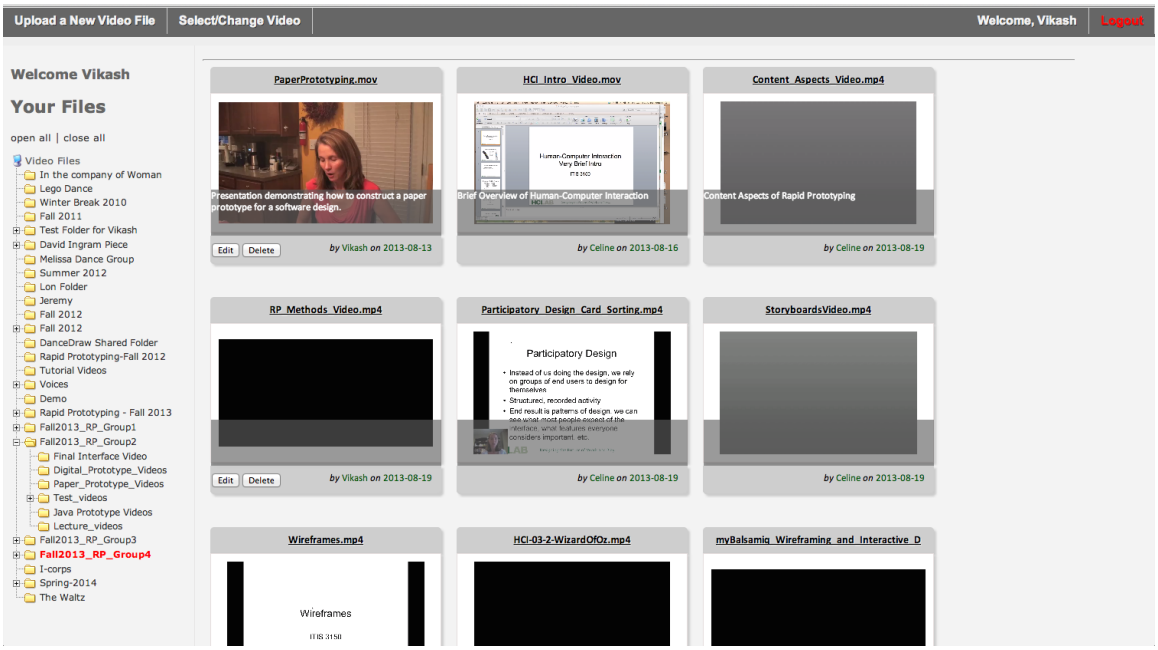

Figure 18: Selecting a video to open in the Video Collaboratory.

of videos and comments to only the collaborators.

- Color-coded annotations: Annotations are color-coded by individual user. The color-coding of comments allows collaborators to visually index comments by other members of the group. (Unique to the Video Collaboratory)

- Point and segment looped annotations: Both individual frames and video segments can be annotated. Point annotations are represented by rectangular markers on the timeline, while segment annotations are represented by inverted triangles. (Annotations on frame are available in vidWiki, viddler, DIVER and videoANT. However, annotations on a video segment is not present in any system)

- Contextual Loops: When a user clicks on a comment, the video automatically loops to display annotations repeatedly in context. The contextual loop was

important for collaboration in dance as it allowed dancers to understand the choreographer's comments in context. (Unique to the Video Collaboratory)

- Variable Playback Speed: Videos can be played at 2x normal speed and as slow as 1/10th normal speed. (Available in YouTube)

- Segment Selector: Users can interact with the segment selector to select or fine-tune a segment of video and to loop over that portion of video at any speed. (Available in Mangold Interact and Techsmith Morae)

- Flexible Navigation: Users can navigate the video using standard controls, the scrubber or clicking on annotations in the view at the right, or clicking on annotation markers on the timeline. (Available in videoANT, viddler and videoNot.es)

- Annotation Previews: Previews of annotations are visible simply by hovering over the annotation marker. (Unique to the Video Collaboratory)

- Keystroke Annotation: Users can create annotation shortcut keys for commonly used annotations. (Unique to the Video Collaboratory)

- Annotation Exports: Users can export timestamped annotations, along with screenshots, for use offline. (Available in MRAS, DIVER, videoANT)

3.5 User Interaction

The Video Collaboratory supports a wide array of interaction with video. In addition to supporting the default interactions for video such as play/pause toggle and

video scrubbing, it supports some novel interaction techniques that are specially designed for video-centered collaboration.

3.5.1 Inserting Comments

On the main screen, comments can be inserted on the video timeline in two different modalities by clicking the 'Add Comment' button. Once a user chooses to insert a comment, he can choose between text or sketch or a combination of both modalities. Sketch commenting currently supports multi-color sketching. The user has the option of clearing the canvas if they are not satisfied with their sketch. Once a comment is submitted, it is added to the list of comments in the comments panel on the right and a color-coded marker appears over the video timeline showing the position of the inserted comment in the video. The application also supports segmented comments which are explained in Section 3.4.3.

3.5.2 Exploring and Editing Comments

Each user's comments are color-coded, which helps in visual identification of comments while navigating. Posted comments can be explored two different ways. A user can click on any comment in the comments panel or on a colored marker on the video timeline. This seeks the video play-head to the appropriate part of the video and loops the playback between 2 seconds prior and 2 seconds after the comment point. Comments related to that marker are then overlaid on the main video. Comments overlaid on the video can be moved around so as to not obscure anything important. This feature delivers comments in context, which makes it easy for users to correlate comments with what is going on in the video. Users can view, edit or delete their

own comments, but can only view the comments of others.

3.5.3 Point and Segment Looped Annotations

The tool supports both point annotation and segment annotation. The point annotation is a comment on the video at a specific point (video frame) on the timeline and is represented by a rectangular marker. When a user navigates to a point comment, a four-second window around that part of the video is automatically looped over. The segment annotation is a comment on a segment of the video, where that segment can be any length, from a few seconds to a few minutes. As with point comments, when a user navigates to a segmented comment, the video loops, but in this case over the selected segment, rather than the default four-second window. Segmented comments are represented by markers in the shape of inverted triangles that are positioned at the start point of the segment. The application allows segmented annotations to overlap, as in each case the start time and end time of the segment is stored to the database.

3.5.4 Annotation Previews

When a video is used by many collaborators, the timeline could potentially become crowded with comments. If a user is looking to revisit a comment, or wants to get a quick sense of the types of comments found in one part of the video, they can hover their cursor over the comment markers. For both point and segment annotations, a preview of the comments is displayed just above the marker, see Figure 19. This helps the user browse and navigate without having to click on each individual annotation marker. Additionally, as a user hovers over a segment marker, the length of the

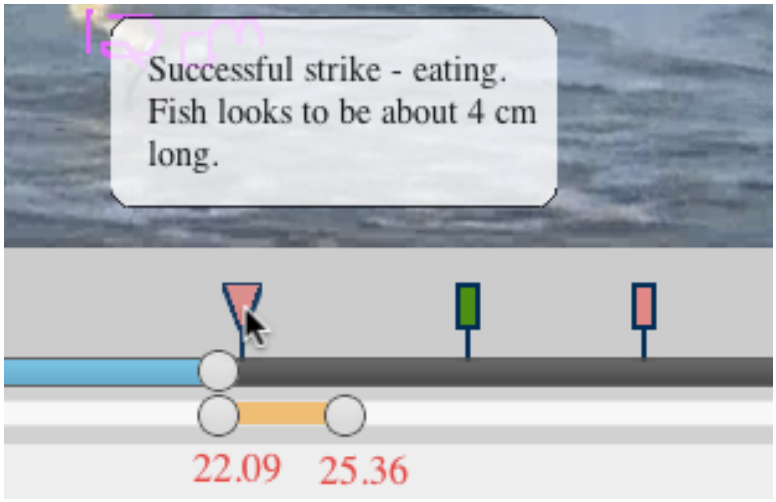

Figure 19: Hovering the cursor over an annotation marker displays a preview of the comment and the segment it applies to.

segment is highlighted on the Segment Selector as a preview.

3.5.5 Segment Selector

Many scenarios where videos are used as a means to an end require working with smaller segments of a larger video. Let us consider the following scenarios:

- A medical student is watching a complex radiology animation and keeps getting confused by two white blobs which appear suddenly on the video. He wants to ask his instructor about these specific blobs.

- A 7th grade student is watching an animation of a cellular process and doesn't clearly understand one part of the process, requiring him to watch that specific part of the video repeatedly, and then to ask his instructor about the process.

- A dancer is watching a recorded video of her last rehearsal where she learned several new and complicated movement phrases, which she needs to practice.

- An ornithologist is analyzing the behavior of a snowy egret in detail from a

video his student recorded and wants his colleagues to corroborate the analysis.

All of the above situations require a closer look at specific segments of a long video. However, the current video interaction techniques don't provide any mechanism that can facilitate selection and annotation of a segment in a long video. Current tools such as YouTube force the users to repeatedly scrub back and forth on the video to engage in annotation, analysis and study. The segment selection technique developed in Video Collaboratory aims to make such tasks less tedious and to enable collaboration within the context of small bits of a longer video.

I created and implemented a slider-control with two handles to allow a better control over video playback, called the Segment Selector (Figure: 20). The Segment Selector was developed using HTML5 and the jQuery UI slider library. The two handles on the Segment Selector represent the start point and the end point of a selected segment of the video. The default positions of the two handles are at the start (handle-1 at 0:00) and the end of the video (handle-2 at video end). The Segment Selector was designed as a separate control from the standard scrubber to provide a user the freedom to either scrub or loop a video.

The video playback in this version of the application follows the state of the slider-control. The position of the two handles of the Segment Selector determines the starting point and the end point of the video loop. When the segment is selected, the video playback will loop inside the segment created by the two handles.

There are multiple ways for the user to create and manipulate video selection segments.

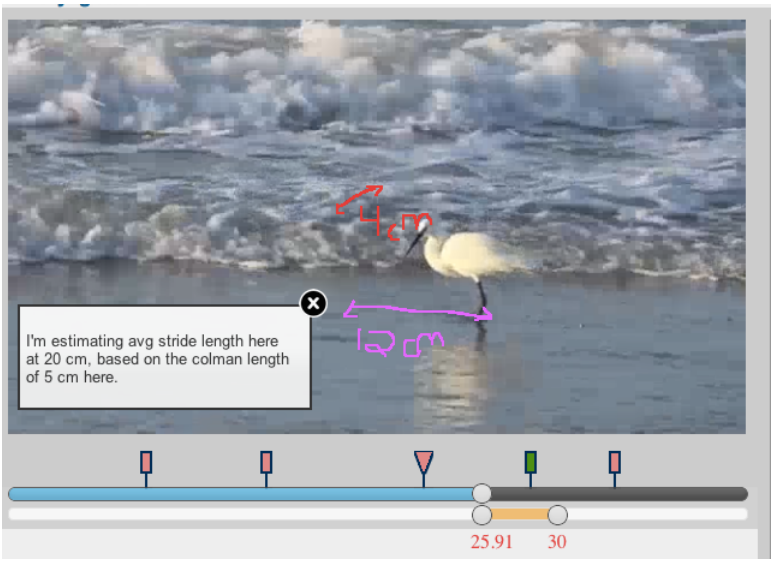

Figure 20: The yellow Segment Selector allows a user to annotate a selected segment with both sketch and text, and these annotations are then shown while the video loops over the segment.

- Manual segment selection: The user acquires one of the handles on the Segment Selector and drags. The user then repeats the process with the handle at the other end of the Segment Selector to specify the selection. The video updates during this interaction to help the user choose the start and end points.

- Auto segment creation: While the Segment Selector is in its default state (with handles at the start and end of the video timeline), double-clicking anywhere along the Segment Selector will automatically create a 4-second segment around the point clicked, with the segment beginning two seconds before and ending two seconds after the clicked frame. This can then be fine-tuned by adjusting either end of the segment.

- Segment sliding: When a segment has already been defined, the user can drag that segment along the Segment Selector to another portion of the video.

- Segment extension: If a user wants to make a selection longer, she can simply click outside the selection on the Segment Selector to extend it.

- Segment shortening: To make a selection shorter, a user simple clicks inside the segment. The portion between the click and the closest handle is trimmed.

- Segment release: If a user wants to dismiss a segment he can manually move the handles to the ends of the Segment Selector or simply double-click inside the segment to have this happen automatically.

3.6 Video Collaboratory - Use Case Scenarios

Consider a scenario where an ornithologist wants to annotate a segment of a long video of a Snowy Egret so that his remotely located colleague can send him feedback. He can specify a segment using handles and click on the 'Add Comment' button (Figure: 21). He can add a text and/or sketch comment and save it. The comment will be saved with the time stamp data of both the handles and the comment will be represented on the timeline in the form of a marker. When the ornithologist's colleague clicks on the marker representing the comment, the segment selector handles move to the beginning and end of the annotation segment and the video will start playing inside the loop created by the two handles. The text and sketch comment will be overlaid on the video. This allows the remote ornithologist to see the comment in the appropriate context thus enhancing understanding and preventing miscommunication.

Consider another scenario where a choreographer recorded a dance rehearsal. After uploading the video, she made some point annotations as well as some segmented

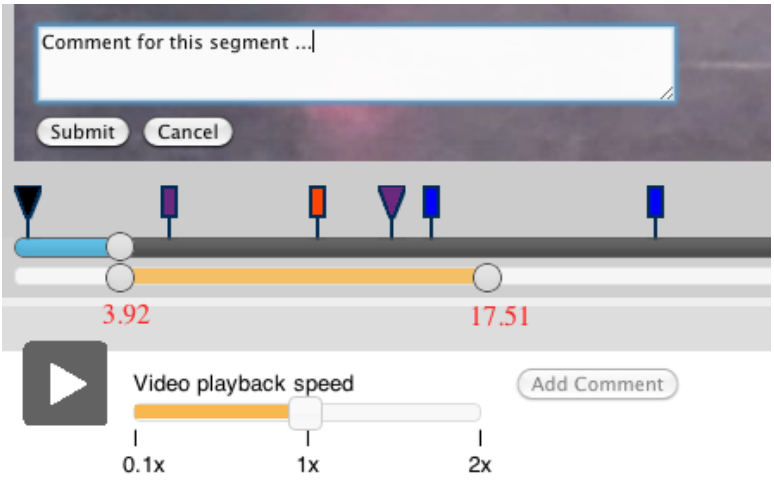

Figure 21: Adding a comment to a segment - The position of handles can be fine tuned to select the length of the segment.

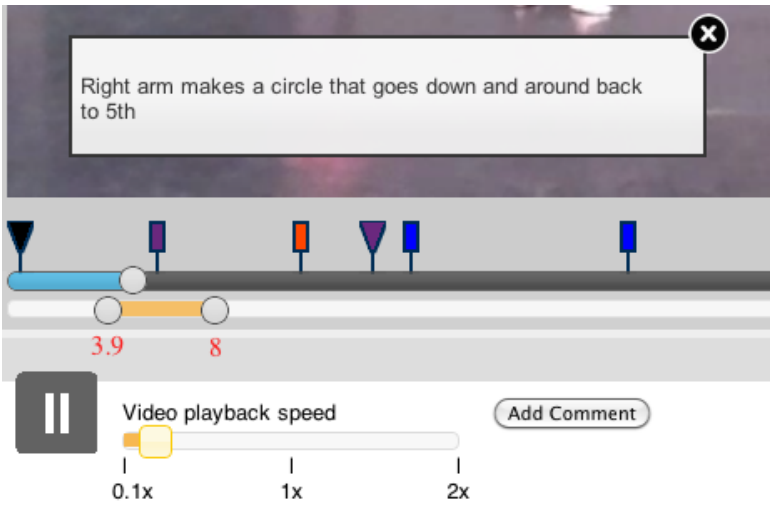

Figure 22: A four second segment is looped when a point annotation is clicked and can be viewed in very slow motion.

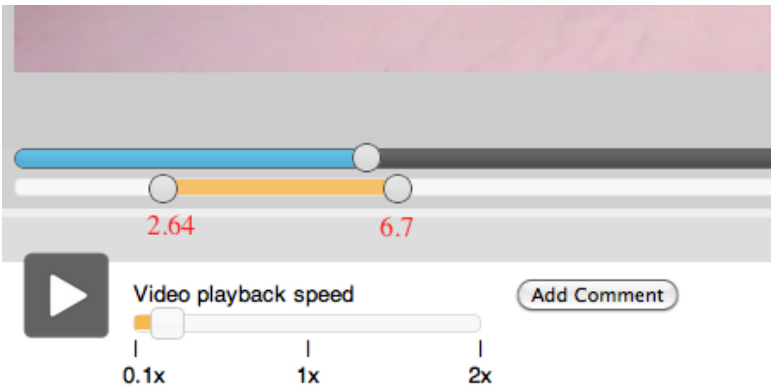

Figure 23: Creating a looping segment and selecting slow playback allows a user to repeatedly study and analyze a portion of interest on a video.

annotations critiquing the dancers' work. The dancers then log in to the application and interact with the annotations to see the comments made by the choreographer. When a rectangular marker (point annotation) is clicked in the application, the handles of the slider control adjust to create a segment of four seconds such that the start time is two seconds prior to the annotation and the end time is two seconds after the annotation. The video playback starts looping inside the four second segment and the text or sketch annotation is overlaid on the video, see Figure 22. This means that the dancer can see the comment in the context of the video, without having to scrub back to the time just before the comment. When a segmented annotation (inverted triangle marker) is clicked, the handles of the slider control adjust to create the segment which was specified when the annotation was created and, as with point annotations, the video automatically begins looping over the segment. With both point and segment annotations, the dancer can play the video at varying speeds. The video playback in ultra slow motion will give the user a chance to look at her dance movements in detail. Our playback controller allows users to adjust playback speed

between 1/10th of the normal speed and 2 times faster than the normal speed, see Figure 23.

3.7 Summary

In this chapter, I presented the design and development of a video-centered collaborative system that is designed for asynchronous collaboration. I discussed the interaction design of the system and its transformation from the first version to its current stage. I also discussed the various interaction techniques that I have developed and deployed in this application. These specialized interaction techniques are designed to allow users to discuss and analyze a video through annotation with text and sketch modality and perform video navigation in novel and unique ways. This chapter highlights the 'research through design' methodology that I have utilized in my research. Starting with a simple motivation to create a collaborative tool for choreographers and dancers, my research evolved into the study of how people do asynchronous collaboration through video and how to design tools for such collaborative activities. Through the iterative process of design development, I designed various affordances for collaboration in the Video Collaboratory. This iterative design process was also informed by various formative and summative evaluations. In the next two chapters, I present some of the evaluations of the system from its early adopters and current users.

CHAPTER 4: FORMATIVE EVALUATIONS

The Video Collaboratory tool (formerly the Choreographer's Notebook) has been extensively used at University of North Carolina at Charlotte (UNCC) by the Department of Dance for many semester-long student dance productions. It has also been used in the Department of Software and Information System (SIS) for teaching various courses. In this chapter, I present some of the design evaluations of the application and the feedback from dancers, choreographers, students, and instructors.

4.1 Dance

The Choreographer's Notebook was used in eight different dance productions as well as in the teaching of dance choreography. (See Table 7). The choreographers, dancers and other users have been very enthusiastic about The Choreographer's Notebook. In this section I present the initial study with the choreographers and dancers and findings from their usage of the tool. The goal of this study was to find the choreographers' and dancers' perception of the useful aspects of the Video Collaboratory.

4.1.1 Participants

Four different choreographers and more than 50 different dancers at UNC Charlotte have used this application. All the dancers were undergraduate students in the Department of Dance at UNC Charlotte. Choreographer1 and Choreographer4 are

Table 7: Choreographer's Notebook usage in the Department of Dance

Name of Dance	**Choreographer(s)**	**No. of Dancers**	**Length of Dance**	**Semester and Year**
In the Company of Women	Choreographer 1	5	22 min	Fall 2010
An Instance Of...	Choreographer 1	3	6 min	Fall 2010
The Angled Angels Assembly	Choreographer 1 & Choreographer 2	7	11 min	Spring 2011
Heavy Recursion	Choreographer 2	5	15 min	Fall 2011
Bodies-Antibodies	Choreographer 2	5	12 min	Spring 2012
A Mischief of mus Musculus	Choreographer 1	5	9 min	Spring 2012
Giselle	Choreographer 3	10	12 min	Spring 2012
Voices	Choreographer 1	4	11 min	Spring 2013
The Waltz	Choreographer 1	4	12 min	Spring 2014
Choreography I teaching	Choreographer 4	4		Fall 2014

Dance professors while Choreographer2 was a student in the Department of Dance. Choreographer3 was a visiting choreographer for one semester. In all cases, the participants were given a demonstration of the application prior to their first use.

4.1.2 Materials

The materials used in the study included the Choreographer's Notebook tool, an interview questionnaire (Appendix H) and questions for focus group (Appendix I).

4.1.3 Procedure

All the participants participated in one of the listed dance productions (See Table 7). They were given a demonstration of the application prior to their first use. The choreographers or dancers recorded the rehearsals and uploaded the videos to the system. The choreographers and dancers then reviewed their movements on the application, sharing comments and thoughts. At the end of each of the dance productions,

the choreographers and dancers were interviewed and sometimes participated in a focus group study. They were asked about their experiences while using the tool in the dance production process. They were also asked about the effects of the application on the collaborative creative process and the aesthetic and technical development of the physical dancing.

4.1.4 Data Collection

Data was collected through interviews, focus groups and interaction logs.

- Focus group - Data was collected from the dancers through 4 different focus groups. They were asked to share their experience while working with the tool. An independent researcher conducted the focus groups to allow participants to freely criticize the system.

- Interviews - The choreographers were interviewed at the end of dance productions. They were asked about their experiences with the tool. Generally, an independent researcher conducted the interviews. In some cases, the choreographers were sent a questionnaire via email which they completed and returned.

- Interaction log - Since it was also important to understand how the application was actually used in practice [61]. I implemented an instrumentation module in the application to track the usage pattern of different types of users. I categorized users into two different groups called 'the dancers' and 'the choreographers'. The system recorded total time spent by different users in each session as well as their usage of different features in the application. The system also

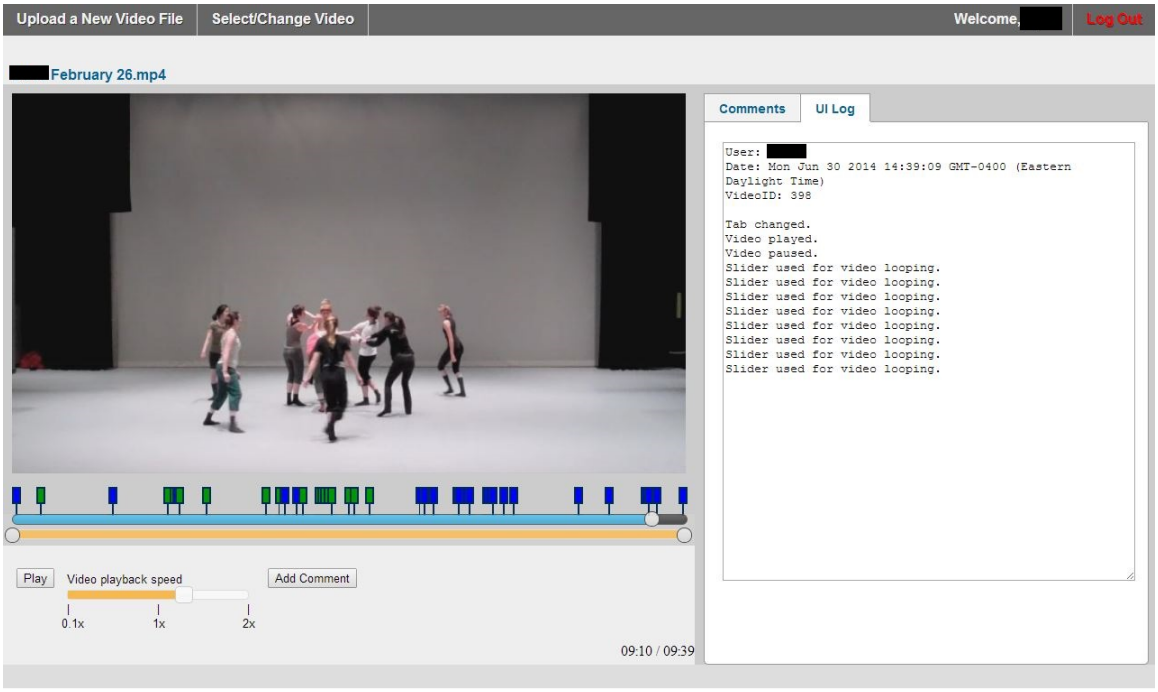

Figure 24: The system logs the commands used and the high-level user interface events.

tracked the commands used, high-level user interface events, and the time of day when the application was used (see Figure 24). The log data provided insights into the usage behavior of different groups.

4.1.5 Analysis

The data collected from the interviews and the focus groups was transcribed by the independent researcher who conducted these interviews and focus groups. This data was then analyzed for recurring themes using the method of thematic analysis [9]. In the early stages of the research, I was most interested in finding the users' likes and dislikes about the various design features and affordances in the application. I analyzed the interaction logs to count the number of logins by different users, the number of comments posted by each user and the amount of time each user spent

interacting with the application.

4.1.6 Results

The usage patterns of the choreographers and the dancers (stakeholders) were very different. While the choreographers spent significant time critically reviewing recorded video, frequently making comments on dancers' positions and movements, the dancers spent most of their time navigating through posted comments. The choreographers spent significantly more time in one sitting than the dancers. For the first six dance productions (Table 7), Choreographer1 logged into the system three times per week and spent an average of 62 minutes in each session and Choreographer2 spent about 40 minutes per session three times per week. The dancers spent between 8 to 26 minutes per sitting and logged into the system multiple times during a week. The rehearsals were generally scheduled 2-3 times a week and the choreographers made it a point to post their comments before noon the day after each rehearsal in order to provide enough time for the dancers to go through the posted comments before the next rehearsal. The dancers used the application at various times of the day. Some of the dancers preferred to go through an annotated video late at night while others used the application to review the last rehearsal an hour or two before the next rehearsal. Though the application was designed to be fairly democratic in nature, allowing everyone to post comments, I noticed that most of the comments came from the choreographers while the dancers used the commenting feature mainly to ask questions about their own movements. While using the Choreographer's Notebook, the choreographers mostly used text commenting to communicate their remarks to the

dancers in comparison to sketching on the video frame which was used less frequently.

The focus groups and interviews provided qualitative feedback. All stakeholders found the Choreographer's Notebook very useful and said that it helped them in the choreographic learning and cleaning process. They used it often in their leisure time as well as just before coming to the rehearsal. One dancer said that, *"It was actually nice that you could integrate a dance rehearsal into the rest of your life. It became part of my routine, my computer routine, like Gmail, school email, Facebook and Choreographer's Notebook."* Awareness of the fact that their rehearsal was being recorded helped them to remain in what the choreographer referred to as *"performance mode".* One dancer noted that, *"... it made me feel more in my character and in my story."* One choreographer liked the ability to watch a rehearsal video whenever she needed to. She said, *"... I was kind of multi-tasking, drinking morning coffee and reading the Choreographer's Notebook."* She also liked the ability to jump from scene to scene while annotating, which she was unable to do with her VCR. While video players are old technology, I note that this older technology is still common in the under-funded arts world. Even where choreographers may be using DVDs, most DVD players do not allow easy or detailed navigation through video and certainly do not provide any annotation functionality.

All choreographers and dancers felt that using the Choreographer's Notebook allowed them to devote more time to actual dancing in the dance studio and that this had positive impacts on the quality of the final performance. Sometimes they also projected the commented video during rehearsal and used it as a rehearsal guide. Some of the dancers asked for permission to use the Choreographer's Notebook for

their own work in their choreography classes. The two choreographers from the Dance.Draw (Choreographer1 and Choreographer2) project continued to use the tool in other productions, even after the project ended. During performance week of one production, the choreographer used the tool to celebrate the work of the dancers by posting many positive comments about each night's performance. The choreographer noted that there is never time for standard video review during performance week, but the Choreographer's Notebook allowed this.

Choreographers also noted that filming rehearsals and putting them on the Choreographer's Notebook made dancers step up their performance by dancing at 100% during rehearsals. This was remarkable because dancing at 100% is an important quality for professional dancers and important to foster in students. For example, dancers made mistakes work; they did not stop and request to start again. Instead, they dealt with the mistake to the best of their ability. This is a critical skill that is important to teach and the application provided an excellent platform for promoting that.

In the Spring of 2011, a guest lighting designer also used the tool to view the production from outside of the country, demonstrating the use of the tool to enable remote, asynchronous collaboration. The lighting designer used the tool to familiarize himself with the dance, which helped him collaborate with the choreographers to plan lighting effects in advance of actually visiting the university.

4.1.7 Discussion

In a conventional dance rehearsal process, most activities related to dance correction and creative editing take place in the dance studio. Dancers learn new material based on the directions of the choreographer. Choreographers differ in their use of filming a rehearsal but generally opt not to make any video recordings available to dancers. Instead, they prefer to watch the dancers in real-time, while making notes in a notebook. Comments, both general and personal, are communicated to the dancers. Inside the studio, dancers receive various forms of feedback from the choreographer and from their peers: cognitive and kinesthetic feedback from the way their body responds to their movements; visual feedback from their peripheral vision watching themselves in the mirrored wall; and often visual feedback from watching peers by their side. When rehearsal is over, the choreographer and dancers leave the studio. Outside the studio, the choreographer reflects and makes mental or written notes for the next scheduled rehearsal. The dancers practice, either physically or mentally, and they go over any written notes taken during the last rehearsal. Dancers use all of these feedback sources to understand the necessary adjustments to refine their movements.

The introduction of the Choreographer's Notebook to the rehearsal process provides another representation of feedback to the choreographer and the dancers. In the studio, the dancers often end the rehearsal with a full run-through of the material that has been learned so far. This material is filmed, and the video is uploaded to the Choreographer's Notebook. Outside the studio, the choreographer watches the recorded rehearsal video and posts comments directed to individuals or groups of

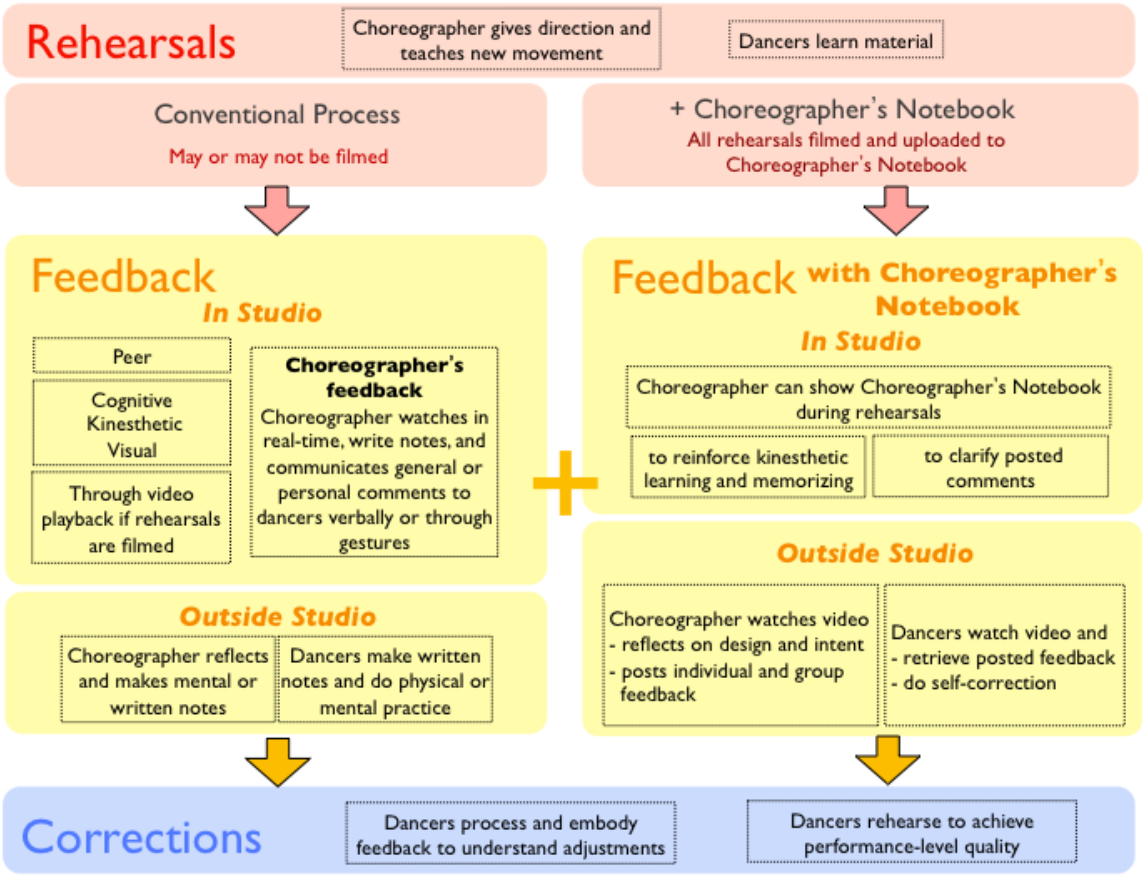

Figure 25: I visualize the conventional rehearsal process (left) and show how it evolved when the Choreographer's Notebook is introduced (left + right).

dancers. The availability of the rehearsal video helps the choreographer to reflect in a more detailed way on the overall design and intent of the piece. Dancers watch the rehearsal video and retrieve comments posted by the choreographer. Although it is not possible to fully practice the corrected movements in the absence of the studio space and specialized floors, dancers make mental notes about the corrected movements, visualize these movements, and come to the next rehearsal as prepared as possible, given practice space and embodiment constraints. During the next rehearsal, the choreographer can show the Choreographer's Notebook in the studio to clarify the posted comments. Figure 25 shows a model that was created with the choreographers as a part of the project. It visualizes the conventional rehearsal process and how the rehearsal process evolved with the introduction of the Choreographer's Notebook.

The use of the Choreographer's Notebook in the rehearsal process adds an additional layer of feedback to the existing conventional rehearsal process: video and annotated comments. These representations benefit choreographers by making choreographic cleaning and creative editing available outside of the studio. The access to rehearsal video and commentary encourages and enables the dancers to prepare for the next rehearsal.

Novel interaction techniques and various other features in the Choreographer's Notebook allowed choreographers and dancers to adapt to the new model of dance rehearsal process. Novel features like video navigation by clicking on comments/markers, color coded representation of comments on timeline for easy reference, overlaid text and sketch comments on video to minimize cognitive load, and the ability to annotate a segment of the video made the collaborative process of choreography more

personal. One of the choreographers described the Choreographer's Notebook as providing dancers with the *"personal attention and coaching as if it was a solo."* She further explained that she doesn't have enough studio time to give individual coaching in real-time to each dancer, especially when there are 6 dancers in one piece. Through the Choreographer's Notebook, individual coaching is more efficient: it can take place outside of the studio, while she is *"sitting in my jammies with my coffee."*

Similar to Trist's review of the introduction of technology into various workplaces [63], it seemed likely that the Choreographer's Notebook would increase the workload associated with the dance production. Both the choreographers and the dancers faced new socio-technical tradeoffs. The choreographers did find the provision of online corrections useful but at the same time they sometimes found that entering comments was time consuming. Similarly, while dancers agreed that using the Choreographer's Notebook required more time, they also appreciated the 'always available' aspect of the tool. On one hand they had more homework to do, but at the same time they were getting more individual attention from choreographers through the Choreographer's Notebook.

4.2 Education

In the education domain, the system has been used for teaching, critiquing and as a tool for active learning. It has been used in five courses over five semesters (See Table 8) and has been used by more than 270 students. In the Fall 2012 semester, students in the Rapid Prototyping course in the Department of Software and Information Systems used the application (v3) to upload videos of their Digital Prototype

assignment. The assignment required students to record a video of their prototype and upload it to the Video Collaboratory. They were then asked to log into the application and critique their colleagues' videos. In the Spring 2013 semester, two different classes used this application. The students in the Rapid Prototyping course used the application to upload videos of three separate assignments. For each assignment, each student created a video demonstrating their design prototype and then uploaded the video to the system to get feedback and critiques from other students and the instructor, see Figure 27. The students in the Principles of Human-Computer Interaction (HCI) course used the system to critique other students' final projects.

All of these courses were taught as 'flipped' classes. The flipped classroom (aka inverted classroom) approach requires students to come to the class after viewing the required materials so that they can engage in learning activities [30, 19, 35]. Learning materials such as lectures and presentations are delivered to students through an alternate medium such as podcasts or video-on-demand services [30, 62]. Students can view these materials on their own time prior to coming to the class, allowing the use of class time for active learning. In-class activities include quizzes, collaborative learning exercises, and working in a group towards a project goal. Various strategies for flipped classroom learning in Computer Science education are described in Maher et al [37].

4.2.1 Participants

The students in the Rapid Prototyping course used the system in the Fall 2012 and the Fall 2013 semesters. 40 students enrolled in the class were divided into four

Table 8: Video Collaboratory usage in computing courses

Course	**Usage**	**No. of Students**	**Semester and Year**
Rapid Prototyping and Interface Building	Peer review of class projects & video lecture annotation	40	Fall 2012
Human Computer Interaction	Peer review of class projects	15	Spring 2013
Rapid Prototyping and Interface Building	Peer review of class projects & video lecture annotation	45	Fall 2013
Human Computer Interaction	Video lecture annotation	50	Fall 2014
Human Computer Interaction	Video lecture annotation	121	Spring 2015

different groups. Four separate group folders were created in the application and each student was granted access to one of the four folders. Each folder contained lecture videos that students had to watch prior to class.

In the Fall 2014 semester, students in the Human-Computer Interaction course used the system. 50 students in the class were divided in 8 groups.

In the Spring 2015 semester, there were 121 students enrolled in the Human-Computer Interaction class - 62 graduate students and 59 undergraduate students. The students were divided into 14 groups. The groups had a minimum of 6 and a maximum of 9 students.

4.2.2 Materials

The materials used in the study included the Video Collaboratory tool and online surveys (Appendix F and Appendix J).

4.2.3 Procedure

In the Fall 2012 and the Fall 2013 semesters, the students used the system in two different ways. First, the students used the tool to watch the course lectures uploaded by the instructor. The instructor also added questions and/or prompts at different points on the timeline of the video and asked the students to respond through comments. Second, the tool was used by the class in their course assignments. There were four different assignments in the semester and each assignment required each student to submit a video of his/her prototype. All students were asked to create a video recording to demonstrate their design prototypes. All students in each group then uploaded their videos to one of the assignment subfolders. Each student in the group was then asked to critique three videos in their group. The instructor also added her critique to the student projects. At the end of the semester, I sent an email to all the students with a link to the survey (Appendix J). Two reminder emails were sent in the following four days.

In the Fall 2014 semester, each group had access to the same set of weekly lectures that they were asked to annotate as a group. Each student was asked to post 2 questions on each video assigned as study material for each week. Sometimes questions posted by students were aggregated with some of the questions incorporated as part of a weekly quiz. The students were graded on the number of annotations and number of questions they posted on the Video Collaboratory throughout the semester.

In the Spring 2015 semester, each group was assigned to watch the same weekly lectures and therefore shared their comments and annotations through the Video

Collaboratory. Each group had their own folder on the Video Collaboratory with their own private copy of the lecture videos. Each student was required to enter 3 comments on the assigned lecture each week to identify 3 multiple choice questions as the significant content of the video lecture. Each group was then asked to reach a consensus on two questions to be sent to course TAs prior to the start of the class each week. These two questions from each of the 14 groups formed the question pool for that week's clicker quiz class activity. The TAs then selected 4-6 questions from the question pool and other resources to create that week's clicker quiz. Students were motivated to produce the multiple choice questions in 3 ways. First, groups with the best choice of questions during the semester were given extra credit. Second, each individual student had to participate in a clicker quiz with questions partly chosen from among the aggregated questions submitted by the groups each week. These quizzes were graded as a part of the students' final grade and groups with the best choice of questions had the chance to answer questions designed by their own group or a similar question in the clicker quiz. Third, the annotations and comments from the entire class were made available to the students in the form of a word document as a study guide for the mid-term exam. A flipped classroom survey was conducted twice during this semester: first before the mid-term and then again before the final exam. The survey included three questions related to the use of the Video Collaboratory in the HCI course (Appendix F).

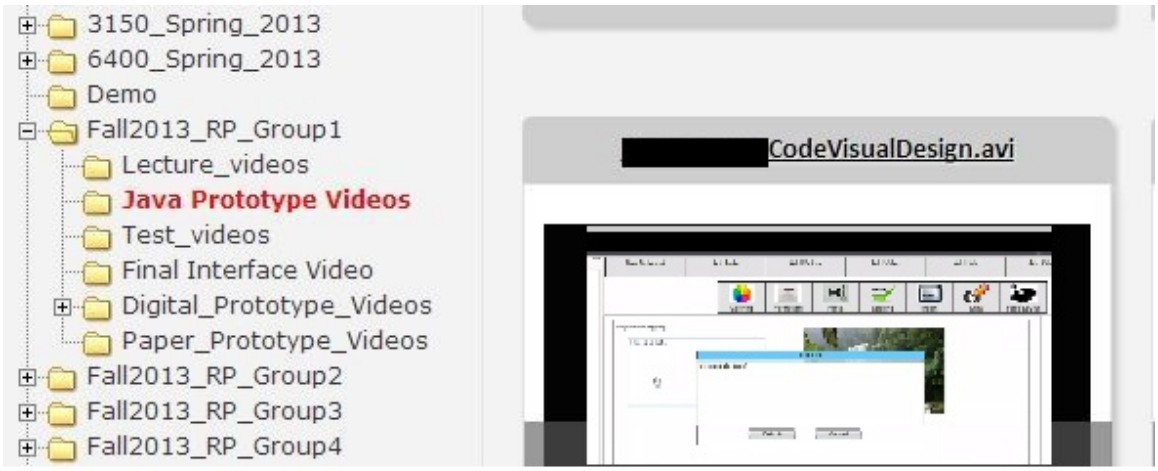

Figure 26: The image showing the folder structure used for teaching the Rapid Prototyping course in the Fall 2013 semester.

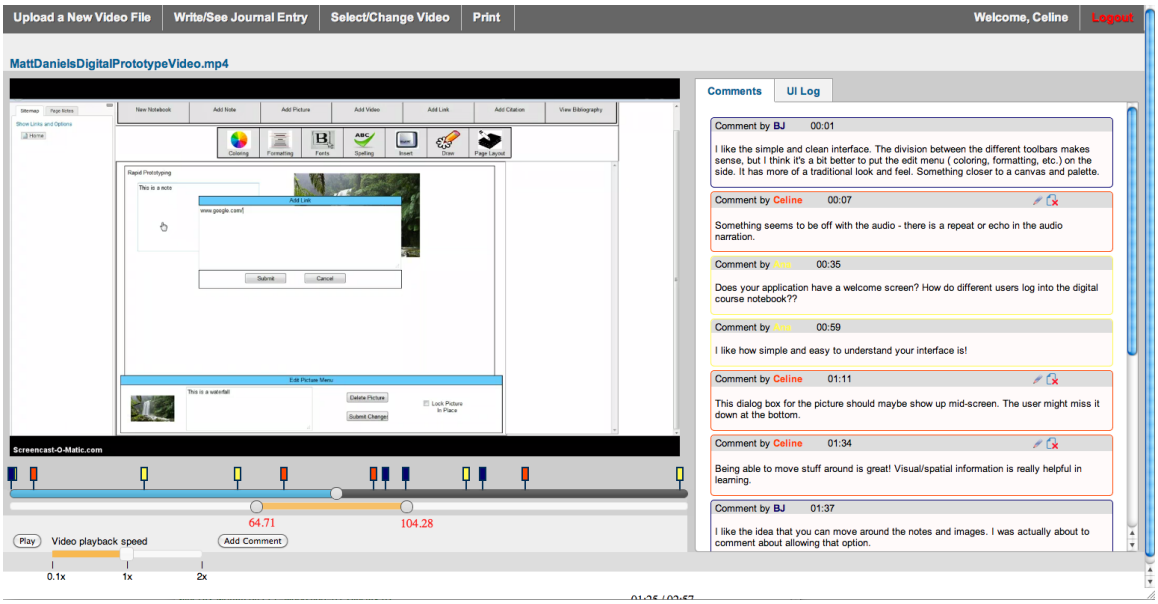

Figure 27: The system showing a prototype video uploaded by a student and color coded comments from her classmates.

4.2.4 Data Collection

Data was collected through interviews, surveys and interaction logs.

- Interviews - Some of the students were interviewed at the end of the semester. They were asked about their experience with the Video Collaboratory application.

- Surveys - A survey was deployed to collect data about students' perception about their usage of the Video Collaboratory. A script of the survey is attached as Appendix F. In the Fall 2014 and Spring 2015 semesters, a flipped classroom survey was conducted twice during each semester: first before the mid-term and then again before the final exam. The survey included three questions related to their use of the Video Collaboratory in the HCI course.

- Interaction logs - The log data provided insights into the usage behavior of different students and groups.

4.2.5 Results

At the end of each semester all the students who used the system in their coursework were asked to complete an online survey to answer questions about their usage of the system. I asked them how they used the tool, what they liked/disliked about it and whether they had any suggestions for improvement. The survey was anonymous and there was no compensation provided to participate in the survey. The results presented here represent use of the Video Collaboratory from the Fall 2012 and the Spring 2013 semesters. 14 students across two semesters participated in the survey.

Table 9: Spring 2015 HCI course survey results - Mean and median of all responses on a 7 point Likert scale

	How helpful were the online videos for learning HCI methods?	**Other students helped me to understand the right answers while we were discussing quiz questions.**	**I helped other students to understand the right answers while we were discussing quiz questions.**
Mid-term			
Mean	4.35	4.73	5.01
Median	4	5	5
Final			
Mean	4.03	4.44	4.68
Median	4	4	4

Some of the students had difficulty uploading their videos to the system due to technical issues of unsupported video codecs and limited support of video formats. Out of 14 respondents, 78% of students agreed that the use of the Video Collaboratory to critique other student's prototypes helped them to understand what makes a good prototype, while 85% of students agreed that viewing other's critique comments in the context of their own video helped them to understand how to improve their own prototype. 13 out of 14 responders (92%) agreed that having access to their classmates' projects helped them to understand the caliber of work that is expected in the class. Overall, 72% of students agreed that the use of the Video Collaboratory in the classroom enhanced their learning experience and they would use the system again when working with video.

In the Spring 2015 semester, 110 students participated in the mid-term 'flipped classroom' survey and 98 students completed the same survey again before the final

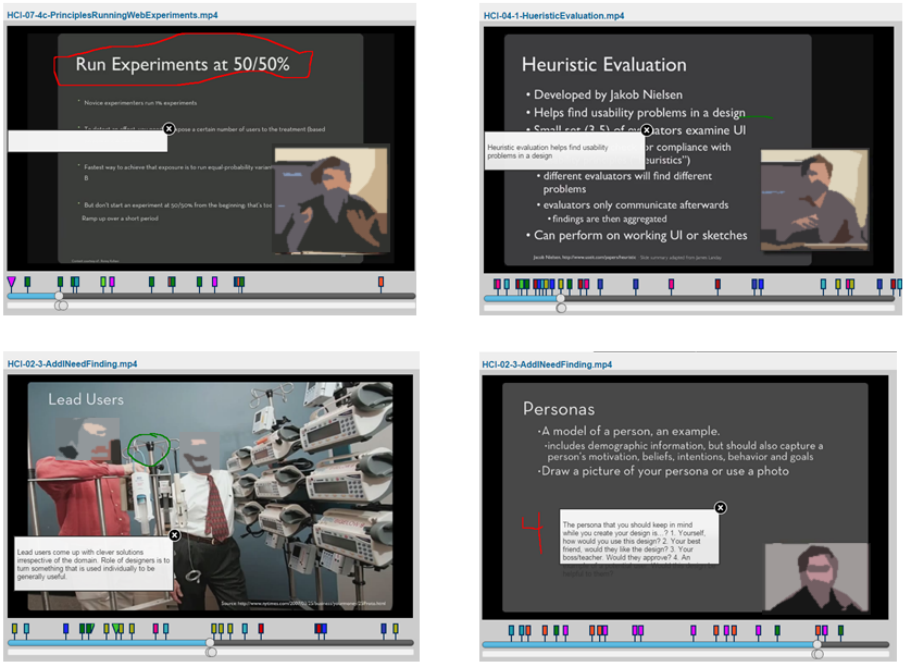

Figure 28: Examples of sketching on lecture videos by students

exam. The survey results (shown in Table 9) were encouraging. Students generally liked watching the videos on the Video Collaboratory. They also liked the collaborative nature of the application that allowed them to prepare for the quizzes by mutually helping each other on the quiz questions. In the Video Collaboratory the students posted questions for each other and let other members of the group answer the questions. Many students used the Video Collaboratory application as a tool for creating references on the video for self-study. Some students used sketching to write answers of self-created quiz questions on the video as shown in Figure 28.

The analysis of the data on the number of comments on video lectures shows interesting patterns in students' use of the VC, and is an indicator of student engagement in the lecture material. Figure 29 shows the total number of comments in VC across the semester, indicating weeks when students were more engaged with the lecture ma-

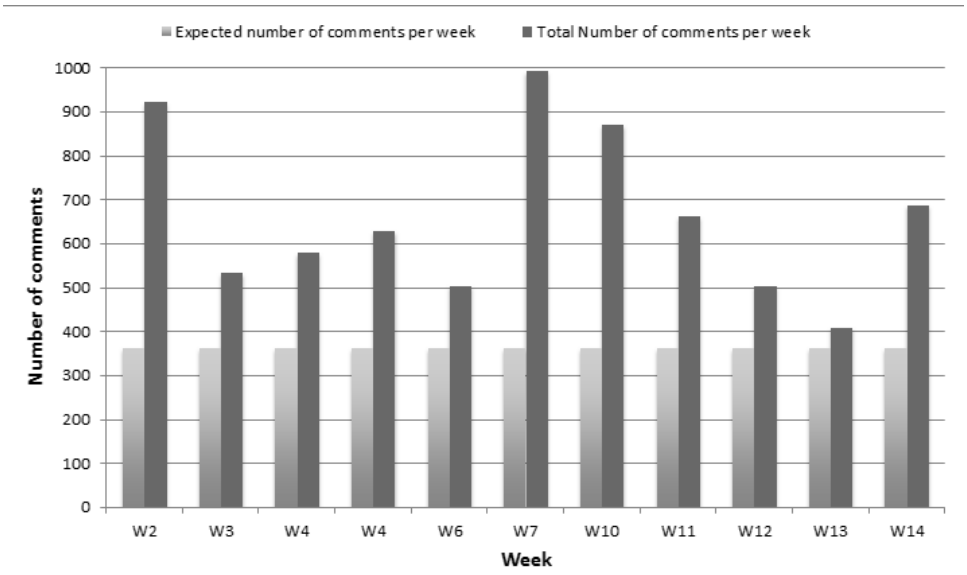

Figure 29: Total number of comments students posted on VC each week compared with the expected number by the assignment

terial. While there are differences in the amount of work done by different groups, the distribution of the number of comments is similar across groups during the semester.

An indication of collaborative communication is the number of times the groups used the reply option. Figure 31 shows how many groups used the reply option each week. More groups used VC as a collaborative communication media at the end of the semester compared with the start of the semester. While in the first week of the clicker questions two groups were using the reply feature on the VC for discussion around the activity, after week 7, 8 groups had used that feature for discussion around the assignment. These groups did more than just enter their quiz questions on the videos, and used the VC communication features (commenting and replying) for choosing the group's best questions for submission each week. Figure 30 shows a few examples of these uses by some of the groups.

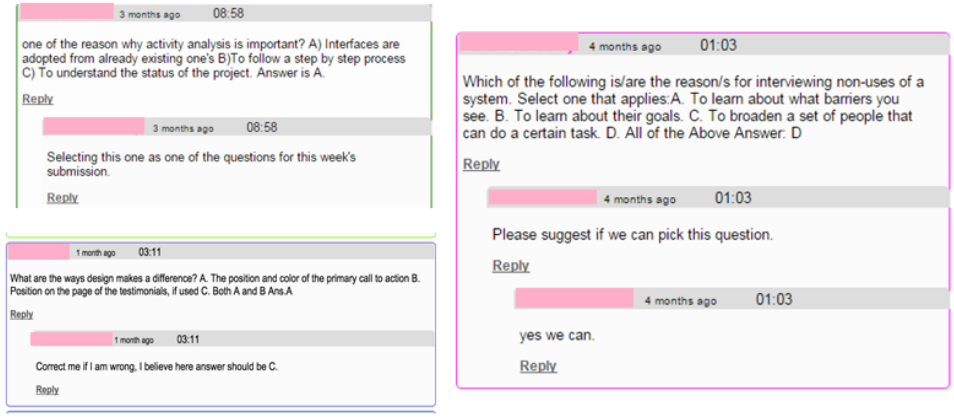

Figure 30: Examples of discussions among students about weekly quiz questions

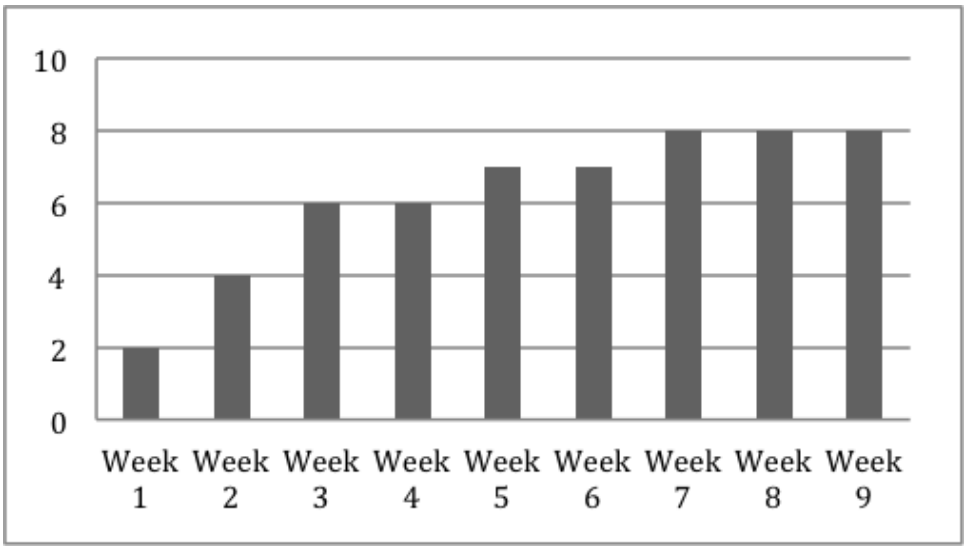

Figure 31: Number of groups using VC reply option for discussion around the assignment each week

4.2.6 Discussion

In education domain with the HCI classes, the introduction of the Video Collaboratory to discuss quiz questions provides students an asynchronous way to collaborate with their team members. Students noted that it was difficult for them to schedule a weekly face-to-face meeting as a group. In the beginning of the semester the groups were using other communication channels such as email for exchanging thoughts about the group weekly assignment, but by the end of the semester more and more groups started relying on the commenting and reply features of VC for conversation around the quiz questions, consensus and decision making, and clarifying misunderstandings. Novel interaction features such as sketching on the video frame allowed students to annotate and mark videos for self-study and for discussions with their team members.

4.3 Summary

In this chapter, I presented the formative evaluation of the Video Collaboratory's usage in education and performing arts domains. The design goal of the Video Collaboratory was to create a private video-centered platform that could support collaboration around video content. The introduction of the Video Collaboratory tool in the dance production process was effective in creating more time for actual dance rehearsals in the studio space. A part of the collaboration among the choreographers and dancers moved outside the studio and took place in this online platform. The choreographers suggested that design affordances in the tool helped them to utilize more of the studio time for dancing, and provided more detailed individual coaching outside the studio.

The affordances for collaboration such as private login, color-coding and contextualization of comments with respect to the video were liked both by the choreographers and the dancers. The Video Collaboratory did not support threaded commenting at the time of these evaluations. Threaded commenting is an important affordance for collaboration and many users of the tool asked for this feature. They also requested a more stream-lined video upload module for the application.

These studies have helped me understand the different ways that asynchronous, web-based video collaboration systems can help users who work together in groups. It has also given me insights into how people use these systems and their expectations. The interviews and focus group study of dancers and choreographers further helped me identify the socio-technical impact of the Video Collaboratory system on the dance production process. The analysis of surveys and interaction logs of students helped me understand different ways in which students use the video collaboration tool.

CHAPTER 5: USER STUDY

5.1 Introduction

Limited affordances in the popular video distribution systems such as YouTube make them a poor choice for fine-grained interaction for video-centered collaboration. People still use these systems for their collaborative needs because of their familiarity with these tools. They overcome the collaborative constraints in these systems by using various other channels such as Google docs or email to facilitate their discussions. These communications become disjointed and often create confusion, resulting in wasted time and increased errors. I posit that the Video Collaboratory tool, which has been designed with specific affordances for collaboration such as a login screen to make the collaboration private for group members, representation of collaborators' comments on timeline, color-coding of group members' comments, and navigation of video through group members' comments, is more suited for a collaborative task around video than commonly used tools like YouTube.

In this user study, I compared the efficiency, immersiveness and power of the Video Collaboratory tool with YouTube for a group based asynchronous task. I measured participant engagement, and the amount and quality of discussion taking place during the process of task completion. I chose YouTube for comparison as most people are familiar with its interface and it is widely used for collaborative tasks with the help

of separate channels like email and text documents. A similar collaborative task was performed by a set of users on YouTube and the Video Collaboratory. The participants in this study, conducted in November 2014, were recruited from the graduate HCI course at UNC Charlotte. I wanted to address following research questions through this study:

- How do various affordances affect the efficiency of contextualization when asynchronously discussing something in a video?
- How is immersiveness of video-centered collaboration affected by using separated vs. integrated discussion channels?
- How do interaction affordances affect the power (amount of work that can be done per unit of time) in video-centered group collaboration?

In order to quantify and measure the efficiency of contextualization, immersiveness and power of the tools, I have defined some variables and metrics that I have discussed later in this chapter. I have defined these metrics because I did not come across any other research that has measured these data before.

5.2 Collaboration affordances in the Video Collaboratory and YouTube

In Chapter 3, I presented the Video Collaboratory application that helps groups to collaborate asynchronously around a video using multi-modal annotations. The Video Collaboratory was designed with various affordances for collaboration such as a login screen to make the collaboration private for group members, representation of collaborators' comments on the timeline, color-coding of group members' comments,

and navigation of video through group members' comments to facilitate asynchronous group collaboration around video documents. YouTube lacks many of these design features and affordances to support collaboration. YouTube doesn't support forming a private group with access control, though a user can make videos private by changing settings of individual videos. In YouTube, comments are not automatically anchored to the video. However, a user can explicitly specify time stamp in comments which makes it more tedious to specify context and could lead to less discussion. Clicking on these explicit time stamps takes the user to that time on the video, however, the video does not loop around that context to help one user understand the context of another user's comment. YouTube does not support color-coding for different commentators on a video. Threaded commenting is another affordance that facilitates collaboration among users and YouTube supports threaded commenting. I added threaded commenting to the Video Collaboratory, which allows users to post comments directly in response to other comments.

5.3 Hypotheses

5.3.1 Hypothesis 1

I hypothesize that the design affordances in the Video Collaboratory will reduce the amount of explicit contextualization needed while collaborating on a video.

$$H_1 : EC_{VCGroups} < EC_{YouTubeGroups}$$

In video-centered collaboration, it is important to note the context of discussion. This is done by specifying a temporal or spatial identifier for a scene or frame of a

video. When a user says something like "When the door opens and the bald man walks in", the user is referring to context with a temporal identifier. Similarly in a video frame, if a user says "the dancer on the right", he is referring to spatial context in a video.

In order to quantify these concepts, I define the following variables:

Total Words = Total words in a discussion log on a single video.

Context-specifying Words = # of words in the discussion log specifying context such as "At 1.05 minutes in video,", or " the athlete on the left."

$$Explicit\ Contextualization(EC) = \frac{\#\ \text{Context-specifying Words}}{\#\ \text{Total Words}} \tag{1}$$

5.3.2 Hypothesis 2

I hypothesize that the design affordances in the Video Collaboratory will lead to users making comments mostly in the Video Collaboratory software and not using the Google Docs for comments. This will mean fewer context switches in the VC condition.

$$H_2 : ContextSwitches_{VCGroups} < ContextSwitches_{YouTubeGroups}$$

Fewer context switches will make the overall experience more immersive in the case of the Video Collaboratory. People use YouTube with other supporting channels such as text documents to collaborate around video. This leads to frequent context

switching between the video and the text document to make sense of the discussion about the video.

5.3.3 Hypothesis 3

I hypothesize that the design affordances in the Video Collaboratory make it a more powerful tool because better affordances may lead to more activity around the video, more time spent on the video and more discussion about the video.

$$H_3 : P_{VCGroups} > P_{YouTubeGroups}$$

Better navigation and annotation affordances and fewer context switches should allow people to do more work in less time in the Video Collaboratory. A tool is more powerful if more work can be done in less time.

Opinion Words = # of words in the discussion log other than the context-specifying words. These words facilitate the discussion towards the task goal.

Total Time= Total time taken to complete the task. This will be actual time spent on the task by the group discussing the video.

No. of Users = No. of users in each group who participated in the discussion.

$$Power(P) = \frac{\#\ \text{Opinion}\ \ \text{Words}}{(\#\ \text{Total}\ \ \text{Time})\ *\ (\text{No.}\ \ \text{of}\ \ \text{Users})} \tag{2}$$

5.4 Methodology

The experiment was designed as a within subjects design as it allowed me to ask users' preference between the two different conditions. Each group performed two similar tasks - one with the Video Collaboratory and the other with YouTube. The groups were counter-balanced to account for the order effects. The experiment was conducted over two weeks. In the first week (Part-1), four out of eight groups were asked to complete the task using YouTube while the other four groups used the Video Collaboratory to complete the task. In the following week (Part-2), groups switched their tools to complete the task. I will refer to the first week of the experiment as Part-1 and second week of the the experiment as Part-2.

To measure Explicit Contextualization (EC), I counted the total number of words posted and the number of context-specifying words used by each group in their discussion log. The discussion log for YouTube consisted of comments posted in the comments section of the application and the comments in the Google document. In the case of the Video Collaboratory the log consisted of comments posted on both the Video Collaboratory and the Google document.

To measure 'Context Switches', I asked the participants in the study to screen capture one of their interaction sessions. The screen recordings allowed me to count the instances when a user switched between the video and Google Docs in the case of YouTube. I also counted the ratio of the number of words in the VC comments vs. in the Google doc and compared this to the ratio in the YouTube condition.

To measure 'Power', I counted the total number of opinion words in each of the

discussion logs. The discussion log for YouTube groups consisted of comments posted in the YouTube comments forum and in the provided Google document. In the case of the Video Collaboratory, the log consisted of comments posted on both the Video Collaboratory and the Google document. The interaction log of the Video Collaboratory users contained frequency of their logging to the system and the total time spent on the task. YouTube recorded the total time spent on a video. By restricting the number of users using each instance of YouTube videos for the task at a given time, I was able to get the total time used by YouTube groups to complete the task.

5.5 Participants

Participants in this study were students who were enrolled in the graduate HCI course at UNC Charlotte in the Fall 2014 semester. All of the 45 registered students in the course participated in the study. The participation in this user study was mandatory for all the students as a part of their HCI course work. However, students were informed that they could choose that their data not be used in the research. Later, data from one student was removed from the analysis upon his request.

All the registered students were divided into 8 groups at the beginning of the semester as part of their HCI course. As a group, they were asked to annotate video lectures posted on the Video Collaboratory. I used the same 8 groups for my study. The number of students in each group is shown in Table 10. In Part-1, Groups A, B, C and D used YouTube while Groups E, F, G and H used the Video Collaboratory. In Part-2, groups switched their tool.

Table 10: User study groups

Group name	**# of participants**	**Tool used - Part-1**	**Tool used - Part-2**
Group A	5	YouTube	Video Collaboratory
Group B	6	YouTube	Video Collaboratory
Group C	6	YouTube	Video Collaboratory
Group D	5	YouTube	Video Collaboratory
Group E	6	Video Collaboratory	YouTube
Group F	6	Video Collaboratory	YouTube
Group G	6	Video Collaboratory	YouTube
Group H	5	Video Collaboratory	YouTube

5.6 Materials

The following materials were used in this study:

- YouTube video player
- Video Collaboratory video application
- Google documents - A Google document was provided to each group to use for discussion.
- Post experiment survey - Participants answered a few questions after the completion of the experiment about their experience with their respective tool. Attached as Appendix F.
- Interview Questionnaire - Attached as Appendix G.
- Video commercials - Two video commercials were used in the study. First was a short commercial about a local basketball team and the second was a short commercial about a rail transit card.

5.7 Task and Procedure

The user study started on 11/18/2014 and ended on 12/17/2014. Table 11 details the timeline of the study. All the participants in the study were divided into groups and each group completed two tasks. In each task, each group was given a 1 minute long video clip and was asked to reach consensus as a group about three things they would like to change in the video to make it better. The video used in Part-1 of the study was a short commercial about a local basketball team [38] while the groups used a short commercial about a rail transit card [39] in Part-2 of the study. Both videos were 1 minute in length. All the participants were told that they could only use the built-in commenting system of their respective tools or the provided Google document to communicate with their group members about the task. They were asked not to meet in person or communicate through emails to complete the task.

Each group was given 22 hours to complete the task. The groups started the task at 7pm on Tuesday and were given till 5pm the next day (Wednesday) to complete the task. The task was explained to all the users during a regular class session on Tuesday (11/18/2014) at 6:45 pm (Script attached as Appendix A). At 7pm all the users logged into their assigned tools and started the task. They spent 10 minutes on the task. At around 7:10 pm I asked them to stop working on the task. All the participants then proceeded to work on the other activities in their class. They were asked to complete the task by 5pm the next day. The following day (Wednesday), I sent 2 reminder emails (Appendix C) to each participant. The first reminder email

[38] Part-1 video - https://www.youtube.com/watch?v=xvlCuY4alkc
[39] Task 2 video - https://www.youtube.com/watch?v=aPHt-YqNSc0

was sent at 11:30am and the second was sent at 3pm. Any data entered after 5pm was not considered for analysis. At 7:30pm on Wednesday, I sent out an email (Appendix D) to all the participants to complete a survey about their experience with their respective tools. I also conducted one-on-one interviews with some participants to know more about their experience during the experiment and their preference between the two tools.

5.8 Data Collection

- Post-usage survey - Each participant in this study was asked to complete a short post-use survey to share his/her experience in working with their respective tool. The survey questions asked participants about their level of engagement and immersiveness with their tools. The participants were also asked to rate their preference between the the Video Collaboratory and YouTube. The survey is attached as Appendix F. (H2)

- Interaction logs - The interaction logs of all the participants with their application were collected. The interaction logs of the users using Video Collaboratory contained frequency of their logging into the system and the total time spent on the task. In the case of Video Collaboratory, the system also kept track of the total number of comments deleted by the users during the process of task completion. The interaction logs of the users using YouTube contained the timestamps of the comments made. (H3)

- Discussion log - The discussion among the participants using both the platforms were collected. In the case of YouTube groups, the discussion conducted in the

Table 11: User study timeline

Date	Time	
Part-1		
11/18/2014	6:45 pm	The study was explained to the participants (HCI students) in the class. An email (Appendix B) was sent to all the students explaining the task and a link to the video. The email also included the instructions to access their respective tools.
	7:00 pm	Participants started the task in the class.
	7:10 pm	Participants stopped working on the task in the class.
	7:15 pm	Participants were told that the task is available till 5 pm next day.
11/19/2014	11:30 am	1st email reminder was sent to all the participants about the task deadline (Appendix C).
	3:00 pm	2nd email reminder was sent to all the participants about the task deadline (Appendix C).
	7:30 pm	An email was sent to all the participants with a link to the post-usage survey (Appendix D).
11/20/2014	2:00 pm	1st email reminder was sent to all the participants to complete the survey.
11/24/2014	11:30 am	2nd email reminder was sent to all the participants to complete the survey.
Part-2		
11/25/2014	6:45 pm	The Part-2 of the study was explained to the participants in the class. An email (Appendix B) was sent to all the students explaining the task and a link to the video. The email also included the instructions to access their respective tools.
	7:00 pm	Participants started the task in the class.
	7:10 pm	Participants stopped working on the task in the class.
	7:15 pm	Participants were told that the task is available till 5 pm next day.
11/26/2014	11:30 am	An email reminder was sent to all the participants about the task deadline.
	9:30 pm	An email was sent to all the participants with a link to the Part-2 post-usage survey (Appendix D).
12/01/2014	2:30 pm	1st email reminder was sent to all the participants to complete the Part-2 survey.
12/02/2014	4:30 pm	2nd email reminder was sent to all the participants to complete the Part-2 survey.
	6:45 pm	Debriefing in the class and request to participate in one to one interview.
12/08/2014	11:30 am	1st email reminder to participate in one to one interview (Appendix E).
12/10/2014	11:00 am	2nd email reminder to participate in one to one interview.
12/16/2014	2:00 pm	3rd email reminder to participate in one to one interview.
12/17/2014	2:00 pm	Study ended.

general comments section was collected, while in the case of the Video Collaboratory groups the discussion embedded in the system was used for analysis. In both the cases, discussion done in the separate Google document was also evaluated. This data helped me to measure the number of context-specifying words and opinion words that were used to calculate explicit contextualization and power as described in equation 1 and equation 2. (H1 and H3)

- Screen capture - All participants were asked to screen capture one of their sessions with each tool. The screen capture of sessions allowed me to measure context switches. (H2)

- Interview - At the end of the experiment, when the participants completed their post-usage survey, I asked them to participate in one-on-one interviews with me. The participation was voluntary. In this interview I focused on their overall experience working with both the tools, their preference and the reason for their preference. The interview questions are attached as Appendix G.

5.9 Analysis

5.9.1 Discourse Analysis

Discourse analysis is done in HCI and the social sciences for making inferences from large bodies of conversation by systematically and objectively identifying special characteristics of messages [57]. In this study I used the content analysis method to analyze the discussions between the participants while completing their collaborative task. This involved the analysis of the discussions on both the systems. In both cases,

participants' discussions and comments inside the application as well as the provided Google document/spreadsheet were analyzed. After collecting all the discussions from both YouTube and the Video Collaboratory in a spreadsheet, I assigned identifiers to each of the comments. These identifiers included the name of the user, the user's group, and the date/time of the comment. Each comment was also assigned a random and unique ID.

A copy of the spreadsheet with all the identifiers removed was then coded by myself and two other researchers. The coders will be referred to as Coder-A (myself), Coder-B, and Coder-C. Coder-B is an Associate Professor of Human-Computer Interaction at UNC Charlotte. Coder-C is a researcher at the University of Haifa, Israel. Her area of study includes linguistics and computer-mediated communication. Two examples from the spreadsheet were explained to each coder. Each coder was then asked to code the entire spreadsheet. They were asked to highlight the context-specifying words by changing them to a red font color, count the total number of contextual words in each of the comments, and report that in a separate column of the spreadsheet. After the coding was completed by all the three coders, I calculated the inter-rater reliability between the three pairs of coders. Agreement between coders was calculated using 'Percent Agreement' method. The Observed Agreement between all the three coders was 82.93% which is considered very acceptable in most conditions [43]. The pairwise percent agreement was also calculated between each of the three pairs of coders. The percent agreement between Coder-A and Coder-B was 90%, between Coder-B and Coder-C was 75% and between Coder-C and Coder-A was 81%. I have used the data from Coder-A and Coder-B for the analysis as they had the highest agreement. For

the analysis, wherever Coder-A and Coder-B differed in their rating of contextual words, I used a union value total number of contextual words from both the coders for the analysis.

I was specifically interested in finding the ratio of contextual content vs. opinion content. Words that are used to identify a part of a video were marked as contextual, while words that were used to say something about that part of the video were marked as opinion content. For example, in a sentence like "... at 3:05, I would like to change the transition to fade in", the phrase "at 3.05" is contextual, while the rest of the sentence is opinion content. Similarly, in a sentence like "Near the beginning of the video, the narrator says ... ", the phrase "Near the beginning of the video" is contextual, while the rest is opinion content. The coders highlighted all the contextual words in each of the comments.

5.9.2 Video Analysis

I asked participants to submit a screen recording of one of their interaction sessions with their assigned tool in each part of the study. In viewing this data, I was interested in seeing the different ways people interacted with video while collaborating. Since this was a crude video analysis, I watched all the videos submitted by the participants and noted any interesting patterns that appeared in the participants' ways of interaction. I also counted the context switches.

5.9.3 Survey Analysis

The survey was posted on Google Drive. Each participant took two surveys - one each after completing the task with each of the two tools. The participants' responses

were automatically recorded in a separate spreadsheet for each tool for each part of the study. It resulted in four spreadsheets - one each for Part-1-VC, Part-1-YouTube, Part-2-VC and Part-2-YouTube.

5.9.4 Interview Analysis

4 participants registered for a 20 minute interview session. I recorded the interviews with the participants. The participants responses were analyzed for their qualitative feedback on their experience with both the tools, their preference and the reasons for their preference.

5.10 Results

Part-1 of the study was conducted on Nov 18-19 while Part-2 of the study took place on Nov 24-25. A total of 204 comments were posted by 45 participants in the user study. Of these 204 comments, 127 comments were posted in Part-1 of the study while 77 comments were posted in Part-2 of the study. Participants were asked to complete a post-usage survey after the end of each part of the user study. 29 participants in Part-1 and 27 participants in Part-2 of the study completed the post-usage survey. Participants were also asked to upload a screen capture of one of their interaction sessions with the tool. 18 participants uploaded a screen capture in Part-1 while in Part-2, only 7 participants uploaded a screen capture. Part-2 of the study evidenced less activity than Part-1 of the study. There could be many reasons for low participation in Part-2 of the study:

- The length of the study - The study was designed to be completed over two weeks. Many participants who actively participated in Part-1 did not partici-

pate in Part-2 of the study. Participants might have become distracted or too busy.

- The repetitive nature of the study - Part-2 of the study required participants to do the same task as in Part-1. Participants might have lost interest due to the repetitiveness.

- Holiday on Nov. 24-25th - Part-2 of the study took place on Nov. 24-25th. Nov 25th was a holiday and some participants might have lost interest due to holiday preparations or travel.

In spite of these issues, more than 82% of participants (37 out of 45) participated in Part-2 of the study and posted at least one comment in the group's discussion. In the following sections, I will first discuss the results from the discourse analysis, and then will continue with the results from the video sessions analysis, survey analysis and interview analysis.

5.10.1 Discourse Analysis Results

Discussion on both the platforms developed organically depending on the choice made by the group in the first few hours of the discussion. Four out of the eight groups used Google Docs for some discussion while working with YouTube. Of these four groups, one group did the majority of their discussion in Google Docs. In contrast, none of the groups used Google Docs while working with the Video Collaboratory.

At the end of the task in each part of the study, groups used the Video Collaboratory's or YouTube's built-in commenting system to convey their consensus in the form

of comments. These comments were not a part of the discussion among participants to reach a consensus on their assigned tasks and were used as a way to inform the evaluator of the final results. There were 10 such comments and these comments have been removed from the analysis. For discourse analysis only 194 (204 -10) comments were analyzed.

45 participants posted a total of 194 comments during the user study. They used a total of 4627 words in these 194 comments. The participants were more active during the first part of the study. The total number of comments used in the first part of the study was 122 (61% of total comments) with 2979 words (65% of the total words). The Video Collaboratory groups posted a total of 82 comments (1773 words) whereas the groups using YouTube posted 40 comments (1206 words) in total. Note that this includes comments posted in Google Docs. Table 12 shows the breakdown of posted comments and total words used by each group in Part-1 of the study.

In Part-2 of the study, the total number of posted comments by both groups was equal. The Video Collaboratory groups posted a total of 38 comments (928 words) whereas the groups using YouTube posted 38 comments (720 words) in total. Table 13 shows the breakdown of posted comments and total words used by each group in Part-2 of the study.

I have analyzed my data using Repeated Measures Analysis of Variance (ANOVA). Reported means were calculated using Least Mean Squares and include standard errors (SE), which take into account the Standard Deviation. Unless otherwise noted, all differences are significant ($p<0.05$).

I have defined Explicit Contextualization (EC) as a ratio between the number of

Table 12: Part-1: Number of comments and Total number of words posted by different groups.

Group name	**Tool**	**Total # comments**	**Total # words**	**Comment(s) in Google Docs**
Group A	YouTube	7	360	1
Group B	YouTube	8	170	
Group C	YouTube	17	333	3
Group D	YouTube	8	343	5
Total YouTube		**40**	**1206**	**9**
Group E	Video Collaboratory	29	764	
Group F	Video Collaboratory	16	364	
Group G	Video Collaboratory	20	372	
Group H	Video Collaboratory	17	273	
Total Video Collaboratory		**82**	**1773**	

Table 13: Part-2: Number of comments and Total number of words posted by different groups.

Group name	**Tool**	**Total # comments**	**Total # words**	**Comment(s) in Google Docs**
Group A	Video Collaboratory	7	261	
Group B	Video Collaboratory	7	243	
Group C	Video Collaboratory	11	156	
Group D	Video Collaboratory	13	268	
Total Video Collaboratory		**38**	**928**	
Group E	YouTube	5	178	2
Group F	YouTube	17	200	
Group G	YouTube	9	208	
Group H	YouTube	7	134	
Total YouTube		**38**	**720**	**2**

Table 14: Mean and standard error of total words posted per participant in different conditions of both parts of the study

Block	Tool	N	Mean (# of words)	Std. Error
1	Video Collaboratory	23	77.08	11.73
1	YouTube	22	54.81	12.0
2	Video Collaboratory	22	42.40	12.0
2	YouTube	23	31.3	11.73

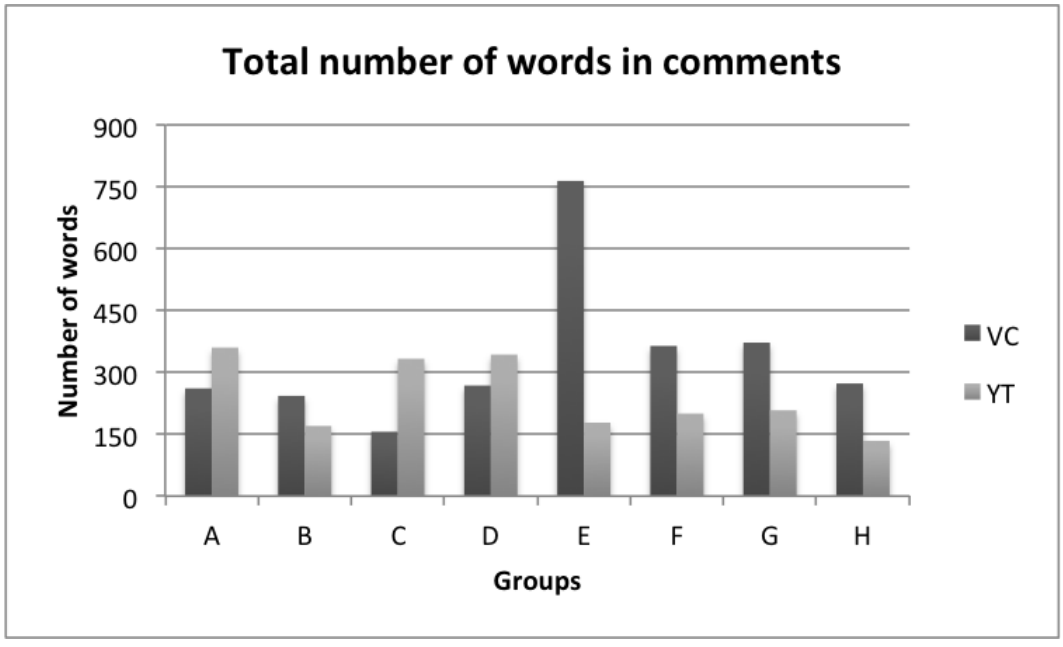

Figure 32: User Study - Total number of words used by participants in their discussions.

Table 15: Part-1: Explicit Contextualization by different groups

Group name	**Tool**	**Total # context words**	**Total # words**	**Explicit Contextualization in Percentage**
Group A	YouTube	35	360	9.72
Group B	YouTube	19	170	11.2
Group C	YouTube	10	333	3
Group D	YouTube	26	343	7.6
Total YouTube		**90**	**1206**	**7.5**
Group E	Video Collaboratory	54	764	7.06
Group F	Video Collaboratory	25	364	6.8
Group G	Video Collaboratory	9	372	2.4
Group H	Video Collaboratory	15	273	5.5
Total Video Collaboratory		**103**	**1773**	**5.8**

context-specifying words to the number of total words in a discussion (see equation 1). Explicit Contextualization should measure the efficiency of communication. I hypothesized that the Video Collaboratory, with better design affordances to specify context in a video will need less 'Explicit Contextualization' than YouTube. In both parts of the study, EC values were higher for the participants collaborating with YouTube (See Table 15 and Table 16).

Figure 33 shows the 'Explicit Contextualization' as percentage by different groups. 7 out of 8 groups (A, B, C, D, E, F, and G) used more explicit contextualization while working with YouTube. The effect was more interesting for groups B, E, F and G as these groups discussed more while collaborating with the Video Collaboratory than YouTube. So, even though the participants from groups B, E, F and G performed more discussion while working with the Video Collaboratory, the EC was much lower

Table 16: Part-2: Explicit Contextualization by different groups

Group name	**Tool**	**Total # context words**	**Total # words**	**Explicit Contextualization in Percentage**
Group A	Video Collaboratory	12	261	4.6
Group B	Video Collaboratory	9	243	3.7
Group C	Video Collaboratory	0	156	0
Group D	Video Collaboratory	11	268	4.1
Total Video Collaboratory		**32**	**928**	**3.4**
Group E	YouTube	27	178	15.1
Group F	YouTube	30	200	15
Group G	YouTube	7	208	3.4
Group H	YouTube	2	134	1.5
Total YouTube		**66**	**720**	**9.2**

than the cases of YouTube. This analysis shows that the Video Collaboratory was effective in reducing the amount of Explicit Contextualization.

However, there was not a significant effect of tool on Explicit Contextualization ($F(1,7) = 5.43$, $p=0.061$).

I have defined Power (P) as a ratio between the total number of opinion words to the total time taken to complete the task multiplied by the number of users (see equation 2). A 'Power' value represents the amount of discussion done per unit of time per participant in a group. Higher power means that the system helped participants do more work in less time. I hypothesized that the design affordances in the Video Collaboratory make it a more powerful tool than YouTube. Table 17 shows the power calculations for both tools by different groups.

For the Power calculation, I counted the total time spent by all the participants

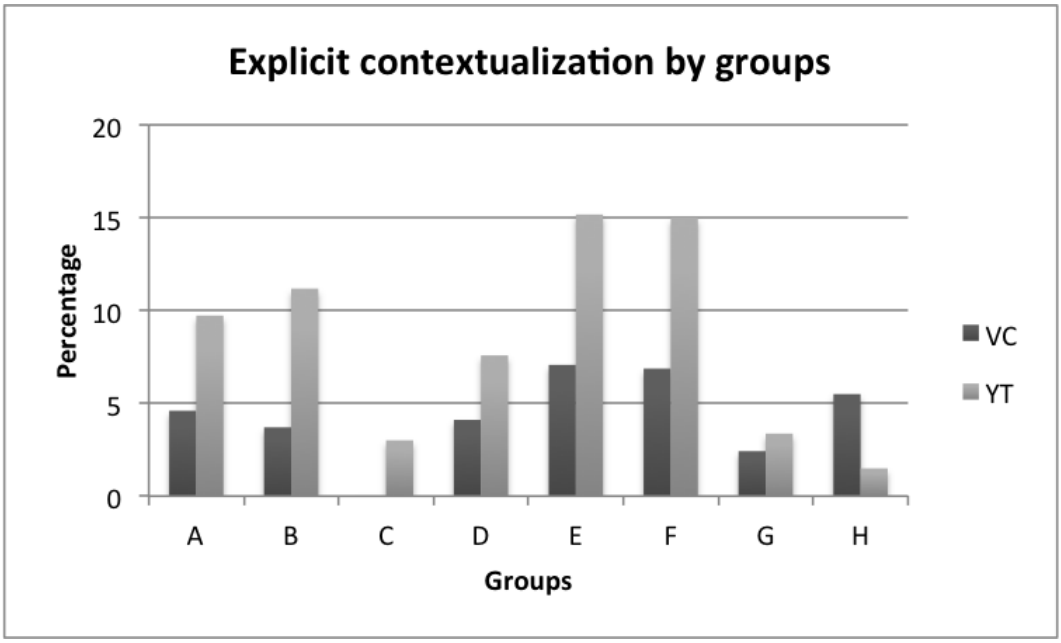

Figure 33: Explicit contextualization used by different groups as a percentage of total discussion.

in a group with each tool. In the case of the Video Collaboratory, the system kept logs of each session of every participant. I counted the number of sessions by each participant, computed the total time spent by each participant and then computed the total time spent by all the participants in a group. In the case of YouTube, the system only provided the total time in terms of the video playback time. The total time did not include the time spent by a participant while performing other interactions such as adding comments etc.

I analyzed the session videos to get a more accurate estimate of the total time spent by different participants during their YouTube sessions. I analyzed six YouTube session videos ranging from 1.55 minutes to 3.20 minutes in length. In all 6 of these videos, participants played a full run of video on YouTube (1 minute in length) in addition to commenting. I calculated the total time spent by different participants

Table 17: Power of tools calculated for different groups. Higher value represents more power.

		Video Collaboratory			YouTube		
Group Name	# of Participants	# Opinion Words	Total Time (in mins)	Power	# Opinion Words	Total Time (in mins)	Power
Group A	5	249	40.7	**1.22**	325	73.6	0.88
Group B	6	234	33.2	**1.17**	151	89.7	0.28
Group C	6	156	31.3	**0.83**	323	108	0.49
Group D	5	257	37.3	**1.38**	317	48.3	1.31
Group E	6	710	104	**1.14**	151	41.4	0.6
Group F	6	339	54.2	**1.13**	170	66.7	0.76
Group G	6	363	57.9	**1.04**	201	43.7	0.76
Group H	5	258	48.9	**1.05**	132	32.5	0.81

in a session on interactions other than watching the video such as commenting or context switching. I calculated the time spent by each of the 6 participants and the mean of all the 6 participants. The mean for 'interaction time' spent on a video, in addition to the video playback time, came to be 1.21 minutes per session. That means that for each 1 minute of playback of a YouTube video (view), participants spent another 1.21 minutes on other interactions, such as commenting. In order to get an estimate of total time spent by participants in each group using YouTube, I multiplied the total number of views (unique playback sessions on YouTube) by 1.3 (1 minute 21 seconds equals one and one-third of a minute) and added total number of views *1 (one minute of video playback). So for Group A, that got 32 views, the estimated total time would be 32*1.3 + 32 (one minute per view for video playback) = 73.6 minutes. The power of the Video Collaboratory was higher in all cases (see Figure 34). There was a significant effect of tool on Power ($F(1,7) = 28.43$, $p=0.001$).

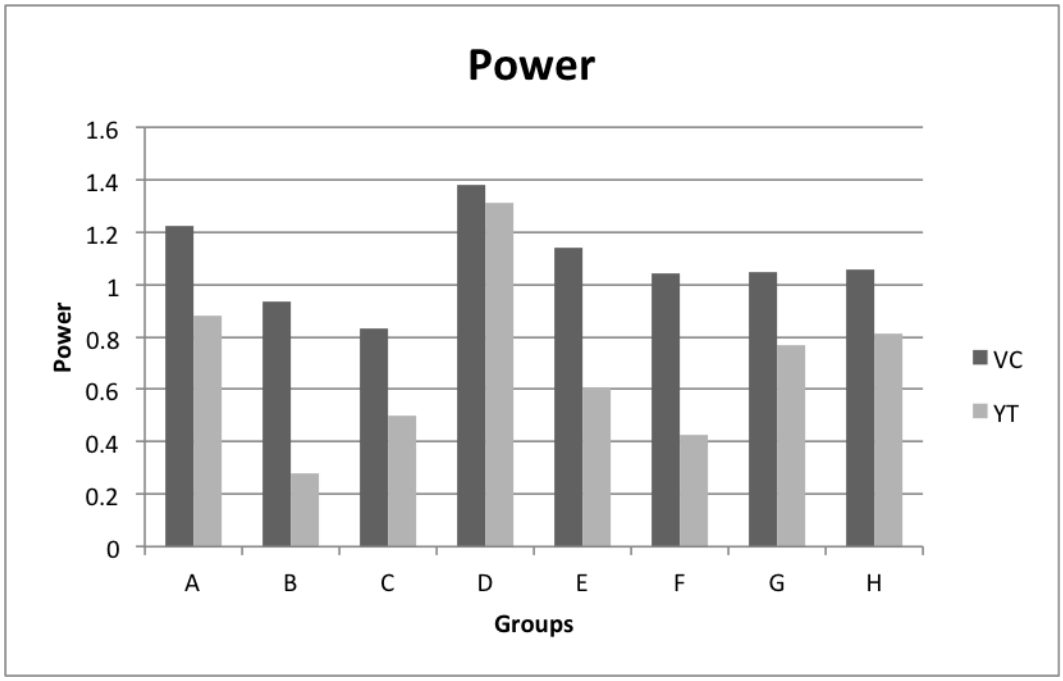

Figure 34: Power of both tools for different groups.

5.10.2 Session Video Analysis Results

I hypothesize that the design affordances in the Video Collaboratory will lead users to make comments mostly in the Video Collaboratory software rather than using the Google Docs for comments. This will mean fewer context switches in the VC condition. I asked participants to submit a screen capture of one of their interaction sessions with the tool. Many participants faced problems while doing a screen capture of their session. Participants using Mac machines used the built-in Quick Time Video Player to complete their screen capture process. Participants using Windows environment had to download a third party application to do the screen capture of their sessions. Many participants couldn't successfully run the video capture application and hence didn't submit any screen recordings. In Part-1 of the study, a total of 19 videos were submitted by the participants. Eleven of these 19 videos were Video

Collaboratory sessions while 8 were YouTube sessions. In Part-2 of the study, only 6 participants uploaded their session videos. Only 1 of the 6 videos was of a YouTube session while others were of VC sessions. Six participants in the study submitted their session video from both parts of the study. I received a total of 25 videos from the participants (expected 90 videos). I expected to measure the number of context switches between the tool and Google Doc based on these videos. However, some of the session videos (n=5) were very short and showed users logging in and reading all the comments posted on the video. The participants had no incentives to put extra effort to capture a screen recording of their session video. The process of screen capture might work better in a controlled environment where each participant could come and complete one interaction session in the controlled set up. There were some interesting patterns that appeared in these session videos. In the case of YouTube, most of the session videos showed participants watching a full run of the provided video once before making any comments. In the case of VC, there were many cases where participants started clicking on posted comments to navigate to different sections of the video after starting the playback. Some participants using YouTube (n=6), scrolled up and down between the video and the comments section multiple times. Some participants (n=4) from the groups that used Google Docs for discussion switched their screen window between YouTube and Google Docs. In this process, the participants lost the visual of the video when they were writing about the content of the video. In the case of the Video Collaboratory, there were instances (n=4) when users clicked on the comment markers to see the comment in context. In two of these cases, the users replied to a comment.

The session video analysis showed some interesting patterns for context switching. While using YouTube, many participants switched their context between the video and the comments many times. For example, Participant 14 did the following steps in 2:09 minutes while working with YouTube: *Played video. Scrolled down to see comments while video is playing. Scrolled up to catchup with the video. Scrolled down. Added a comment. Switches context multiple times.* Similarly, Participant 11 did the following steps in 40 seconds (YT): *Clicked on different part of scrubber on the video to navigate. Switched context to Google Doc. Typed a text comment.* Participant 8 did the following steps in 3:03 minutes (YT) : *Scrolls through the comments, video out of frame. Scrolling from bottom to the top. Goes to Google docs. Posts a comment on Google docs. Jumps between YT and GD 2 times to verify comments on YT before completing his comment.* While working with YouTube, groups posted 11 out of 78 comments on Google Docs while no comments on Google Docs were posted while working with the Video Collaboratory. Participant 20 did the following steps in 0:39 minutes while working with VC: *Clicks on 5 of the posted comment to read the comments in context.* Participant 18 while working with VC in 0:56 minutes did the following steps: *Clicks on 2 of the posted comments to read the comments in context. Posts a reply to the second comment. Clicks on 1 other comment to see it in context.*

5.10.3 Survey Results

Participants were asked to rate their experience with both the tools. Each participant completed the survey twice. I have named the surveys as Part1-VC, Part1-YT, Part2-VC and Part2-YT to represent the surveys from different parts of the study.

I received 17 responses on Part1-VC, 13 responses on Part1-YT, 14 responses on Part2-VC and 13 responses on Part2-YT. The survey questions are attached as Appendix F. In Table 18, I present the results from the survey. The survey questions were designed to gather responses from the participants to measure the usability of the two tools in a collaborative task. The responses on the System Usability Scale (SUS) [5] shows the difference between ratings to be insignificant for the Video Collaboratory (66%) than for YouTube (62%). For SUS, a higher score indicates higher satisfaction with the system. Results show that the Video Collaboratory allowed participants to be more specific in their communication and made the task of communication easier than YouTube. In the second part of the study, the survey also included a question to learn the preference of the participants between the two tools for a collaborative task. Of the 27 participants that completed the survey in Part-2 of the study, 60% (n=16) preferred the Video Collaboratory over YouTube to collaborate with others around a video document.

The survey also included the following open-ended questions to assess the joy points and pain points of the participants while working with both the tools:

- What do you like best about the VC/YouTube for collaborating with others around a video document? (Joy points)
- What do you like least about the VC/YouTube for collaborating with others around a video document? (Pain points)
- What would you do to improve the YouTube/Video Collaboratory system for collaborating with others around a video document?

Table 18: Survey Results. Values are mean of responses on a 5 point likert scale. SUS values are in percentage. For SUS, a higher score indicates higher satisfaction with the system.

Survey name (# of Responses)	Percentage score on System Usability Scale (SUS)	If I had to collaborate with others around a video document then I would like to use VC/YT.	When collaborating with others around a video document the VC/YT allowed me to be very specific in my communication.	When collaborating with others around a video document, the VC/YT made the task of communicating with my collaborators easy.
VC Part-1 (17)	68.56	3.88	3.59	3.76
YT Part-1 (12)	66.14	3.61	3.30	3.46
VC Part-2 (14)	63.14	3.79	3.43	3.57
YT Part-2 (13)	57.93	3.61	3.38	3.38
Total Video Collaboratory (31)	**65.85**	**3.83**	**3.51**	**3.67**
Total YouTube (25)	**62.03**	**3.61**	**3.34**	**3.41**

- Do you have any other comments or suggestions?

Participants liked the design affordances for collaboration in the Video Collaboratory. Participants noted that they *'... can quickly perceive which areas of the video received the most commentary.'* and *'it is easy to recognize when the same user has made multiple comments on the video.'* Other features such as speed control were also appreciated. One participant said *'The speed controller is good. This can help skim the video easily. This is fruitful when preparing for exams using VC.'*

On the other hand, the UI and system robustness of YouTube was appreciated by many participants. One participant noted that *'YouTube has been around and has this 'reputation' of being THE tool for sharing videos. YouTube is familiar because I've used it millions of times before.'* Participants liked the 'like and dislike' feature

in YouTube and found it helpful during the collaborative task to indicate agreement with a comment made by another group member.

Participants noted the difference between YouTube and the Video Collaboratory and appreciated the features of the latter. One participant said *'I like video collaborator[y] and never realized how useful it was for noting on a video until I compared it to YouTube. Even though I'm not sure what all the features are on YouTube.'* Others noted that with YouTube *'Communication was not very effective.'* and *'feels a little complicating in the beginning.'*

Many participants were not sure about the usage of the Video Collaboratory as a group collaboration tool. One participant said *'Nice tool for leaving comments about class videos, not sure how much communication really needs to happen. I wouldn't use this to make group decisions.'* Participants also disliked the automatic looping feature on 'comment clicks' and found it irritating. Many users also requested features like full screen toggle, and support for the Video Collaboratory on browsers other than Google Chrome.

5.10.4 Interview Results

Four users agreed to be interviewed after the user study. The interviews were conducted between Dec 8 and Dec 17 and participants P1, P2, P3 and P4 took part in the interview. Each participant was interviewed for 20 minutes. The interview was designed to elicit the participant's experience with both the tools while completing the task and their preferred tool. P1, P2 and P3 preferred the Video Collaboratory for completing the task. P2 and P3 found the Video Collaboratory to be a better

tool to communicate with their group members. P2 said that the Video Collaboratory allowed her to communicate more because *'I didn't have to double check which moment I am speaking about, which part I am speaking about'*. The contextualized commenting in the Video Collaboratory also made it easy for her to follow others because *'At the same time, they were addressing something which I didn't know to check. So I simply [clicked on the comments]'*. Similarly, P3 liked that in the Video Collaboratory *'if you clicked on somebody's comment you jump immediately to [the] moment they are talking about or at least the ball park of that moment whereas in YouTube, I have to drag down that little control thing ...'*. P4 found the email notification in YouTube to be helpful for enhancing the communication and noted that this feature was missing from the Video Collaboratory. P1, P2 and P4 found the color coding for different users in the group to be a very helpful feature in VC. P2 liked *'that comments were color-coded so I could follow some specific person's comment'*. P1 and P3 pointed out that the technical glitches in the Video Collaboratory made it frustrating to use the tool. The issues were related to responsiveness and delayed feedback from the system. P1 noted that there were many instances when he added comments to a video but the Video Collaboratory did not display the comment. It could be because of some network issue such as poor Internet connection. However, I was not able to duplicate the issue on my end and I didn't receive similar complaints from any other participant.

5.11 Discussion

In this user study, I defined three new metrics for the measurement of efficiency of contextualization, immersiveness and power. These metrics were important because I wanted to quantify the efficiency of discussion among collaborators. Communication efficiency is important because if the tool is inefficient to use, there will be less collaborative discussion.

Participants used more words in YouTube to specify context on the video. The content analysis of the participants' discussion showed that users frequently specified context on a video using short phrases like 'here', 'this guy', 'this scene', 'this shot' and 'till this stage' when using the Video Collaboratory. However, when participants used YouTube, they depended on longer phrases such as 'The part of the video that plays the basketball match' and 'ending of the video'. There were more than 10 cases in YouTube where participants used either timestamps or other temporal identifiers to talk about specific context in the video. The EC value for 7 out of 8 groups was higher while working with YouTube (Figure 33). However, the overall difference between the EC values for YouTube and the Video Collaboratory was not significant ($p=0.061$). These results suggest that further study, with a larger sample size, might demonstrate that EC is statistically lower with the Video Collaboratory.

The results of session video analysis was inconclusive. Due to unavailability of sufficient number of videos, I counted the number of Google Doc comments as a proxy for context switches. Every time a comment is entered into the Google Doc, it means that there was a context switch between the video and Google Doc. However,

it is important to note that a participant can post multiple comments on Google Doc in one context switch or he can perform multiple context switches before completing one comment on Google Doc. Analysis of the submitted session videos showed that when participants worked with YouTube, they frequently switched contexts. They switched windows between YouTube and Google Docs and scrolled from the video to the comment section. In the case of YouTube, four teams used Google Docs for some of their discussions. One team did most of their discussions on Google Docs. While working with the Video Collaboratory, all teams preferred to work with the built-in commenting system in VC and no one used Google Docs. The number of Google Docs comments in YouTube (11) was higher than VC (0) but due to lack of enough data and many limitations the results cannot be considered significant. However, these results suggest that the context switch hypothesis is likely to be accepted if the users were studied in a lab setting where all their activities could be recorded.

The results of power calculations supported the hypothesis H3 (Power for VC groups >Power for YT groups). The Video Collaboratory helped participants to work more in less time. It is important to note that YouTube didn't provide the actual total task time used by the participants and I have used a close estimation of total task time for YouTube based on session video analysis. The results showed that the difference between Power of the Video Collaboratory and YouTube was significant ($p=0.001$).

5.12 Summary

The results of the user study showed that people used longer phrases to specify context in the case of YouTube than the Video Collaboratory. In the Video Collaboratory, explicit contextualization happened but the participants used very short phrases. The Video Collaboratory also allowed people to do more work per unit of time making it a more powerful tool than YouTube for collaborative tasks.

The session video analysis did not provide any conclusive results about the context switches but it showed that when the participants used the Video Collaboratory, they clicked on different comments to contextually navigate the video which was absent in the case of YouTube interactions.

The survey results showed that the participants liked the affordance of quickly perceiving the comment density on the video timeline. It helped them find the sections of the video getting the most attention from the group members. The participants also liked the affordance of color-coding for different members in the group as this allowed them to easily follow the position of multiple comments from the same group member.

CHAPTER 6: DISCUSSION & CONCLUSION

6.1 Dissertation Summary

In Chapter 1, I introduced the importance of a video-centered collaboration system, and I discussed the general lack of such systems and the growing importance of video work. I also discussed the research problem of evaluating such systems. In Chapter 2, I provided background on video-centered collaboration and annotation systems, video interaction techniques and a comparison of existing tools and systems.

In Chapter 3, I discussed the design and development of the Video Collaboratory and how it evolved from the Choreographer's Notebook. The Video Collaboratory, a web-based video annotation system, was developed through an iterative design process. I discussed the user interface of the application and various features and interaction techniques that have been developed and deployed in the system.

In Chapter 4, I discussed the results of various studies including focus groups, surveys and interviews with dancers and choreographers who used the system in 8 different dance productions. I discussed the effect of the Choreographer's Notebook on the overall dance production process. I also discussed the survey results from the students in three computing courses who used the Video Collaboratory system as a part of their course work. I concluded the chapter by discussing findings from these evaluations of the Video Collaboratory system.

In Chapter 5, I described the user study I conducted to verify my research hypotheses and explained the design of my experiment. The experiment compared the Video Collaboratory system with YouTube for completing a collaborative task around video. I presented the qualitative and quantitative results of the experiment and lessons learned from this experiment.

Finally, in this chapter, I summarize my dissertation by highlighting contributions from this research. First, I present a discussion on the various findings of this research. Then, I present guidelines for designing various affordances in asynchronous video-centered collaboration systems and finally, I discuss some potential future directions in this research area.

6.2 Discussion

With the pervasiveness of video, collaboration around a video document has become important in many domains. For video-centered collaboration, the general video tools with generic interaction techniques designed for passive consumption are insufficient. Applications with better design affordances and interaction techniques will be needed. The Video Collaboratory has proven to be a useful tool over the past 5 years for collaboration around video-centered documents. The overall feedback from users of the Video Collaboratory application has been very positive, although as a prototype tool there has been many technical glitches to overcome.

Video Collaboratory in Performing Arts: The Video Collaboratory is an extension of the Choreographer's Notebook. It has been used by 5 choreographers and more than 100 dancers in the past 5 years. I have reported results from focus groups with

various dancers and interviews with the choreographers in Chapter 4.

The dancers and choreographers agreed that using the Video Collaboratory (the Choreographer's Notebook) allowed them to devote more time to actual dancing in the studio. Availability of more time in the studio for dancing resulted in the higher caliber final performances. The introduction of the Video Collaboratory added another layer of feedback to the dance rehearsal process. Various features in the Video Collaboratory, such as adding annotation right at the context and easy video navigation through these posted annotations, made the collaborative process of choreography more personal. One choreographer noted that the Video Collaboratory made it possible to provide individual dancers with 'personal attention as if it was solo.'

Interviews and focus groups brought out some exciting themes which are contextual as well as behavioral. The over-arching context of use of the Choreographer's Notebook was high expectations for excellence and responsiveness. The choreographers felt that the dancers who used the application could be 'trusted'. During the rehearsal process, there existed a tension of how best to utilize rehearsal time. The choreographers wanted to take advantage of viewing rehearsal video as a group, but on the other hand didn't want to spend a lot of time just sitting and watching the video during rehearsal time. Choreographers noted that as dancers had already done their homework (watching videos with comments), it took less time in group discussion and so they were able to spend more time perfecting the dancing.

Choreographers also noted that filming rehearsals and putting them on the Choreographer's Notebook made dancers step up their performance by dancing at 100% during rehearsals. This was remarkable because dancing at 100% is an important

quality for professional dancers and important to foster in students. For example, dancers made mistakes work; they did not stop and request to start again. Instead, they dealt with the mistake to the best of their ability, as they would in live performance. This is a critical skill that is important to teach and the application provided an excellent platform for promoting that.

Video Collaboratory in Classroom Education: The Video Collaboratory has been used by the students and instructors of the Department of Software and Information Systems (SIS) at UNC Charlotte. The application has been used in various courses including Rapid Prototyping, Human-Computer Interaction and Web-based Application Development. It has been used by more than 270 students.

Collaborative learning is a complex social process and any software environment intended to support collaborative learning must afford and encourage ideas from multiple viewpoints that can be further developed and can approach consensus [60]. The Video Collaboratory provides affordances to support this social process around video material. Students can watch a video privately in a small group, mark up and annotate different points and segments of the assigned videos. In HCI class, the Video Collaboratory not only allowed students to collaboratively reach a consensus on weekly tasks but also helped them create collective self-study material. The analysis of the use of VC in a flipped classroom learning environment shows that students engaged with the video content more than was required. The number of annotations on a video and discussion through threaded commenting also provides the instructor with a better understanding of students' engagement with video content. This data shows more than just the amount of time they watch the video by including data about

their active note taking and communication with others around the video content.

6.3 Affordances for Video-centered Collaboration

Based on the user studies and other evaluations of the collaborative processes such as choreography and classroom education I present a list of design affordances that are suitable for video-centered collaboration. I also present some of the signifiers that have been used in the Video Collaboratory system to represent various affordances.

- Context awareness - While working with collaborators on a long video, it becomes important to specify context of the content to facilitate discussion. The context integration should be seamless with the content of the video. A video's timeline represented by a scrubber is an important signifier as it represents the full length of a video. In the Video Collaboratory, the timeline-based markers acted as an important affordance that represented the position of various comments on the video timeline. These markers act as a signifier for the position of various comments on the video timeline. They allowed users to have a preview of any comment at a glance or navigate to that point on the video by clicking on the marker. This feature is important for collaboration because while working on a long video it becomes easy to follow interesting sections by analyzing the density of discussion activities on the video timeline. In the survey, one user noted that he *'... can quickly perceive which areas of the video received the most commentary.'* Another user from the HCI class noted *'At the same time, they were addressing something which I didn't know to check. So I simply [clicked on the comments]'.*

- Contextual navigation - It is very important to have correct context about the content of the video during discussion and collaboration. In the Video Collaboratory, users really liked the ability to navigate videos by interacting with various elements of the system. The video could be navigated through comments in the right panel or the markers on the timeline. Two different kind of signifiers were used to specify whether the marker represents a comment on a frame (rectangular) or on a segment of video (inverted triangle). The contextual navigation is important for collaboration because it helps collaborators quickly interpret the meaning of comments from other group members by seeing the video segment in comment's context. A choreographer noted that she liked this *'ability to jump from scene to scene while annotating, which she was unable to do with her VCR.'* Similarly, in HCI class a student noted that *'if you clicked on somebody's comment you jump immediately to [the] moment they are talking about ... whereas in YouTube, I have to drag down that little control thing ...'.*
- Color-coding - Different color-coding of each member's comments allows collaborators' to visually identify different member's comments from a list of comments. It helps in following a group member's activity. In HCI class, users noted and liked *'that comments were color-coded so I could follow some specific person's comment'* and *'it is easy to recognize when the same user has made multiple comments on the video.'*
- Threaded discussion - Threaded commenting is an important design affordance for collaboration. It facilitates discussion among collaborators by replying to a

posted comment. In the Video Collaboratory, the 'Reply' button at the bottom of each comment signified that a threaded discussion is supported in the system. The threaded conversation retained the color-coding of different collaborators clearly representing the participants in a discussion.

- Multi-modal annotations - Adding various modalities to the application allowed users to collaborate around videos in different ways. Sketching on the video frame allowed users to specify spatial context that is not possible with text comment. One of the choreographers used the sketching to specify positioning and alignment of dancers in a dance piece. He also created smileys at various points to show his happiness with the efforts of dancers. In the HCI course, the students used sketching to highlight various content of the video lecture for self-reference as well as for collaborating with other group members. The sketching modality is important to collaboration because it allows users to communicate spatial information and to collaborators in ways that text cannot.
- Synchronous awareness - Collaborative document editing tools such as Google Docs support synchronous awareness in the system. When two or more collaborators are working at the same time on a document, Google Docs uses thumbnail signifiers to show the presence of other collaborators. It is an important aspect of collaboration because when collaborators are aware of the presence of other group members they can work together synchronously towards their task goals. In the Video Collaboratory, the synchronous activities are possible but there is no signifier to show the presence of other collaborators in real time.

6.4 Contributions

In summary, this work contributes a better understanding of how people asynchronously collaborate with video when they are a part of a group. For this dissertation, I have focused primarily on the asynchronous communication that takes place when collaborating on a project around a video document. To this end, I designed, developed and deployed a video-centered collaborative system which has affordances for groups of users to navigate, select, mark and annotate specific segments of a video using multiple modalities.

The results of interviews and focus groups showed that design features and affordances such as the login screen to make the collaboration private for group members, representation of collaborators' comments on the timeline, color-coding of group members' comments, and navigation of video through group members' comments helped the dancers, choreographers and students in their collaborative tasks. The introduction of the Video Collaboratory in dance production process resulted in many socio-technical impacts on the collaborators and trade-offs for its users that I have discussed in Chapter 4.

The comparison study between YouTube and the Video Collaboratory showed that the difference between design features and affordances for collaborations did not make a significant difference in the amount of contextualization ($p=0.074$) but allowed more work per unit of time while working with the Video Collaboratory, significantly increasing its power ($p=0.009$). The limitations in the experimental design did not allow me to find any conclusive claim about the difference between the context switches

in both cases. However, the context switch hypothesis is likely to be accepted if the users were studied in a more controlled setup such as a lab setting where all their activities could be easily recorded.

Finally, I presented guidelines for designing affordances in asynchronous video collaboration tools based on the results of the experiments I conducted.

6.5 Limitations

In my comparison study, I wanted to quantify, measure and compare the efficiency of contextualization, immersiveness and power of the Video Collaboratory with YouTube. In the absence of any metrics to measure these concepts in previous research, I defined three new metrics - Explicit Contextualization (EC), Context Switches and Power. It is important to measure communication efficiency as if the tool is inefficient to use, there will be less collaborative discussion. However, the absence of any established metrics in my experiment design is one of the limitations of this study.

To measure immersiveness, I wanted to count the number of context switches between the tools and Google Docs. I asked participants to send me a screen capture of one of their recorded interaction sessions with each tool. However, I noticed later that the participants had no incentive for doing so and this affected my data collection. I could have made it mandatory for each of my participants to come and record one interaction session in a more controlled lab setup. That would have allowed me sufficient data to examine my hypothesis.

In the comparison study, YouTube only recorded the total video playback time and

did not record any time information about users' other interactions such as scrolling, commenting etc. To measure power, I made a close approximation of users' interaction time on YouTube analyzing the data from the screen capture.

6.6 Future Work

The design of the features and affordances in the Video Collaboratory has focused on the user experience, assuming that the user is collaborating around video content. In the context of education, the Video Collaboratory user experience has focused on the student as user while in the context of performing arts, it focused on the dancers. In a learning environment, developing the user experience for the instructor and choreographer is equally important and the Video Collaboratory could be expanded to include that. The analysis of user engagement with video content shown in this dissertation required extracting the logged data and performing an analysis outside the Video Collaboratory. Future versions of the Video Collaboratory could provide this analysis built into the system as an aid to the instructor and the choreographer.

The Video Collaboratory system has been used in dance and education. There are many other domains where the usage of the Video Collaboratory could be employed. Sports analysis, sales training, medical training, music teaching, and ornithology are some of the domains that depend heavily on video-centered collaboration and the Video Collaboratory could seamlessly be expanded to these domains.

The Video Collaboratory is designed for collaboration around a single video. However, there could be many scenarios where collaboration requires analysis of multiple videos at a given time. Analysis of a boxing match from multiple camera angles

or watching three surgical videos of a medical procedure for sensemaking are some activities that could easily benefit from a system that could support multiple videos at a given time. Designing for multiple videos has its own challenges [65] and the Video Collaboratory could be used as a starting point for the research in this domain. Currently, the Video Collaboratory is a web-based system that is supported through an Internet browser. With the increasing popularity of native apps for mobile-based systems, it will become important to look at the challenges and issues of developing a scalable mobile app for the Video Collaboratory.

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APPENDIX A: USER STUDY - EXPERIMENT SCRIPT

Hello Everyone,

Thanks again for participating in this user study.

1. In the second part of this user study, each group will complete the task using the other application. So the groups that used YouTube last week in part 1 of this user study will use the Video Collaboratory to complete the task and vice versa. You will start the task today and will spend around 7-8 minutes on the task. You will have access to the video till tomorrow 5pm to complete the task.

2. You have been sent an email that contains the URL of YouTube video or URL of video collaboratory depending on your group.

3. Task - Reach a consensus on 3 things you would change in the provided video to make it better. The three things should be specifics about different segments or a point on the video. It shouldn't be about the general quality of video such as "the video is not clear" or " sound quality should be better." It should be about specific points in the content of the video. The 3 things must be ranked in the order of priority. All the communication must happen through the video platform and/or Google docs. You should not use email or get together in person to perform the task.

5. You can use your assigned application's inbuilt commenting system and/or you can use the google doc link to discuss the video. The google doc link is included in the email that I sent to you.

6. I will send some emails tomorrow to remind you about the remaining time to complete the task.

7. Make sure to capture screen recording of one of your sessions and upload it to the shared dropbox folder. You can use Quicktime on MAC or VLC player or Camstudio on Windows. A link to download VLC player and another YouTube link on how to use it to screen capture has been included in the email.

8. After the completion of the task, I will send you a link to a post-test questionnaire. Please complete the questionnaire.

Thanks again for taking out time to participate in this user study. Let me know if you have any questions.

APPENDIX B: USER STUDY - FIRST EMAIL SENT TO EACH PARTICIPANT

Hello Group D members,

Thanks for participating in this user study. Please read the following details about this study:

1. Your group will complete the task using YouTube application. You can access the video on YouTube at any time at your convenience by tomorrow till 5pm to complete the task.

2. URL - Link to the video on YouTube or link to the VideoCollaboratory

3. Task - Reach a consensus on 3 things you would change in the provided video to make it better. The 3 things must be ranked in order of priority. All the communication must happen through the video platform and/or Google docs. You should not use email or get together in person to perform the task.

5. You can use the YouTube inbuilt commenting system and/or you can use the following google doc link to discuss the video.

Google doc link: Link to the Google Doc

6. I will send reminder emails tomorrow.

Thanks again for taking out time to participate in this user study. Let me know if you have any questions.

-Vikash

APPENDIX C: USER STUDY - REMINDER EMAIL

Hi Group D members,

I wanted to let you know that you have till 5pm today to complete the HCI user study. Your group is working with YouTube to complete the task. Please note that as a group you have to reach a consensus on 3 things you would like to change in the video. You also need to rank those 3 things in order of preference.

You can only use the YouTube inbuilt commenting system and/or you can use the following google doc link to discuss the video. YouTube URL - Link to the video Google doc link: Link to the Google Doc

I have shared a dropbox folder through another email where you can upload the screen recordings of your sessions.

Thanks again for participating in this user study and helping me in this research. Let me know if you have any questions.

-Vikash

APPENDIX D: USER STUDY - EMAIL TO PARTICIPATE IN A SURVEY

Hi Group A members, Thanks for participating in this user study. Please find attached a short survey asking questions about your experience with the tool you used. This shouldn't take more than 10-12 minutes of your time. Your reply will be anonymous and it will help me understand your experience with the tool.

URL: Link to the survey

Let me know if you have any questions.

-Vikash

APPENDIX E: USER STUDY - EMAIL TO PARTICIPATE IN AN INTERVIEW

Hello everyone, Thank you for taking part in the HCI experiment 'VC vs YouTube'. As a final part of this experiment I would like to interview you for 15-20 minutes. The location can be UNCC Library, Union, Woodward or any other place that is convenient for you. Please select a date and time from the following link that fits best for your busy schedule. Let me know if none works for you and you could be available on any other day/time.

URL: Link to Doodle to schedule interview

Thanks, Vikash

APPENDIX F: USER STUDY - SURVEY QUESTIONS

All of the following survey questions were responded through a linkert scale: 1(Strongly Disagree) - 5(Strongly Agree). The following questions use the Video Collaboratory (VC) as example. The questions for participants who used YouTube were same but the phrase 'the Video Collaboratory' replaced with 'YouTube'.

- If I had to collaborate with others around a video document then I would like to use the Video Collaboratory (VC).
- I found the VC unnecessarily complex for collaborating with others around a video document.
- I thought the VC was easy to use for collaborating with others around a video document.
- I found the various functions in the VC well integrated for collaborating with others around a video document.
- I thought there was too much inconsistency in the VC for collaborating with others around a video document.
- I would imagine that most people needing to collaborate with others around a video document would learn to use the VC very quickly.
- I found the VC very cumbersome to use for collaborating with others around a video document.

- I felt very confident using the VC for collaborating with others around a video document.
- I needed to learn a lot of things before I could get going with the VC for collaborating with others around a video document.
- When collaborating with others around a video document the VC allowed me to be very specific in my communication.
- When collaborating with others around a video document, the VC made the task of communicating with my collaborators easy.

Following questions were asked in the survey as short answer questions:

- What do you like best about the VC for collaborating with others around a video document? (Joy points)
- What do you like least about the VC for collaborating with others around a video document? (Pain points)
- What would you do to improve the Video Collaboratory system for collaborating with others around a video document?
- Do you have any other comments or suggestions?

In the Part 2 of the study, the survey also included the following question: Which of the two tools would you prefer to collaborate with others around a video document?

APPENDIX G: USER STUDY - INTERVIEW QUESTIONS

- How did you use the two systems for completing the task? Could you explain the process?
- What did you find different about the two systems?
- What did you like about the VC/YouTube for working on this task?
- What did you not like about VC/YouTube for working on this task?
- Which system made you want to communicate more?
- How complex or easy was VC/YouTube to work with on this task?
- How confident did you feel working with VC/YouTube on this task?
- How easy or difficult was it to communicate with your team member using VC/YouTube?
- How pleasing was the UI of VC/YouTube visually?
- Which system would you prefer to use again and why?
- Which system was better in user experience and why?

APPENDIX H: CHOREOGRAPHER INTERVIEW QUESTIONS

- How did you use Chono? (prompt: video uploaded, sketching/commenting?)
- How why when (daily and weekly time patterns, in relation to rehearsals?)
- How was Chono used in the different development stages? (prompt: design phase (early) vs. practice period (mid) vs. refinement (late) and production week)
- How did the dancers know a video had been uploaded to Chono?
- What do you like and dislike about Chono?
- What are advantages and disadvantages of using Chono?
- From your perspective, comment on the use of Chono for assigning homework?
- From your perspective, comment on how Chono impacted the feedback and correction process?
- From your perspective, comment on how dancers commented/communicated through Chono?
- From your perspective, comment on how chono influenced the quality of dancing?

APPENDIX I: DANCER FOCUS GROUP SCRIPT

- How did you use ChoNo? (prompt: video, sketching/commenting?)
- Melissa set exercises/homework using Chono? Can you describe that experience and comment on it?
- Can you comment on how Chono impacted the feedback and correction process?
- How why when (daily and weekly time patterns, in relation to rehearsals?)
- How was Chono used in the different development stages? (prompt: design phase (early) vs. practice period (mid) vs. refinement (late) and production week)
- How did you know a video had been uploaded to Chono?
- What do you like and dislike about Chono?
- What are advantages and disadvantages of using Chono?
- Did you add comments to Chono? Comments on that experience?
- Did ChoNo influence your dancing? (eg the quality of your dancing)