Hypervideo and Cognition:
Designing Video Based Hypermedia for Individual Learning and Collaborative Knowledge Building

Abstract: This chapter discusses how advanced digital video technologies, such as hypervideo, can be used to broaden the spectrum of meaningful learning activities. Hypervideo is conceptualized as the true integration of video into non-linear information structures by means of spatio-temporal links. Based on cognitive-psychological perspectives, the discussion focuses on the way cognitive and socio-cognitive processes relate to the specific characteristics of hyperlinked videos, and how they inform their design. Then, with regard to technology, two approaches are introduced, providing tools for knowledge building and interaction with non-linear information structures based on dynamic video information. Case studies and research findings are presented and prospects for future research are outlined.

Keywords: Web-Based Learning, Collaborative Learning, Technology-Enhanced Learning, Knowledge Integration and Sharing, Hypermedia Technologies, Educational Multimedia, Interactive Technology, Digital Video, Annotation, Instructional and Presentation Design

INTRODUCTION

New technologies do not only meet existing needs in terms of communication and learning practice, they can also redefine our educational culture by enabling new learning experiences in resource-rich learning environments (Beichner, 1994). For example, the advent of video technology, including both analog and advanced digital video, has substantially altered some of our traditional paradigms of educational practice in schools and higher education. Film and video technologies can be used to enrich regular lessons and lectures with dynamic visualizations of knowledge that foster a better understanding, to depict concrete real-world problems or cases in authentic ways, or to conduct video projects, a specific kind of media project where students engage in active video production in a motivating and authentic collaborative task (Baake, 1999). However, by itself, video provides a limited support for reflection and it is difficult to relate it to other materials and activities in learning environments.

Hypervideo technology, which refers to the integration of video in hypermedia structures, can provide the additional means to augment video educational capabilities, contributing to learning in several distinct ways: as a presentation medium, it can support self-regulated cognitive processing of dynamic visualizations; as a non-linear and interactive medium, it allows for interactive learning, as well as for reflective and elaborative knowledge building individually or in group (Chambel & Guimarães, 2002; Chambel 2003; Guimarães et al., 2000; Zahn et al., 2002, 2004; Zahn & Finke, 2003). These ideas, their underlying assumptions, and the mechanisms for the design and realization of systems that support them in learning contexts, will be discussed in more detail in the following sections.

WHAT IS "HYPERVIDEO"?

The term "hypervideo" reflects the idea of true integration of video in hypermedia spaces, where it is not regarded as a mere illustration, but can also be structured through links defined by spatial and temporal dimensions (Chambel et al., 2001; Chambel & Guimarães, 2002). Hypervideo structures may also be defined as a combination of interactive video and hypertext, as they consist of interconnected video scenes that may further be linked with additional information elements, such as text, photos, graphics, audio or other videos in the hypermedia space (Zahn et al., 2002).

The roots of hypervideo structures lie in the early days of hypertext, when Ted Nelson extended his hypermedia model to include “branching movies” or “hyperfilms” (Nelson, 1974). However, technology has been slow in bringing these ideas to full realization (Chambel et al., 2001; Chambel & Guimarães, 2002). HyperCafe (Sawhney et al., 1996) is one of the earliest hypervideos, featuring digital video and revisiting hypermedia concepts in this scenario. Since then, different levels and types of video integration in hypermedia have evolved (Zahn et al., 2002). For example, regarding the **media types** that are involved in the hypervideo, we might differentiate between:

- *Homogeneous hypervideo*, where video is the only medium involved, consisting of dynamic audio-visual information presented as a continuous stream of moving pictures that can be navigated by the user;
- *Heterogeneous hypervideo* that integrates other media, providing further and related information to the video, or having video illustrate and complement it. For this broader perspective, the name of “video based hypermedia” or “hyperlinked video” (Chambel & Guimarães, 2002; Zahn & Finke, 2003) is sometimes adopted.

We might also differentiate between different types of hypervideo with regard to their **structure** and **navigational** options:

- Video nodes may be structured in a *network-like* hypervideo, where a substantial number of short video scenes are linked together to be *freely navigated* by the users, as is exemplified in “HyperCafe”, (Sawhney et al., 1996);
- A linear film may be divided into single scenes, according to different themes that can be navigated as *thematic paths* in the hypervideo. Depending on the theme

specified, different sequences of the film's scenes can be arranged and selected by the users, to be viewed in succession. By following different thematic perspectives, viewers are assumed to develop a more flexible mental representation of the structure and content of the film. This concept is exemplified in a well-known hypervideo tutorial for the interpretation of Orson Welles' film "Citizen Kane" described by Spiro & Jehng (1990);

- Another type of hypervideo can be described as a *film supplemented by multimedia "footnotes"*. Basically, a "main" film is presented in its original form (i.e. in linear sequence), but contains dynamic hyperlinks attached to visual objects within the video that branch out to additional information elements, such as a text, an image, or another video clip. After having visited the link destination, the users get back to the main video and may continue watching it as before. This type is very similar to hierarchical hypertext.

Hypervideo shares with classical hypertexts the characteristic of being structured in non-linear ways according to different patterns, offering the users opportunities of taking different "routes" through learning materials and learning processes. This cognitive dimension in the design and use of hypervideo is the main focus of the next sections.

LEARNING WITH HYPERVIDEO

An effective design of tools and environments that support learning requires the understanding of human cognition and learning processes. This section presents the main cognitive concepts relevant for discussing video and hypervideo as supporting tools for learning.

Cognitive Modes, Learning Phases and Learning Styles

Norman (1993) identifies two **Cognitive Modes**: the *experiential mode* relates to a state in which we perceive and react to events in an effortless way, it is about perception and motivation, and good for accretion of facts and tuning of skills; the *reflective mode* relates to comparison and contrast, thought and decision making, essential for restructuring of knowledge. Both are important in human cognition, but they require different kinds of technological support.

In addition to cognitive modes, different **Learning Phases** have been identified for the learning process. The classic learner centered pedagogy model has three phases:

1. *Conceptualization* of the subject and its domain;
2. *Construction*, where the learner actively engages with the subject, while relating to her own knowledge framework;
3. *Dialogue*, where the learner expresses aspects of the emerging understanding and relates this to the understandings of fellow learners and tutors.

Besides different cognitive modes and learning phases in individual learning, people also develop different **Learning Styles**, or cognitive preferences, that determine the ways of learning best suited to them. There are many theories, models, and instruments to determine learning styles, but they are all essentially based on the idea that individuals perceive, organize or process information differently (Chambel & Guimarães, 2005). Examples of these theories include: the VARK Perceptual Learning Styles (Fleming, 1995), distinguishing four styles: visual, aural, read-write, and kinesthetic; the Kolb's Learning Styles Inventory (Kolb, 1984), identifying four styles: reflector, pragmatist, theorist, and activist; and the Howard Gardner's Theory on Multiple Intelligences (Gardner, 1983), identifying eight intelligences: verbal-linguistic, logical-mathematical, visual-spatial, musical-rhythmic, bodily-kinesthetic, interpersonal, intrapersonal, and naturalist.

This differentiation suggests a need for a flexible support of different styles. An ideal learning environment would support all the learning styles, with the flexibility to allow each learner to spend more time on her preferred style, and induce the development of skills in non-dominant styles.

It is important to note in this context, that not only different individuals, but also possible *interactions* between different individuals in learning groups, might be considered. The dialogue phase and some learning styles, like the one underlying the interpersonal intelligence, already refer to this interactive dimension, but learning in groups involves more specific aspects that will be addressed in the next section.

Learning in Groups – Group Learning

Although learning in the long run is always based on individual cognitive processing, it is at the same time situated, process-oriented and related to social activity (Salomon, 1993). Many theorists of educational psychology and pedagogy therefore argue that intelligence is not an individual property but distributed within socio-technical systems (Pea, 1993) and that most learning occurs within a framework of knowledge communication and knowledge-related cooperative and collaborative action (Salomon, 1993; Scardamalia, 2004). Such a framework can be provided, for example, by collaborative problem solving tasks including collaborative activities such as writing texts or editing hypertext and multimedia (Beichner, 1994; Scardamalia, 2004; Stahl, 2002).

The educational value of such collaborative tasks may be seen on both a motivational and a socio-cognitive level. On the *motivational level*, the experience of solving a complex problem or designing any kind of product in collaboration with others (peers, teachers, etc.) and thereby using a modern and culturally extended technology (computers, software, authoring tools, and video) can promote a feeling of importance (Carver et al., 1992), and improve the self-conceptions of learners (Lehrer, 1993). It may also particularly increase feelings of becoming a competent member of a "community of practice" (e.g. Penuel et al., 1999).

On the *socio-cognitive level*, collaborative tasks serve as a setting where individual knowledge interacts with group knowledge. Applying Salomon's (1993) spiral interaction model, we can assume that repeated interactions between individual knowledge and group knowledge during discussions and discourse steadily lead to higher levels of knowledge related to both individual cognition and to the knowledge resources of the group. The basic argument underlying such positive expectations derives from developmental psychology, where individual cognitive development is generally assumed to be facilitated most where it naturally occurs from the very beginning of life, i.e. during the social interaction with 'significant others' and during peer interactions (e.g. Vygotsky, 1978). Or in terms of contemporary Computer Supported Collaborative Learning (CSCL) theory, individual knowledge develops best within group knowledge processes involving both socio-cognitive processes and cultural artifacts (Stahl, 2002).

Group knowledge is also referred to as "shared knowledge" or "common ground" (e.g. Baker et al., 1999). In contrast to individual knowledge, group knowledge must be identified, negotiated upon and *expressed in the form of shared information* during different phases in collaborative knowledge acquisition. Group knowledge is developed by learners acting collaboratively on shared information such as texts, images or even dynamic videos or animations. Activity contexts for interactions between learners should be provided for groups to develop this common ground and to express their shared knowledge in a shared information environment.

After having outlined the general arguments in favor of flexible support for learning, we will consider in the next section why and when using dynamic visual materials, and video in particular, might be a good choice.

Video as a Cognitive Tool

There are a number of topics or problems that can hardly be understood without using dynamic visual materials as a referential basis. Imagine, for example, geography students exploring the formation of a thunderstorm (Mayer, 2001), or a group of school children trying to understand Newton's laws in their physics class. In some learning situations, videos or animations are not only a desirable, but an important prerequisite for successful learning to take place. From a cognitive perspective, audiovisual materials support learning:

- by *'replacing' real experience*, because of their authenticity and realism, which evoke feelings of "observing real situations" (Schwan, 2000). Concrete real-world problems or cases can be depicted in authentic ways and then related to more abstract knowledge and problem solving skills. This is illustrated, for example, by the famous "Jasper Woodbury Series", a set of interactive videos developed by the Cognition and Technology Group at Vanderbilt University in the late 1980's and 1990's for complex mathematics problem solving (Jasper Project, 1997). Here, video is supposed to help to situate knowledge for the purpose of "anchored instruction". It could be shown in an experiment that those groups of students who were asked a) to pose their own subordinate questions while working with the video, and b) to self-dependently find the relevant information to answer these questions in a video episode, outperformed other groups of students who just viewed the video episode and received general text-based information on problem solving unrelated to the video (Van Haneghan et al., 1992);

- by *visualizing dynamic processes*, which might not be observable in reality or which are hard to describe verbally (Park & Hopkins, 1993). Empirical findings on learning with video media consistently show that audiovisual presentation formats facilitate the comprehension and transfer of knowledge, especially in those domains where dynamic processes and concrete objects or complex systems need to be observable for a proper understanding of the topic (for overview, see Wetzel et al., 1994; Park & Hopkins, 1993);
- by *combining diverse symbol systems*, such as pictures, texts and narration, into coherent media messages (Mayer, 2001). The specific qualities of video presentations are supposed to support the construction of rich mental representations and, by dual coding (Paivio, 1986; Mayer, 2001), improve the transfer of knowledge;
- through the *conducting of "video projects"*, where learners engage in active video production, relying on an idea sometimes described as "learning by design"

(Reimann & Zumbach, 2001) or "project-based learning" (Baake, 1999; Bereiter, 2002). Video is not only used to present information or situate a problem to be solved; creating video artifacts is the problem to be solved.

In accordance with these assumptions, empirical findings have consistently shown that dynamic media facilitate the comprehension and transfer of knowledge in individual learning (Park & Hopkins, 1993; Mayer, 2001). In specific *collaborative scenarios*, video can also be considered supportive for cognitive processing. For reasons similar to those in the case of individual learning, video is helpful when meaningful collaboration depends on visual perceptions of concrete objects, actions, or complex relations; and when knowledge is created within networked groups, where learners do not meet in the same place at the same time and, hence, cannot observe the same things in the same situation. In these cases, video might support mutual understanding by acting as a referential anchor for collaborative activities.

To summarize, video, as dynamic and figurative information combined with verbal audio, forms a powerful means of communicating meaningful-scenarios rapidly and efficiently (LiestØl, 1999; Paivio, 1986). It can bring context to topics and enhance the authenticity of a computer based learning environment, thus fostering what Norman (1993) called an experiential cognitive mode. However, to allow reflection, a system must have a medium that affords adding, modifying and manipulating representations, and performing comparisons. It must also afford time for reflection, elaboration, and comparison processes. Broadcast television, and most videos, are usually watched in an experiential mode, and cannot augment human reflection in this sense (Norman, 1993). According to

Eco (1979), the lack of communication and debate is also an important drawback in television teaching capabilities. He claims that learning should take place in a broader context where discussion could happen.

The Role of Hypervideo

Television and video could as well be a powerful tool for reflection, if designed in a way that would allow the viewer to select what to watch, to control the pace of the information flow, to stop and make annotations, and to relate to other materials or to other people's points of view (Norman, 1993; Correia & Chambel, 1999; Zahn et al, 2004).

Hypervideo technology can provide this kind of support to the different learning modes, phases and styles, and integrate an environment that allows the communication and collaboration among learners, teachers, and other experts on the subjects at hand (Chambel & Guimarães, 2002; Correia & Chambel, 1999; Guimarães et al., 2000; Zahn et al., 2002; Zahn & Finke, 2003). Hypervideo might promote learning in its main modes and phases, for different individuals, by providing and supporting:

1) *Interactive access* to rich audio-visual information, contextualized in video based hypermedia spaces;

2) *Construction of knowledge* in a sense of relating concepts and expanding on them, using annotations and cognitive maps;

3) *Communication*, allowing the debate of ideas, the exchange and sharing of information and knowledge, or the collaborative elaboration of the previous hypermedia spaces.

By allowing the viewer to watch video in her natural experiential mode, and by inducing and supporting more active and reflective attitudes, through control, comparison, and annotations, hypervideo can support both cognitive modes suggested by Norman (1993). Its ability to integrate heterogeneous media and activities also allows the support of diverse learning styles and the interaction between different learners.

However, all this power is accompanied by potential complexity and may not be used to its best in all cases, especially for learners and authors with little experience and background knowledge. Hence, design guidelines play an essential role in the authoring of effective hypervideo spaces (Chambel & Guimarães, 2002; Zahn et al., 2002).

DESIGN FOR LEARNING WITH HYPERVIDEO

Hypervideo shares with traditional hypermedia the potential of an increased *cognitive load* that might also lead to *disorientation* (Conklin, 1987; Nielsen, 1995). But, in the case of hypervideo, this kind of problem might be even more pronounced. Due to its richness, video itself sometimes carries with it the risk of overstraining the cognitive capacities of the learner; and the dynamic nature of nodes and links may put time pressure on the users, when they are required to make navigational decisions (Zahn et al., 2002). The integration of a dynamic medium, like video, with static media, such as text and images, also raises important rhetorical and aesthetic challenges to hypervideo, since they induce different attitudes in the user (Liestøl, 1994; Sawhney et al., 1996, Chambel & Guimarães, 2002). It is important to avoid discontinuity, especially when navigating from a passive video watching to an active text reading experience.

The effective design of hypervideo spaces may greatly benefit from following guidelines that help to face the extra challenges video brings to the scenario, and from an adequate support from the underlying systems that bring these hyperspaces to life, as exemplified in the next two sections. Many of the mechanisms adopted for hypermedia need to be extended for hypervideo, in order to accommodate its increased complexity, and should address the provision of (Chambel & Guimarães, 2002):

- *Control*, to be able to navigate the videos and the hyperspace, for example, extra mechanisms have to be available in order to provide users with information about the existence (where, when, for how long) of links on the video – 'link awareness' (Chambel et al., 2001), a more complex issue in hypervideo, since video changes in time;
- *Consistency* and *coherence*, in terms of structure, interface and navigation, to reduce cognitive load (Zahn et al., 2002);
- *Context* for orientation purposes, for example through the synchronization of video with navigation maps;
- *Familiarity*, for example through the adoption of metaphors, like television, books, and traveling;
- and *Continuity*, especially when navigating between dynamic and static media, for a sense of unity and coherence.

Thus, it is a basic necessity to think carefully about how to adapt technology to the cognitive prerequisites of potential hypervideo users, thereby setting the groundwork for effective and satisfying learning to take place. The design approaches specified in the next sections encompass the following: (1) information is mainly presented by audiovisual media, (2) knowledge can be created collaboratively on the basis of video presentations, by means of both linking information and annotating, and (3) the process of knowledge building is reflected in resulting visualizations in the hypervideo structure.

HYPERVIDEO IN HTIMEL

To explore the use of hypervideo in learning environments, we developed the HTIMEL (HTML with Time Extensions) model and language, as an extension to HTML and existing Web tools (Chambel et al., 2001). The temporal dimension was considered to allow the addressing of video in space and time, for the definition of link anchors, and to synchronize media elements. New forms of integration, annotation, and navigation of video in hypermedia were conceived, with a special concern to the support of cognitive processes. These tools were used to create course material, mainly in literature and mathematics, following our ideas about the way video should be integrated and augmented to support learning (Chambel & Guimarães, 2002). Case studies were developed at the University of Lisbon, in collaboration with the Portuguese Open University, in the context of literature distance learning, and with the Center for Mathematics and Fundamental Applications at the University of Lisbon, the California Institute of Technology, and the Technical University of Berlin, for the communication and learning of mathematics.

The example presented in Figure 1 illustrates one of our case studies. The information is organized around text based and video based pages, that closely relate to the book and videotapes that were originally used in the course. Through their integration in hypervideo, relations among them could be fully captured, maintaining the original context. In text centered pages (Figure 1a), video is integrated as an illustration that is played when the hypervideo links defined in the text are followed. While keeping some familiarity with the book metaphor, the user has an augmented experience of text reading.

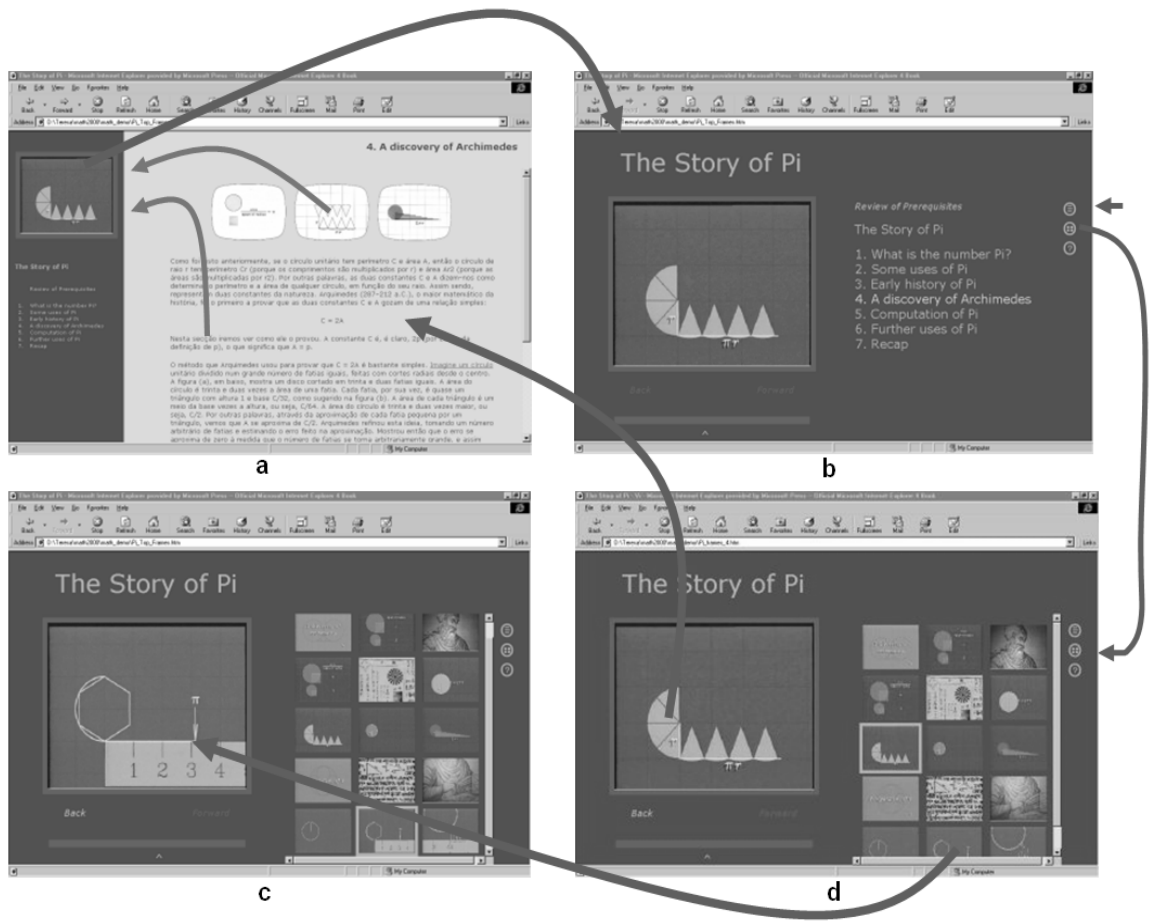

Figure 1. Hypervideo example in HTIMEL

The user may focus on the videos, through video centered pages (Figure 1b,c,d), where the whole video can be played. Indexes, synchronized with the video, make the video structure explicit, provide for user orientation, and can be used to navigate the video, handing control to the user. Different types of indexes act as different views or maps of the video. For example, a table of contents (Figure 1b) represents the video structure, whereas an image map (Figure 1c,d) is a visual summary of the video; a cognitive map represents its knowledge structure (Guimarães et al., 2000), while user annotations (Correia & Chambel, 1999) capture a personal view of the video (Figure 2c,d), and exercise maps (Chambel & Guimarães, 2002) relate activities and quests to video content. In video centered pages, while keeping some familiarity with the TV/video metaphor, the user has an augmented experience of video watching.

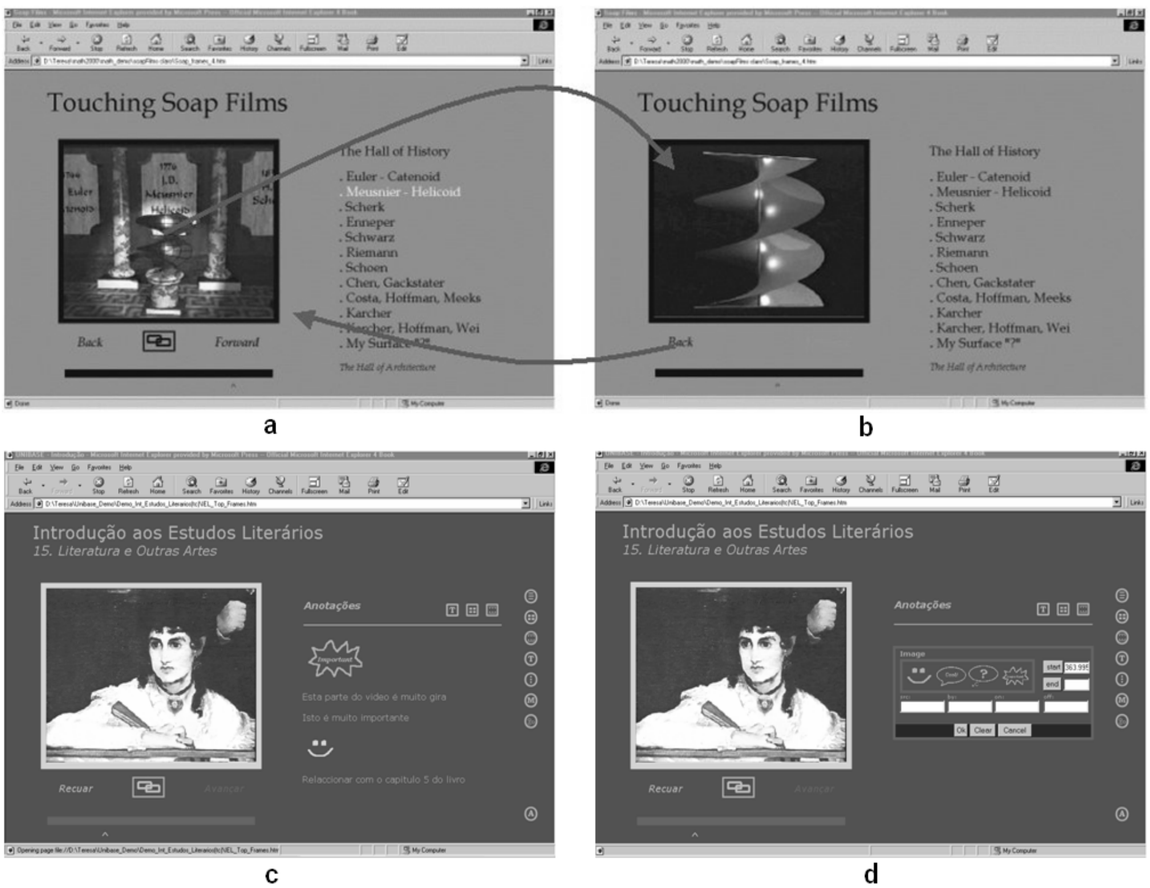

Figure 2. HTIMEL a-b) spatial-temporal link from video to video, and navigation history; c) annotations map; d) insertion of an image annotation to video

Links can also be defined among different parts of the video, addressed in space and time, allowing the user to navigate it through related information (Figure 2a-b), or among portions of video and text (Figure 1d-a), complementing or contextualizing the information conveyed by each of them. Another type of video linking is achieved through video montage. Authors can assemble video segments to make personalized versions of their favorite movies; and a teacher can make available portions of a video, in a particular order, to illustrate concepts in a context where the original video would not be so efficient or concise. Thus, it provides the means to construct hypervideo paths.

Navigation history is recorded, and lets the user go back and forward along visited nodes in the hyperspace (Figure 2b-a). When following from video centered to text centered pages, video or audio may provide context and smooth the transition from an experiential to a reflective medium. This was adopted when accessing exercises from a video on the Story of Pi. When arriving at the text centered page, the portion of the video introducing the solid the exercise refers to is played, promoting continuity in navigation.

Navigation can also be made through a timeline, positioned beneath the videos in the presented examples. It provides direct access to any position on the video, in a continuum, and in this sense it contrasts to video indexes that give access to specific positions in a discrete space. HTIMEL timelines also play a part in link awareness, representing the source and/or destination time interval, when the cursor is over any link that involves the video in the context. Besides, while the cursor is over the timeline, all the context changes, reflecting what would happen if the video was to play from that position, providing for context awareness. Other forms of link awareness mechanisms are discussed in (Chambel & Guimarães, 2002; Chambel, 2003). Being developed for the Web, these hypermedia spaces allow an easy integration of communication mechanisms. Students may then create their own versions of hypervideo documents, expand upon the original ones, through annotation, and share them with colleagues and teachers.

From our studies and experiences, we conclude that students are more motivated to watch the videos in this type of hypervideo than in traditional settings, as the process becomes more flexible and engaging; and it is easier to search for information and to capture the videos' messages through the different maps available. Video course material, as rich as it is, is better used in a reflective mode if presented in a way where the content or knowledge structure is made explicit. The full integration of video in hypermedia also allows the capturing of important relations between video and other media, like text, through contextualized explanations and illustrations that promote deeper understandings of the different materials. Different learning styles are also supported, through the integration of different media and perceptual modalities, interactive, and navigational choices (Chambel & Guimarães, 2002; Guimarães et al., 2000).

```
<DIV ClassName="HTIMEL_Video" ID="video1"
     activeColor="#EAAB4D" inactiveColor="#993347" spotColor="#FFFFFF">

  <OBJECT CLASSID="CLSID:05589FA1-C356-11CE-BF01-00AA0055595A">
         <PARAM NAME="FileName" VALUE="E:HPi.mpg">
  </OBJECT>

  <MAP name="map1" orgT1="226" orgT2="230">       <!-- spatio-temporal link from video-->
    <AREA shape="rect" coords="132, 131, 238, 242"
     ClassName="HTIMEL_link" destT1="1455" dest="video1">                <!-- to video-->
  </MAP>
  ...

</DIV>
```

Figure 3. HTIMEL code for video with a spatio-temporal link

From a technical perspective, HTIMEL is an extension of HTML. New elements and attributes were defined, and their functionality is supported by a set of scripts that are generic, reusable, and almost transparent to the author of the hyperdocument. The authoring process is done in a declarative way in HTIMEL. The current prototype is based on Dynamic HTML and uses VBScript language and ActiveMovie technology. Scripts deal with these language extensions, acting as a browser extension, in order to make the declarative authoring possible, without the need for plug-ins or the development of a different browser. Figure 3 exemplifies the definition of a spatio-temporal link from video to video, like the one presented in Figure 2a-b.

The adoption of a declarative format allows the externalization of documents' behavior and provides for maximum portability and reuse of created documents. While programming-based approaches may offer some performance advantages in the short run, a declarative approach provides wider access to quality information with less author effort. It contributes to easier authorship, either using a simple text editor, or through automated production. Open and flexible production frameworks that use video and audio processing techniques, for segmentation and indexing, were conceived to automate the authoring of hyperdocuments with markup languages like HTIMEL (Chambel, 2003). The image map presented in Figure 1c,d and the alignment of the video with the text transcriptions of its audio, in text maps, were constructed this way. From both cognitive and technical perspectives, HTIMEL has had good results as a proof of concept approach.

DYNAMIC INFORMATION SPACES (DIS)

To explore the use of hypervideos in collaborative learning scenarios, the Hypervideo System presented in the following paragraphs was developed. Here, hypervideo is conceptualized as a complex dynamic information space ("DIS"), where learners may add their own materials to selected video objects and make specific annotations, while collaboratively expanding their knowledge on the topic at hand. The general approach is aligned with considerations of cognitive psychology and theories of CSCL (Stahl, 2002).

Thereby, the system provides specific facilities to jointly elaborate on video materials and to change a hypervideo presentation according to the development of knowledge present in any group. Accordingly, a hypervideo document can be changed and extended as a basis to share knowledge and to communicate within a community. The underlying model of the dynamic information space defines three categories of content types (annotated video, additional information and communication contribution) as separate nodes. Video sequences, which contain sensitive regions, are denoted as annotated videos. Additional information, which is linked to objects in the annotated videos, can be of any kind of multimedia content (text, pictures, graphics, etc.). Communication contributions are the outcome of group conversations and can be linked either to video objects directly or to the associated additional information units.

The web-based HyperVideo System is based on a client-server architecture. The DIS containing the content of the hypervideo is stored entirely at the server side preventing the users from any form of data inconsistency. The clients are allowed to extract (presentation mode) and to integrate (authoring mode) content to and from the DIS on request. The web-based graphical user interface consists basically of a special video player that presents visually the spatio-temporal hyperlinks besides the movie sequences within the video display and offers functionalities in order to create new video annotations.

The cross platform video player itself is written in JAVA using the Java Media Framework for the purpose of manipulative video rendering. New created video annotations are immediately transferred from the client to the server, in order to be instantly shareable by the community. The system concept allows the adaptation due to different GUI layouts. Thereby different end-device types can be supported. Figure 4 shows the overall system architecture concept of the collaborative hypervideo-system, as suggested by Finke & Balfanz (2004).

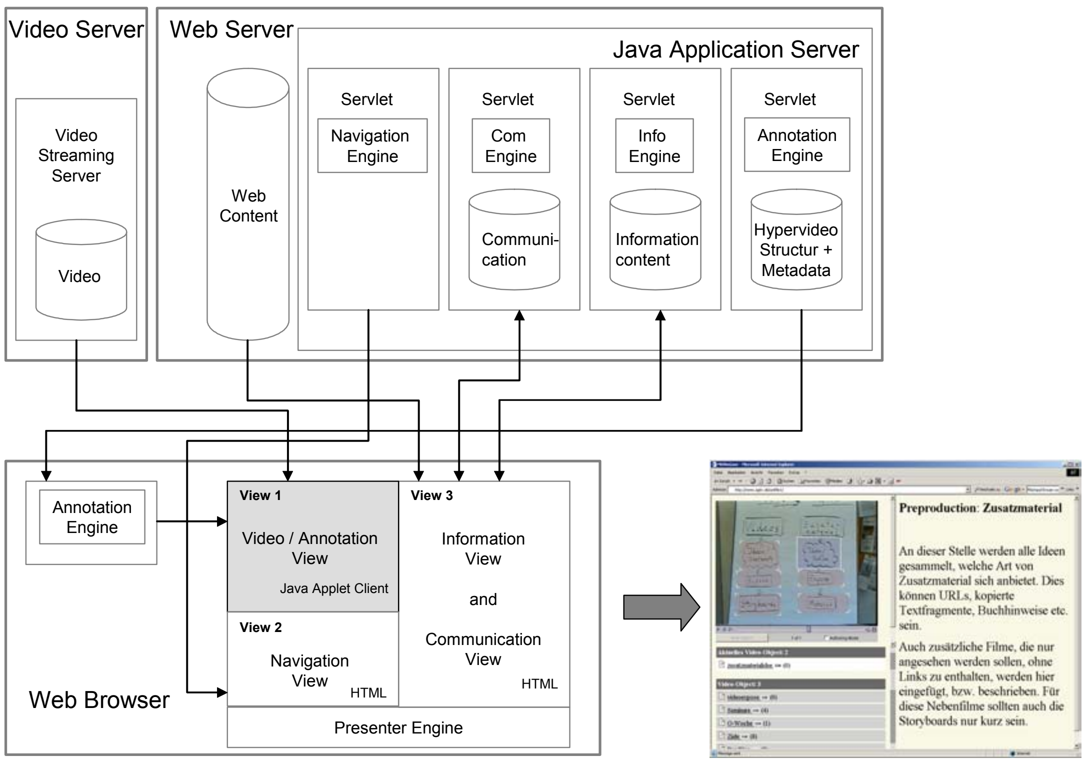

Figure 4. DIS - System Architecture

The human computer interface concept is based on a view model (see figure 5). This model allocates for each node type (annotated video, additional information, and communication) a separate view within the graphical user interface. In addition, a fourth view is introduced that enables the disclosure of the hypervideo-structure in order to support user orientation within the graphical user interface.

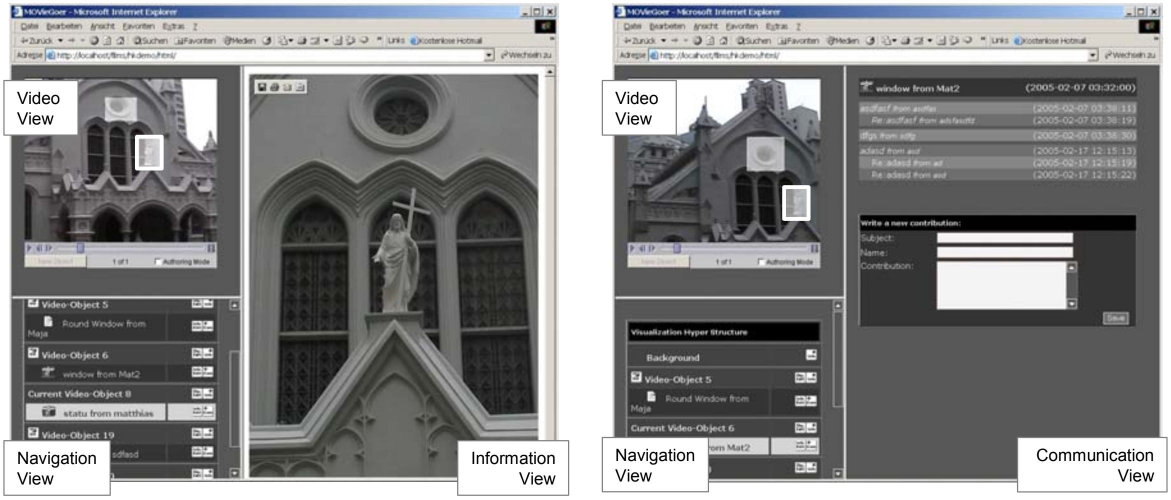

Figure 5. DIS - Examples of the graphical user interface showing the different views

Each view provides its own user interface to access certain parts of the dynamic information space (see figure 5). By means of these interfaces, a user can initialize so called system events, for instance the activation of a hypervideo-link, by clicking on an object in the video view. Each view offers a number of different facilities:

- *Video view:* The video view presents video sequences containing video annotations. By means of VCR-functionalities, a user can control the tempo of the presentation. The existence of a video annotation is announced by the visualization of its sensitive region within the video display. Since it might be disturbing in some learning situations, the user is in charge of initializing the visualization process of sensitive regions. Hypervideo-links can be activated by clicking on the corresponding sensitive region with a mouse pointer. Furthermore, the video view is used by the user to generate a sensitive region, which defines the anchor of a hypervideo-link;

- *Information view:* Within this view, the information nodes are displayed, which are linked to sensitive regions in the annotated video sequences. The information view offers the definition of hypervideo-links. Thereby, more than one information node can be linked to a sensitive region in the video view (multiple link strategy);
- *Communication view:* The communication view presents the group conversation in the form of text based dialogs. Users can reply on existing conversation or start a new dialog. Thereby, a dialog is always related to an object in the video or to a specific information node. This provides us with the opportunity to combine conversations with associated subjects within the hypervideo. The advantage is that a user has a fast access to specific conversations and does not have to go through the entire communication contribution created by the community;
- *Navigation view:* Within this view, the disclosure of the hypervideo-structure is presented in order to support user orientation. The arrangement of all node types within the structure is visualized in a text-based manner. Users can browse the navigation view and activate hypervideo-links, which will lead to the presentation of the content in the associated views.

The development of the web-based user interface based on the view model was paralleled with experimental work on learning with hypervideo environments and case studies in the context of university teaching. The experimental research was conducted at the University of Tuebingen in Germany, in cooperation with the Computer Graphics Center at Darmstadt in Germany with an earlier version of this HyperVideo System. Results revealed that hypervideos provide a very successful mode of learning, also positively acknowledged by the satisfaction of the 74 subjects. Results further suggest that slight variations in design options concerning position and number of links to additional information did not significantly influence navigation and successful knowledge acquisition in individual learning, but individual strategies and navigation behaviour, including exploration activity, redundancy, and duration of links activated, were significantly and positively correlated with knowledge acquisition (Zahn et al., 2004).

Our current research projects focus on collaborative "learning by design" and include an implementation study with two media psychology courses at the Universities of Muenster in Germany and Linz in Austria (Stahl et al., in press). In this project, about 30 advanced psychology students collaboratively designed hypervideo structures on "presentation techniques". Results indicate a great general satisfaction with the work of crafting hypervideos with the system.

CONCLUSIONS AND PERSPECTIVES

From a cognitive viewpoint, video can be considered a powerful referential anchor, serving to stimulate and facilitate both individual and collaborative processes of learning and knowledge building, particularly in specific domains such as the natural sciences, which rely heavily on visual phenomena. Video provides context information in an efficient way but has limited advantages to reflective learning. Hypervideo additionally allows more control and the composition of rich and flexible knowledge structures, corresponding to enriched mental models. Learners may also express their internal knowledge structures externally and share and discuss them with other students. Thus, hypervideo provides a better support to reflection and learning, in accordance with learners’ individual needs and styles, at different learning phases (Chambel & Guimarães, 2002; Guimarães et al., 2000; Zahn et al., 2002).

From our experiences, we concluded that the ability to integrate video in rich hypermedia spaces enables learners to create rich representations and promotes deeper understandings. It improves both text and video understanding, due to the contextualized explanations made possible by the integration of both materials. Important relations with video information can be captured. However, there are some main challenges, including the management of a potentially high cognitive load in processing information based on hypervideo, and usually significant investments involved in the production of multimedia and video based products. The definition of design guidelines and the development of effective and flexible production frameworks and authoring tools can help to meet these challenges. Some work has been done in this direction (Chambel et al., 2001; Chambel & Guimarães, 2002; Zahn et al., 2002; 2004), but more research needs to be done.

Our directions for future research, either from a cognitive and technical perspective, include new developments in tools and design guidelines for hypervideo in different environments and contexts of use. This process involves the definition and evaluation of new mechanism to support individual and collaborative learning with video on the Web and also in interactive TV and mobile environments. It also includes the interaction with video augmented books, furthering our previous research on hypervideo and digital talking books. In collaborative learning, for example, a project will investigate the interactions of modern hypervideo technology with individual cognition and teachers’ instructions while supporting group discussion. The topic at hand will be “persuasive strategies of TV advertising”, for media education in secondary schools, and the learning goals include visual and digital literacy skills. The main focus will be put on students' communication patterns, collaborative hypervideo design processes and the groups' products. In summary, we intend to explore a broader approach to the support of individual and collaborative learning, inspired by field studies in different learning contexts that might raise specific challenges and require differentiated support.

Our cognitive relation with video is not only experienced in formal learning. Most of the considerations made, and the approaches proposed also apply to many other applications, including situations of informal learning and art works. Because video has important communicative, entertaining and artistic properties, hypervideo can be used to support new forms of expression in new media (Url-nm) in many areas of culture and entertainment, for example in interactive cinema, electronic literature and museums. These areas can benefit from many of the mechanisms developed for learning environments, but they may as well raise new challenges that will inspire new methodological and technological developments.

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