Do it yourself? Interactive visualizations as cognitive tools

Stephan Schwan
Department of Applied Cognitive Psychology and Media Psychology
Konrad-Adenauer-Straße 40
D-72072 Tübingen, Germany
stephan.schwan@uni-tuebingen.de

Abstract: The present paper discusses the benefits of enriching traditional visual-iconic media (e.g. films and videos) with interactive features. It will be argued that while traditional visual media allow for adapting the information presentation to the human cognitive system *in general*, interactive visual media allow for an adaption to the *individual* cognitive needs of its users. But in order to be effective and efficient, interactive visual media must meet a number of requirements, including a fit between the author´s conception of interactivity and the user´s respective expectations, the availability of adequate usage strategies, as well as a positive balance between the cognitive costs of a heightened workload and the cognitive benefits of a reduced mental effort due to epistemic activities.

Introduction

Over the last two decades, the art of presenting information has undergone dramatic changes due to the development of computer systems which are capable of processing and displaying huge amounts of information almost instantly. Therefore, new visual media like interactive videos, hypervideos, or virtual realities have emerged, which combine realistic, iconic depictions with three main characteristics of the so-called "new media": Its non-linear structure, its concerted use of a great number of different symbol systems, and its interactivity, which gives the users the opportunity to decide on the "what" and the "how" of the information presentation. It is this last aspect of the new visual media – its *interactivity* – which will be the focus of the following sections. In particular, it will be discussed if and under what circumstances the enlarged scope of action on the side of the user leads to a better processing und understanding of the presented information. From a cognitive standpoint, this problem may be decomposed into two different aspects. In the first section, the difference between direct and mediated experience will be considered. Against this backdrop of the cognitive purposes of media *in general* the second part will address the question of the cognitive benefits of *interactive* visual media in particular.

The cognitive benefits of media-based information over direct experience

Cognitive psychology rests on the assumption that the main purpose of the mental apparatus of human beings is to represent and process information (Thagard, 1996). From the perspective of human evolution, the human information processing system has developed in times where no media were at hand (Donald, 1991). Thus, the cognitive apparatus is well adapted at conditions of direct, unmediated experiences. Nevertheless, a large number of empirical studies in the field of media psychology have shown that recipients can also deal with media based information with apparent ease. This is especially true for iconic depictions – be it static pictures and photographs or dynamic movies and video clips (Messaris, 1994) - which leads to the conclusion that at least realistic, iconic media make use of general, media-unspecific cognitive skills (Anderson, 1996).

But iconic media should not be conceived as simply being convenient means of storing and transmitting information which is otherwise more or less cognitively equivalent to its "natural", unmediated counterparts. Instead, one of the main benefits of media-based information presentations is that they allow for *customizing* its contents according to the cognitive needs of its users. For example, Schwan, Garsoffky & Hesse (2000) could show that film depictions of complex activity sequences were better understood if activity boundaries were made more salient through the placement of film cuts, thereby facilitating the process of cognitively segmenting the stream of activity into comprehensible units. Also, Schwan, Garsoffky & Hesse (manuscript submitted) could show that film summaries of complex activity sequences led to mental representations which were similar to those developed from complete,

unshortened depictions of the event, thereby reducing the necessity for the viewers for cognitively selecting and aggregating relevant parts of the activity.

To put in more general terms: Media-based information presentations like photographs or movies are not merely valid reproductions of real facts, but are *instruments for information processing*. They give its authors and producers a great degree of freedom for shaping the presentation of information. These degrees of freedom may even be greater than for a common observer under conditions of natural, everyday experience. For example, a film director can record a given event simultaneously from multiple viewpoints, and can subsequently choose the best, "canonical" view for each part of the event. In contrast, everyday observers typically are restricted to their particular standpoint (Garsoffky, Schwan & Hesse, in print). In other words, media authors have possibilities of optimizing the experiencing conditions for events which ordinary observers do not possess. As a consequence, this leads to a kind of "working division" between author and recipient (Figure 1). The recipients delegate the shaping of their conditions of experience to the author. In turn, the author designs the information presentation in order to facilitate and partly anticipate the cognitive processes of the recipients. The recipient then follows the media presentation and processes it in a mostly predetermined way. This is exemplified by watching a movie or a TV report: Here, sequence and pace of the film presentation determine to a large extent the mental processes of the viewers. Keep in mind, that this model is not equivalent with the notion of the recipient as a kind of passive "couch potatoe". Instead, comprehending the media presentation encompasses a number of information processing activities. But these activities are restricted to internal, mental processes, whereas overt activities in the sense of modifying the given media presentation are kept at a minimum.

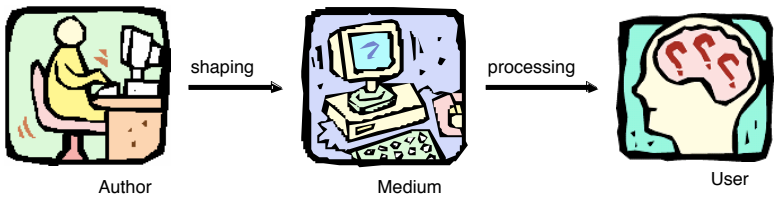


Figure 1: Traditional media are based on a strict working division between author and user

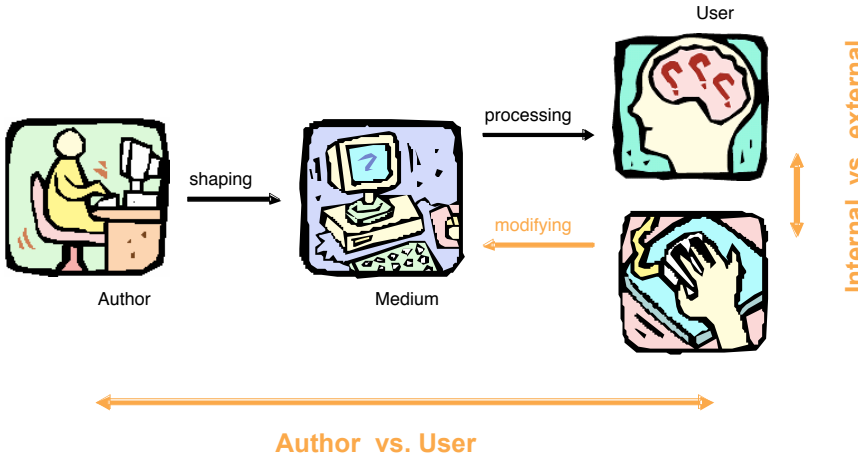


Figure 2: Interactive media require author and user to collaboratively shape the information presentation. This has implications for the working division between author and user as well as for the relationship between the user´s external, media-directed activities and his or her internal cognitive processes

The prospects of new media: The case of videos as interactive visualizations

According to the above arguments, the main advantage of media over direct experience lies in their possibilities to intentionally shape, arrange, and optimize the to-be-experienced information with regard to the cognitive apparatus of its recipients. But this optimizing process also has its limitations. In general, media presentations address a great number of people, which differ in their cognitive characteristics to a more or less extent, e.g. with regard to their cognitive skills, their prior knowledge, their current interests, or their metacognitive strategies. For traditional media, it is almost impossible to take these individual differences into account. Instead, they have to rely on the notion of an "modal user", who is equipped with a set of common or average cognitive characteristics. Here, interactive media come into play, because they return parts of the process of shaping the information presentation to the user. They therefore allow him or her to adapt the presentation to his *individual* cognitive needs by actively deciding about the "what" and the "how" of a given information presentation (Figure 2). As a consequence, the introduction of interactivity into a given information presentation is reflected on two dimensions, which relate to the *working division between author and user*, and to the *interplay of internal (mental) and external (media directed) user activities*. Both topics will be discussed in the following paragraphs by comparing traditional videos with different kinds of interactive videos.

Working division between author and user: The problem of fitting design decisions with design expectations

During the course of developing an interactive information presentation, the author has not only to determine its content and form, but also to decide which aspects of the information presentation will be made modifiable to the user, which consequences these user-triggered modifications will have, and how these interactive opportunities can be made salient to the users. Thus, the strict working division between author and user is given up in favor of a more balanced approach. But for this balance to work, the design decisions of the author have to fit to the corresponding design expectations of the users.

To give an example, about ten years ago, the public TV channels in Germany launched a pilot project on interactive television. Two version of a thriller were broadcasted simultaneously over the two public channels, and the viewers could "assemble" their individual version by switching between the channels via remote control. As it turned out, the viewers largely ignored the cues that were included in the films in order to induce a meaningful interactive behavior, indicating an imbalance between the design principles of the interactive movie and the interaction expectations of the viewers (Kirchmann, 1994).

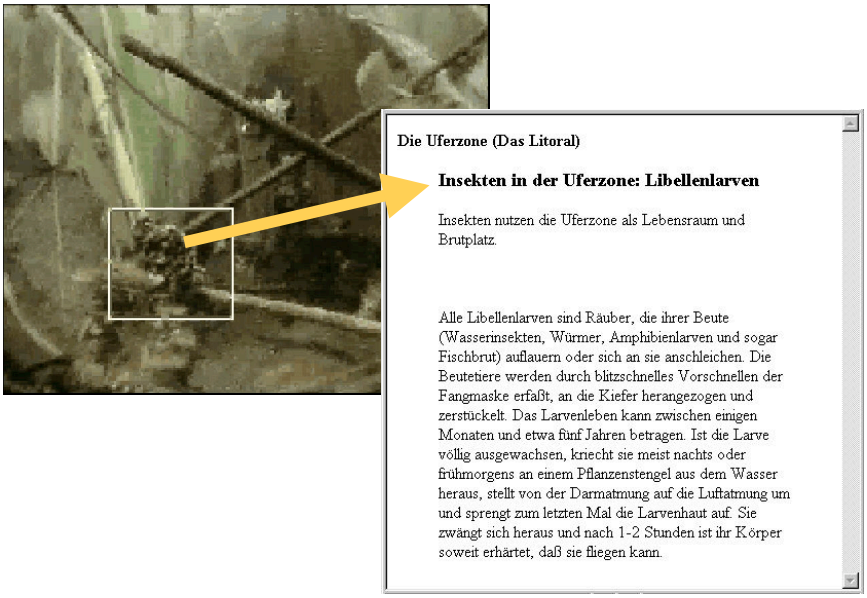


Figure 3: Example of a Hypervideo: By clicking on a hotspot, the user is branched to additional information

The same question was also addressed in a study on "Hypervideos" (Zahn, Schwan & Barquero, in print). Hypervideos are videos which contain so-called "hotspots", which are similar to links in hypertexts. They allow users to interactively branch to additional information screens, be it other video clips, texts, or illustrations (Figure 3). In our study, three different groups of participants, namely professional biologists, media designers, and biology novices were required to transform three different videos on biology into respective interactive videos by specifying the location, duration, appearance and content of hotspots. By comparing the design decisions of biologists and media designers with the design expectations of the users, we found a number of similiarities with regard to the duration, appearance and location of the hot spots.

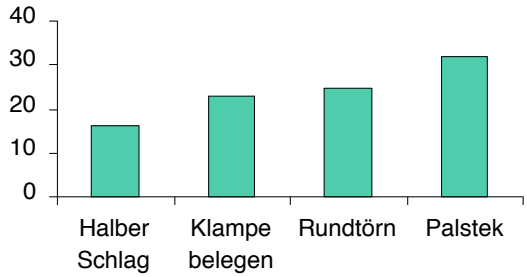
In sum, whereas the introduction of interactivity bears the danger of a mismatch between the design conception of the author and the design expectations of the user, this must not necessarily be the case. Instead, the findings of our study show that at least in this specific case users did formulate design expectations that the authors were able to accurately anticipate and implement.

The interplay between internal and external user activities

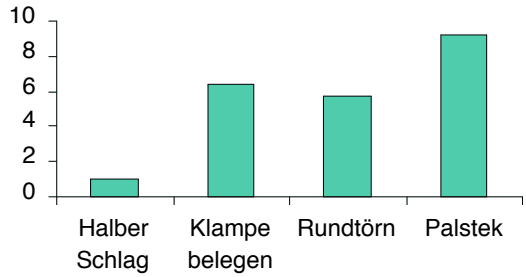
Making videos interactive does not only change the balance between author and user, but as also a profound impact on the mental processes of the users. Whereas the cognitive costs of introducing interactivity have been extensively discussed within the framework of cognitive load (e.g. Conklin, 1987), its possible cognitive benefits have not attracted a comparable attention. But according to Kirsh & Maglio (1994), interactively modifying an external information presentation may serve a number of cognitive purposes. By use of such "epistemic actions", mental processes may be facilitated and simplified, either by reducing the number of elements that have to be held in memory, by reducing the number of mental processing steps, or by making the whole process more reliable. In particular, one major cognitive problem of traditional films is their high pace of information presentation, leading to dangers of shallow processing and cognitive overload (Wetzel, Radtke & Stern, 1994). Therefore, one important purpose of making such video interactive may be to give the viewers the opportunity to adapt the pace and sequence of the presented information to their cognitive needs and skills.

Figure 4: Video still from the experimental videos

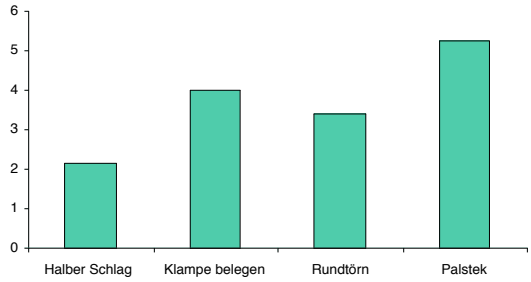
We addressed this issue in an experimental study, in which participants were required to learn nautical knots of different difficulty by watching videos which demonstrated to tying of the knot (Figure 4). For one group, the videos were non-interactive and could only be watched completely, for the other group, the videos were interactive, allowing the users to stop the video, to change its speed, and to play parts of the video back and forth. In the condition with interactive videos, the users made heavy use of its possibilities. Specifically, with increasing knot difficulty, the learners more frequently run parts of the video in slow motion. They also played parts of the videos back and forth more frequently. In effect, this led to an increased variability of the viewing times of the different parts of the videos for the more complex knots. In other words, the viewers used to interactive possibilities to watch the more difficult parts of the videos selectively, more slowly and repeatedly, indicating that they possessed a repertoire of adequate epistemic actions to adapt the videos to their cognitive needs (Figures 5a - c).



(a) Frequency of slow motion



(b) Changes in playing direction



(c) Variability of viewing duration within video clip

Figures 5 a-c: Relationships between knot difficulty (increasing from left "Halber Schlag" to right "Palstek") and usage of interactive features (a) Frequency of slow motion (b) Frequency of changes in playing direction (c) Variability of viewing duration of different parts within the video clip

Conclusion

While visual-iconic media possess the adavantage of being able to customize the presentation with regard to the cognitive system of its recipients, this design processes is limited by the individual differences of its potential users, which cannot be taken into consideration. Here, interactive media like hypervideos, interactive videos or virtual realities come into play by offering the users the opportunity to adapt the information presentation to their individual cognitive skills and needs by means of epistemic actions. But for these types of new media to be effective and efficient, some important questions must affirmatively be answered:

- Does the design conception of the interactive opportunities match the design expectations of the users?
- Do the viewers possess adequate usage strategies with regard to the interactive features of the presentation?
- Do the cognitive benefits of interactively modifying the information presentation though epistemic action must outweight the cognitive cost of experiencing a heightened cognitive load?

If these conditions are met, then interactive media may indeed lead to a more effective and efficient process of knowledge acquisition than traditional, non-interactive media. Again, this is exemplified by our study on nautical knots. Here, the group with interactive video clips needed significantly less time for viewing the videos as well as for practicing the knots, leading to a significantly reduced overall learning duration (Figure 6).

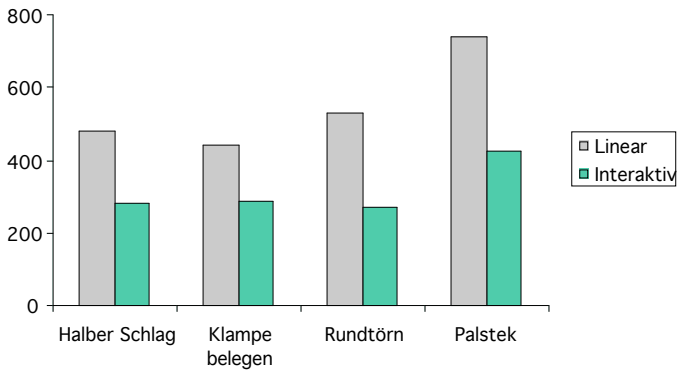


Figure 6: Overall learning duration for the non-interactive and the interactive video clips

References

Anderson, J.D. (1996). *The reality of illusion. An ecological approach to cognitive film theory*. Carbondale: Southern Illinois University Press.

Conklin, J. (1987). Hypertext: An introduction and survey. *IEEE Computer Magazine, 20 (9),* 17-41,

Donald, M. (1991). *Origins of the modern mind*. Cambridge, Mass.: Harvard University Press.

Garsoffky, B., Schwan, S. & Hesse, F.W. (in print). The viewpoint dependency of recognizing dynamic scenes. *Journal of Experimental Psychology: Learning, Memory, & Cognition.*

Kirchmann, K. (1994). Umschalten erwünscht? Wen ja, von wem? In H. Schanze (Hrsg.), *Medientheorie – Medienpraxis. Arbeitshefte Bildschirmmedien 48* (S. 23-60). Siegen.

Kirsh, D. & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science, 18*, 513-549.

Messaris, P. (1994). *Visual literacy. Image, mind, & reality*. Boulder: Westview Press.

Schwan, S., Garsoffky, B. & Hesse, F.W. (2000). Do film cuts facilitate the perceptual and cognitive organization of activity sequences? *Memory & Cognition, 28 (2),* 214-223.

Schwan, S., Garsoffky, B. & Hesse, F.W. (manuscript submitted). The cognitive representation of filmic event summaries.

Thagard, P. (1996). Mind. *Introduction to cognitive science*. Cambridge, Mass.: MIT Press.

Wetzel, C.D., Radtke, P.H. & Stern, H. (1994). *Instructional effectiveness of video media*. Hillsdale, N.J.: Erlbaum.

Zahn, C., Schwan, S. & Barquero, B. (in print). Authoring Hypervideos: Design for learning and learning by design. In R. Bromme & E. Stahl (eds.), *Writing Hypertext and learning*. Pergamon Press.