Instructional Design for Hyperaudio Learning with Cellular Phones

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ABSTRACT
Instructional Design using non-linear information media has become an established research area in applied learning sciences and cognitive psychology. Although there are many studies focussing on navigation strategies within non-linear hypertext and hypermedia, there is little or no contemporary research on non-linear audio-based learning environments. Non-linear audio learning environments (Hyperaudio) provide several opportunities of flexible and ubiquitous learning, e.g. by using cellular phones. As cognitive mechanisms in hyperaudio learning are different from mechanisms in hypermedia learning, issues of non-linear audio in learning environments have to be carefully examined. In several studies we examined the effects of hyperaudio learning environments on learning processes and outcomes. Results from the study presented here suggest that learning with hyperaudio opens a new research field offering a wide range of potential applications. Nevertheless, in order to gain benefits and to avoid cognitive overload in non-linear auditory learning environments the learning material has to be carefully designed.

KEY WORDS
Hypermedia – Cognitive Load Theory – Hyperaudio – mLearning

1. Introduction

In this paper the concept of hyperaudio as a certain kind of learning environment for mobile learning (mLearning) will be presented. While the concept of hypertext or hypermedia is well-known and there is a huge body on research on learning and instruction with hypertext, no or little research is dedicated to the use of different forms of codality or modality. Current developments leave the text-based level and address other forms of mediating information with computer technologies (e.g. hypervideo [1]).

This paper contributes to a new area within the field of non-linear information media: the use of non-linear auditory instruction. The concept itself is not a new one and is commonly used in everyday telecommunication: nearly everyone is faced with non-linear audio in using voice-mail boxes or automated helpdesk systems. Such service offerings are predominantly hierarchically structured hyperaudio systems. You most certainly have made your experience with voice-based menus via the phone or your own voice mail system: "If you want to receive your new messages press 1"; "If you want to receive your old messages press 2"; "If you want to change your basics press 3", etc.

Such systems can be assessed via cable based phone or cellular phone and are mainly non-instructional service offers.

There are some exceptions like audio-based services in museums or for sightseeing purposes. Normally, such offerings include audio-documents on demand explaining more about exposited objects or places of interest. In contrast to non-linear learning environments like hypermedia programs, such documents are locally and globally coherent and are not connected among each other via hyperlinks. Each audio document has to be navigated separately by choosing a specific code (e.g., by dialling a certain phone number on a public place) or is automatically played (e.g., when a visitor in a museum is approach a certain object that triggers playing of a audio file by means of a infrared sensor).

In this paper, a certain kind of stand-alone auditory instruction is addressed which is defined as a set of multiple navigable audio documents.

2. What is Hyperaudio? A Definition and Differentiation

Hyperaudio is defined here as an arrangement of information that is presented exclusively on the auditory channel and is mainly of non-linear nature [2]. Corresponding to hypertext, information is located within nodes (i.e., single audio files) that are locally coherent. These audio nodes are connected via hyperlinks that enable users to navigate within a hyperaudio learning environment. Global coherence building should be enabled by navigating a hyperaudio learning scenario. Users should be able to understand relationships between single audio nodes by accessing node by node via hyperlinks.

Similar to hypertext and hypermedia, possibilities of linking nodes and creating an overall navigation structure of a hyperaudio learning environment include several strategies of connecting content. Nodes can be connected and

accessed via hyperlinks in a linear, in a hierarchical, in an elaborative, in an associate manner, etc. [3].
Also similar to hypertext, the use of a linear hyperlinks leads to a special type of electronic resource that is, if the linking strategy is exclusively a linear one, a specific type of auditory instruction known as audiobook (the corresponding format of linear hypertext is an electronic book; although it seems contradictory to regard nodes linked in a linear manner as “Hyper”.-documents, most non-linear learning environments integrate partly linear information retrieval (e.g., by means of guided tours [4]). Audiobooks in general are read versions of printed books (sometimes enriched by music or sound) that do not have to meet the requirements of local coherence within single audio nodes. There are fiction and non-fiction products available within a steadily growing market. Yet, the structure of audio books is similar (linear) to that of printed books or electronic books.
In contrast to audio books, hyperaudio is understood here as a learning environment that enables learners to navigate freely within a network of locally coherent audio nodes. Thus, navigating each single node allows a learner to understand the content of this node without hearing other nodes or a prerequisite node sequence.
Application and distribution of hyperaudio learning environments is possible by means of current technological developments. Especially standards and developments in software (data reduction, e.g., MP3) and portable hardware devices (e.g., portable MP3-Players, integrated audio players in cellular phones or use of calling servers with audio services by a cellular phone) open a wide range of applications and can contribute to mLearning within ubiquitous computing learning environments [5] and learning with handheld computer devices [6].

3. Auditory Learning and underlying Cognitive Processes

Learning via auditory instruction is the most common way of teaching ever since humans were able to express themselves by means of language. While early forms of teaching and learning (e.g., in ancient Greek Philosophy) have used speech-based learning almost exclusively, the development of written and typeset text dramatically increased access to shared information and knowledge. With the beginning of learning research at the beginning of the 20th century, the comparison of auditory instruction with text-based instruction has started [7]. Some of the first studies comparing auditory instruction with text-based instruction showed advantages of the spoken word over the written word related to issues of knowledge acquisition. There were, however, many constraints of these early studies like role and behaviour of the reader or shortcomings in data analysis methods. 1950s on, contemporary research presented ambiguous outcomes of research on auditory vs. text-based instruction (for an overview see [7]). Travers (1970, quoted after [7], p. 954) states that “One cannot reasonably ask the general question whether the eye of the ear is more efficient for the transmission of information, since clearly some information is better transmitted by one sensory channel than by another”.
Nevertheless, theories – especially in the area of Cognitive Science – have emerged over the past decades to explain differences between uses of modality-based differences for learning purposes.

3.1 Working Memory and Learning with Text and Audio

A popular model in multimedia learning research (e.g., used in order to explain the modality effect [8]) is the theory about systems and subsystems of our working memory presented by Baddeley [9; 10]. In Baddeley’s model of our working memory there are two basic subsystems postulated. First, a visual-spatio sketchpad for storing and processing verbal and imaginary information. Second, a subsystem storing and processing auditory information. The latter one is assumed to have a superior kind of storage, the so-called phonological-loop, that keeps auditory information longer and in a repeated slope in our short-time memory. Based on Baddeley’s assumptions about the human memory, current research explains for example occurrences of the modality effect, because both subsystems are involved in processing information containing mixed audio and visual instructional material (while written text and images only activate information processing within the visual-spatio sketchpad).
Nevertheless, Baddeley’s is theory only marginally helpful in explaining differences between written and spoken information. By means of auditory instruction, the phonological subsystem of the working memory is mainly addressed. In contrast, the visual-spatio sketchpad is assumed to be basically involved in processing written information. Nevertheless, the use of spoken instruction is hypothesized to be superior to the use of written text-based instruction, because the part of our working memory responsible for processing these information has a phonological loop that repeats and stores information longer than the corresponding instance within the visual-spatio sketchpad.
Despite these issues on the level of a descriptive theory, research on text vs. auditory instruction is ambiguous and does not reveal an outstanding advantage of spoken versus text-based instruction. Especially leaving the linear level and focussing aspects of linearity and non-linearity of navigation and instruction makes integration of other cognitive theories necessary. Leaving the basic level of information processing by means of integrating interactive leaning within learning environments that demand additional resources for navigational decisions, Cognitive Load Theory might me a suitable frame for analyzing effects of hyperaudio compared to hypertext learning.

3.2 Cognitive Load Theory and Hyperaudio Learning

Cognitive Load Theory (CLT) is recently a common approach for examining learning processes with linear and non-linear knowledge media [11; 12]. CLT differentiates between Intrinsic Cognitive Load (ICL), Extraneous Cognitive Load (ECL) and Germane Cognitive Load (GCL; [13]). ICL is necessary in order to process information given during an instructional process. ECL is influenced by information or instructional message design: If the material is presented in an unbeneficial way (e.g., too complex of ambiguous etc.) ECL will be raised. GCL is necessary for activation of prior knowledge and information processing schemata. ICL, ECL and GCL are assumed to be additive. In case of exceeding working memory resources (e.g., by instructional material that causes a high ECL and, thus, reduces available resources for GCL) information processing will be limited [14].

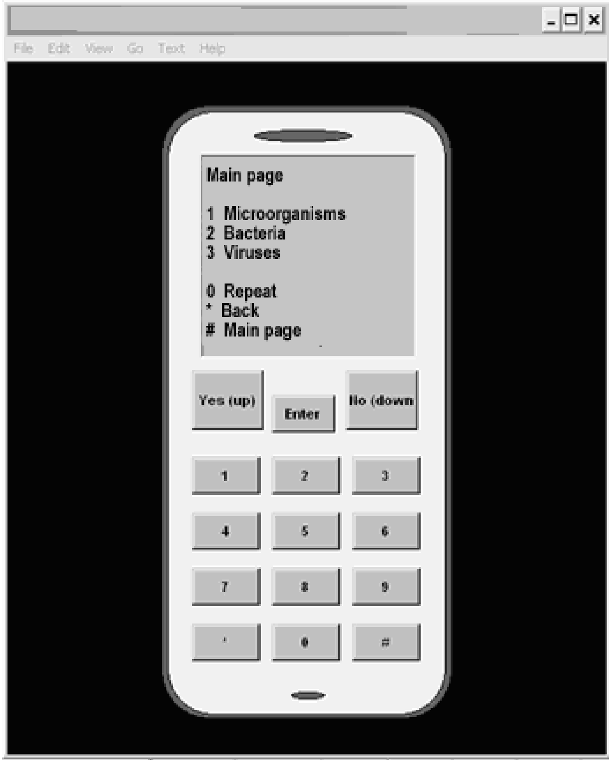
Designing non-linear learning environments like hypertext, hypervideo or hyperaudio is a difficult task for an Instructional Designer. The basic idea of non-linear information access is to provide information in a manner that contributes to development of cognitive flexibility [15]. However, ECL should be minimized but is likely to occur due to issues of navigation planning and monitoring of progress [16; 17].

If issues of planning and monitoring navigation in non-linear learning environments would only lead to increased ECL, learners should always profit more form linear information presentation than from non-linear sequencing because learning with non-linear (hyper-)audio requires additional mental effort in navigation planning and monitoring. However, Cognitive Load Theory postulates that additional mental effort can also enhance learning, for example, if the additional effort leads to deeper elaboration processes (in the sense of Germane Cognitive Load). A similar effect of hyperaudio in linear/non-linear comparison as in basic text/hypertext comparisons is expected here: a hyperaudio learning environment that enables learners to develop mental representations according to Cognitive Flexibility Theory [15] is expected to lead to the same or better learning outcomes than a linear audio book presenting the same information. A major prerequisite is to provide an information access that does not dramatically increase Extraneous Cognitive Load. Thus, basic principles of navigational support as known from hypermedia research have to be considered and adapted [18].

4. Development and Evaluation of a Hyperaudio Learning Environment

Following these considerations about nature and design of hyperaudio learning modules, we developed several prototypes of hyperaudio learning environments using a cellular phone metaphor. This interface design was chosen due to its high ecological validity for use in mLearning. Due to experimental and technical constraints we simulated cellular phones run as computer programs (see Figure 1).

Figure 1: Prototype of a Hyperaudio Learning Environment Application Running on a Cellular Phone



The computer programs simulated a hyperaudio learning environment navigable by using the keys of the cellular phone. There was a basic navigation set with options "Repeat", "Back" (return to the last visited audio node), and back to "Main page" (see Figure 1). In first trials, there were also attempts with voice only commands, i.e., hyperlinks were integrated at the end of each audio node (e.g., "If you want more information about viruses press button 3") but first usability studies revealed that with a growing number of hyperlinks this navigation per audio node was too confusing for learners.

For the present study, a non-linear hyperaudio learning environment and a linear version containing the identical audio nodes were developed. Whereas in the non-linear program audio nodes were associatively linked, the linear program had only a "back & forward"-navigation, realized by key commands provided by the cellular phone interface.

The main purpose of these two prototypes was to investigate the influence of linear vs. non-linear auditory instruction on learning outcomes and measures of cognitive load. Based on the considerations about Cognitive Load it was expected that Extraneous Cognitive Load due to issues of navigation planning would be higher in the non-linear program version. Nevertheless, the complexity of the hyperaudio learning environment was also expected to provide appropriate means to trigger activation of prior knowledge and schemata and, thus, contribute to Germane Cognitive Load [17]. By that means, so that possible disadvantages in knowledge acquisition were expected to be compensated.

4.1 Study

In order to analyse differences between a hyperaudio and linear audio mLearning environment, an experiment was conducted. Thirty-two university students at the University of Heidelberg majoring in different fields participated in this study. Participants were randomly assigned to one of the two experimental groups (hyperaudio vs. linear audio).

One dependent variable in this study was knowledge acquisition. In order to measure individual's learning success a knowledge pre-and post-test was conducted. It included a 12-item multiple-choice test and an essay task in order to measure learner's knowledge and understanding. Essay tasks were analysed by a propositional analysis [19]. Each participant's essay was analysed regarding propositions included in the learning material. Each correct essay proposition received one point.

Another dependent variable was Cognitive Load. Two instruments assessing Cognitive Load were used in this study: the Mental Effort Rating Scale (MERS) [20] and a slightly adapted form of the NASA-TLX (Task Load Index) [21]. NASA-TLX consists of five subscales each represented by a one-item self-report question (i.e,. task requirements, effort in understanding content, expectation of success, effort in navigation, and stress).

The learning material consisted of a collection of articles in the area of molecular biology. The text material was taken from several articles about bacteria, viruses and genes with their underlying scientific concepts. This was recorded as audio files. Overall, there were 19 audio nodes with 2538 spoken words.

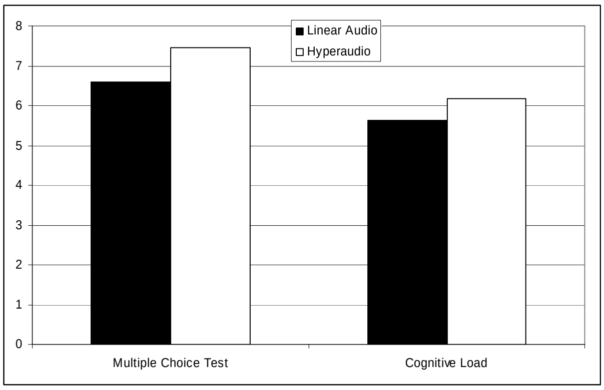
Each audio node was integrated into a computer-based learning environment with either linear or non-linear navigation access as described above (see Figure 1). The sequence in the linear hyperaudio condition was realized by arranging audio nodes in alphabetical order depending on the topic of each node. For the non-linear hyperaudio condition we linked the nodes associatively providing possibilities of gaining multiple perspectives on the topic of the program. In addition, hyperlinks leading to the main page and back to the last visited audio node were added.

The experiment started with oral and written instructions about the task and the handling of the learning programs followed by a pre-test assessing participants' prior knowledge (multiple-choice test and essay task). In the learning phase, participants at single desktop PCs had 35 minutes to navigate the learning environment. During this phase, they were not allowed to take notes. Afterwards, they had to complete the post-test (same essay task and multiple-choice test as in the pre-test and Cognitive Load measures).

4.2 Results

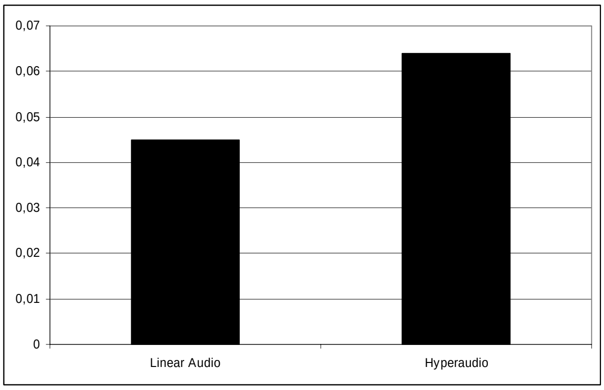
There were no significant differences in participants prior knowledge related to the domain of the learning environments. An analysis of variance showed no significant post-test effects. Neither of measures of knowledge acquisition nor cognitive load showed significant differences between linear audio and hyperaudio condition (overall: $F(2, 29)=1.28$, $p=0.29$). However, descriptive results showed a higher learning performance of learners in the hyperaudio condition compared to learners in the linear audio condition (see Figure 2).

Figure 2: Outcomes in Cognitive Load and Knowledge Acquisition in Multiple-Choice Tests



The hyperaudio program led to slightly increased values in Cognitive Load Measures and to an increased performance in the Multiple-Choice test. An analysis of the percentage of newly acquired propositions revealed a similar result (see Figure 3).

Figure 3: Percentage of Newly Acquired Propositions Comparing Pre-Test and Post-Test Essay



5. Conclusion

Compared to the body of research related to hypertext and hypermedia, research on other non-linear instructional information media like hyperaudio is still in its infancy. In this paper, the influence of linear audio vs. non-linear hyperaudio on Cognitive Load and knowledge acquisition was investigated. Results strengthen on the one hand the assumption that non-linear hyperaudio leads to increased Cognitive Load. On the other hand, there is also evidence that this increased Cognitive Load does not automatically inhibit knowledge acquisition in hyperaudio learning compared with linear presentation of the same content.

Results provide first evidence that learning with well-designed hyperaudio provides opportunities to activate Germane Cognitive Load and, thus, help learners benefit from complex, ill-structured Instructional Design, and develop cognitive flexibility.

In this study, there was only a slight difference in self-reported measures of Cognitive Load. Due to the requirement of navigation in both conditions (though the navigation in the hyperaudio condition was much more complex) and the unusual information media, Cognitive Load was measured as fairly high. In addition to benefits of multiple accesses to single audio nodes in the hyperaudio condition, auditory memory might be able to compensate for problems deriving from issues of navigation planning.

Descriptive results in both measures of knowledge acquisition revealed a slight advantage of the hyperaudio learning scenario. An explanation for this effect might be the complexity of the learning material. Possibly, the non-linear presentation format of this loosely structured information was the better way of presentation.

Overall, these first results are encouraging. They suggest that hyperaudio might be a promising way of delivering non-linear information to learners within mLearning scenarios differing from their primarily text-based counterpart oncepts of hypertext and hypermedia. As the basic technology for distributing this kind of audio-based non-linear learning environments is nowadays in almost everyone’s pocket, cellular phones offering hyperauditory learning might be a promising future development of self-directed mobile learning.

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