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# INCORPORATING COGNITIVE STYLES IN AHA! (THE ADAPTIVE HYPERMEDIA ARCHITECTURE)

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## Abstract

Adaptive educational hypermedia environments use properties of the application domain (e.g. conceptual structure of a course, with prerequisite relationships) to perform adaptation based on the user's browsing behaviour. This paper adds the idea of including cognitive styles in the adaptation decisions. Research on cognitive styles suggests that taking the styles into account can significantly influence a user's performance in an educational hypermedia system. AHA! provides a general-purpose Web-based adaptive environment. It allows to adapt the content of the webpages shown to the individual users and the links on these pages on the basis of arbitrary user characteristics such as (perceived) knowledge, interest or preferences. This paper describes how to incorporate cognitive styles in AHA!. We apply recommendations from existing research on the design of hypermedia systems aiming at providing adaptation to cognitive styles. The main objectives we want to achieve are: (1) avoiding the questionnaires for identifying cognitive styles and instead trying to infer aspects of a user's cognitive style by observing his browsing behavior, (2) providing the designers with the ability to associate different teaching strategies with particular cognitive styles which they want to take into account for their adaptive applications.

## Key Words
Cognitive styles, user modeling, adaptive hypermedia, field dependence/independence, verbalizer/visualizer

## 1. Introduction

One of the main aims of adaptive hypermedia is dealing with the individuality of users. Most adaptive educational hypermedia system research focuses on adapting to user features like goals/tasks, knowledge, background, hyper-space experience, preferences, and interests [1]. Although this research takes into account the evolution of knowledge (and interest) of users it ignores adapting to the *best way* for users to study, which is also an individual characteristic, linked to the user's *cognitive style.* Researchers in this area suggest that matching users' cognitive styles with the design of instruction is an important factor with regard to learning outcome. A number of experiments indicate that the users' performance is much better if the teaching methods are matched to the preferred cognitive style [2]. At the same time a number of other experiments show that when applying various teaching methods for different cognitive styles no significant difference between the learning outcomes has been observed. Another research shows that for more able users mismatching learning materials to cognitive style may be advantageous as it encourages users to develop learning strategies that could cope with a wider range of materials and experiences in the future (review taken from [3]). We conclude that there is no general consensus whether it reasonable or not to apply cognitive styles in adaptive hypermedia design in order to match the presentation to the cognitive style of the user. Another important relationship to be researched has been the connection between cognitive styles and teaching styles. It is appropriate to assume that the cognitive style of the designer (or teacher) may influence the way in which they design their applications. How to foresee this possible problem of "style conflict"? Designers should know about the peculiarities of their own styles and use multiple methods of teaching to improve users' learning instead of applying a single style [3].

Currently only a few systems have been developed with regards to cognitive and learning styles. Many authors use the terms "cognitive" and "learning style" interchangeably. However there is a difference between their use. Cognitive style deals with the "form" of cognitive activity (i.e., thinking, perceiving, remembering), not its content. Learning style, on the other hand, is seen as a broader construct, which includes cognitive along with affective and psychological styles. Systems like INSPIRE [4], CS388 [5], ILASH [6] provide adaptation to various learning styles. A good example of adaption in an educational system with regards to cognitive styles is AEC-ES [7]. It is based on the field dependent/field independent cognitive styles. The system uses navigational support tools (concept map, graphic path, advance organiser) and adaptive presentation techniques. Users are provided with instructional strategies that suit their cognitive preferred style with an option to switch it to a non-preferred version.

The purpose of our research is to extend the AHA! system with the ability to provide adaptation to users' cognitive styles as well as providing the designers with the ability to assign different teaching strategies for various styles while creating their adaptive applications. First the paper briefly presents AHA! (a number of publications about AHA! can be found at http://aha.win.tue.nl). Then we discuss the general problems while trying to apply cognitive styles for adaptive hypermedia design in connection with their incorporation in AHA!. We also present some example of how our ideas can be realized.

## 2. A brief overview of AHA!

AHA! is a (Java servlet based) server side extension that provides *adaptive presentation and adaptive navigation support* [1]. Conditional inclusion of fragments is the main technique to accomplish adaptive presentation. Adaptive annotation and hiding of links gives the user additional information about the suitability of the destination of a hyperlink. (Link annotation is achieved through different colors of the link anchors. Link hiding is the same, but with one color equal to that of normal text, i.e. black). The adaptation is accomplished on the basis of information from the user model.

The user model (UM) contains attribute-value pairs for all the concepts in the application domain model (DM). Domain-independent user-related information like name, password and possible preferences is stored as attributes of a pseudo-concept "personal". An author may add arbitrary attributes to all concepts, including the "personal" concept. Therefore the webpages provided by AHA! can be both "adaptable" and "adaptive", as the adaptation can be based on the information manually stated by the user through the registration form (and stored in the "personal" concept) and also based on the user's actions (or browsing behavior). The overall AHA! architecture is presented in figure 1.

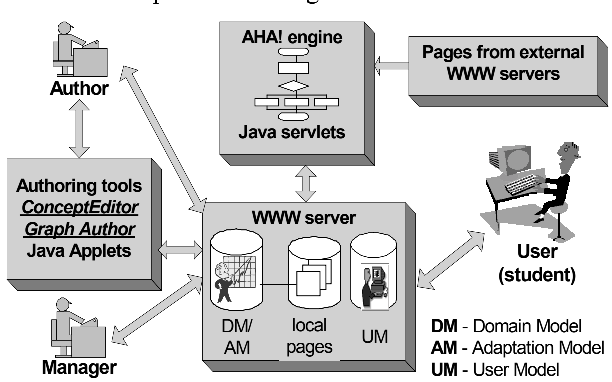


Figure 1. AHA! Architecture.

The following users interact with the system: manager, authors (or designers) of the adaptive applications and end-users. In order to create an adaptive application an AHA! author has to define the (application) domain model consisting of concepts and the "adaptation model" (AM) consisting of adaptation rules. This can be done using one of the AHA! authoring tools – the low-level "Concept Editor" and the high-level "Graph Author". Apart from these models (DM and AM) the author has to create the application content which usually consists of a set of (x)html pages. Steps of the authoring process are described in [8]. We only look at the Graph Author tool in this paper as we investigate its use for defining adaptation based on cognitive styles.

AHA! works through the use of Java servlets and can adapt local as well as remote pages to the user. The DM/AM and UM are stored as xml files on the server, or in a mySQL database.

AHA! has been used in educational applications but is not limited to this domain. Any application in which content and links need to be adapted based on the user's browsing behavior can be realized, including on-line information services, museum websites, corporate showcases, recommender parts of shopping sites, etc..

## 3. Incorporating cognitive styles into AHA!

This section presents the main objectives of our research. First, on the basis of recent findings [2], [9] we discuss the application of the styles Field Dependence vs. Field Independence [10] and of Verbalizer vs. Visualizer [11] or Verbalizer vs. Imager [12]. We show how the authors may incorporate these cognitive styles into the system using the Graph Author. The question "how can we assess the users' cognitive styles in AHA!?" is treated in Section 4.

### 3.1 Application of Field Dependence vs. Field Independence in AHA!

Among the various dimensions of cognitive styles Field dependence/independence (FD/FI) is probably the most widely studied one, with the broadest application to problems in education. FI users follow an analytical approach. They pick a topic and study it in detail. FD users see the global picture and ignore the details (until later). Also, FD individuals are more likely to require externally defined goals and reinforcements, whereas FI ones tend to develop self-defined goals and reinforcements [10]. The researchers are trying to apply knowledge about these differences in the strategies and approaches of FD and FI individuals for instructional design.

Some studies suggest [2] that nonlinear learning may be more suitable to FI users. FI users are relatively capable of setting the learning paths by themselves. They are focused and task oriented. The index and other tools that can help them to find specific information in hypermedia systems are very useful for FI users. On the other hand, FD users may have more difficulties in "non-linear" learning; they may get confused more easily than those with a strong Field-Independence tendency, so they benefit from a linear presentation at a global (introductory) level before diving into the details. In [2], [9] a number of suggestions are made on how to provide "help" for FD learners. We will briefly review these suggestions and show how they can be realized in AHA!:

*Highlighting Context*, *Effective Feedbacks* and *Graphic Visualizations*

FD users need *navigation-* and *orientation support*: they need to know where they are and where to go next. In Interbook [13] an annotated partial table of contents can be shown. This provides context, and since the table of contents contains annotated links it also provides the guidance FD users need. The indentation used for the chapter/section/subsection hierarchy provides the graphical visualization of the context, needed by FD users. AHA! has recently been extended with this Interbook functionality [14]. It can offer a presentation that is almost identical to that of Interbook.

*Adaptive annotation*

FD user need guidance as to which links to follow next. In AHA! this guidance is possible through the use of link colors: *good*, meaning desirable and not previously visited, *neutral*, meaning desirable but previously read, and *bad*, meaning not desirable. The author and end-users can choose which "real" colors correspond to these three notions. The default color scheme is *blue*, *purple* and *black*, resulting in the *link hiding* technique. This link annotation provides an FD user with a picture of what is available and recommended, and what has been done, and it hides links to confusing detailed information, not on the desired learning path.

*Navigation support*

In [15] it is shown that FD users prefer to be guided through the hierarchical structure of a course in a breadth-first way. FI users preferred to take the depth-first order. Ford and Chen recommend applying this finding by adapting the order of presentation for the links. This means that FD users should first be given an overview of all of the material at a high (global) level before introducing the details. On the other hand, for FI users each topic should be presented in detail before going to the next topic.

To implement this recommendation in AHA! we use the high-level Graph Author tool, described in [16]. With this tool *concept relationships* can be created and automatically translated to the low-level adaptation rules used by the AHA! engine. A typical concept relationship type that occurs in educational applications is the *prerequisite relationship*. Another type we have used does exactly the opposite: the *inhibitor relationship* type. For different kinds of applications the authors may define different relationship types (e.g., *defines, exemplifies*). [16] describes how this can be done using an XML notation for the translation templates. In order to design an application for FD and FI users, we will apply new concept relationship types that result in guidance towards either breadth-first or depth-first navigation. The new types are a variant of prerequisite relationships. When *concept1* is a prerequisite for *concept2* the links to a page associated with *concept2* become *good* when the knowledge of *concept1* exceeds some threshold (which is 50 by default).

The translation template for a concept relationship can use two *variables* (called "source" and "destination" or "parent" and "child"), as well as (attributes of) fixed, named concepts. The standard template for a prerequisite sets *destination.suitability* to *source.knowledge>var:50*. (The var means that the author can specify a different threshold for an instance of the prerequisite relationship.) Prerequisite relationships in AHA! are *transitive* (when A is a prerequisite of B and B of C then A is a prerequisite for C). This significantly reduces the number of relationships an author has to create.

In order to implement different navigation strategies for FD and FI users we create *prerequisite_FD* and *prerequisite_FI* relationships, and make each of them only "work" for the right type of user. For this we add an attribute "FDvsFI" to the "personal" concept. The value of this attribute is an integer between 0 and 100. We use the value 50 to indicate that the cognitive style is unknown. Higher values indicate more confidence that the user is an FD user, lower values indicate an FI user.A *prerequisite_FD* can be implemented using a template that sets *destination.suitability* to *source.knowledge >var:50 && personal.FDvsFI>var:70*. (The value 70 expresses how certain the system needs to be that the user is of type FD.

Assume the author creates an AHA! application with a hierarchical structure. Figure 2 shows the structure of *prerequisite_FD* relationships that is needed to effectuate a breadth-first navigation for FD users.

To define the sequence in which the concepts should be presented to the user the author simply draws a graph of concept relationships in the right frame of the Graph Author window.

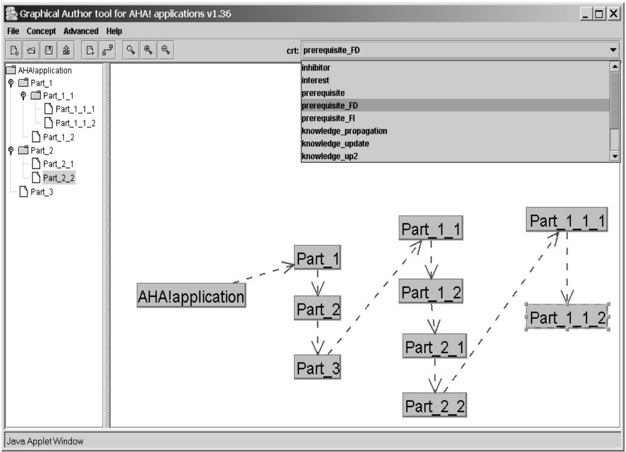


Figure 2. Breadth-first navigation for FD users.

Figure 2 indicates that, for example, concept *Part_1_1* will become desirable for the FD user when the overview pages about *Part_1*, *Part_2* and *Part_3* are read. *Part_1_2* comes after *Part_1_1*, etc. The preferred reading order is linear at each level of detail. However, the author is free to define more, or fewer *prerequisite_FD* relationships. Instead of enforcing breadth-first navigation for FD users, AHA! simply provides an author with the means to suggest (or enforce) *any* navigation strategy for FD users.

Figure 3 presents the structure of the application as it should be presented to FI users. The author specifies *prerequisite_FI* relationships between the concepts. This graph shows that concept *Part_1_1* becomes suitable for an FI user when he has read an overview page *Part_1* about the same concept.

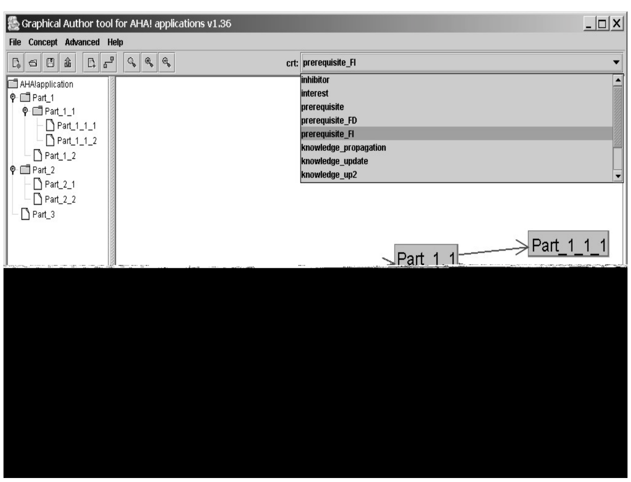


Figure 3. Defining the structure of an application for FI users.

Again, the author is free to chose which prerequisites to apply for FI users. Figure 3 shows how to suggest a depth-first navigation but the author may choose additional or simply different prerequisites.

We intend to develop a small high-level tool which will generate the breadth-first and depth-first navigation structures, so that the author only has to create the desired exceptions (instead of the whole structure, with the exceptions).

## 3.2 Application of Verbalizer vs. Visualizer or Verbalizer vs. Imager style in AHA!

Another aspect which is of particular interest for adaptive hypermedia is the verbalizer/ visualizer style. In terms of the choice of presentation mode, the designer should provide textual material to the verbalizers and pictorial material to the visualizers (such as pictures, diagrams, charts, and graphs) [9]. A term similar to verbalizer vs. visualizer is verbalizer vs. imager. According to researchers [17], [18] the imagers tend to be internal and passive, while the verbalizers tend to be external and stimulating. The imagers perform better in a "text-plus-picture" condition, whereas the verbalizers are better in a "text-plus-text" condition (text is illustrated or elaborated with more text). In addition, the imagers more often use diagrams to illustrate their ideas than the verbalizers.

Some authors [19] claim that when using predominantly either verbal or visual material it is not possible to build an adequate mental representation of the problem situation for both verbalizers and visualizers. Therefore using the ability of AHA! to conditionally include fragments or objects we suggest the authors of adaptive applications to present textual description of some concept followed by a (link to) pictorial representation of this concept for verbalizers and, vice versa, a picture followed by (a link to) text for visualizers (imagers). In this case the additional material is provided through a link the users can decide for themselves to follow the link to the additional material or not.

The conditional presentation or inclusion of information can be defined using the Graph Author. Assume the author considers that in his AHA! application the concept *Part_1_1_1* should be presented with more textual material for verbalizers and more visual material for visualizers/imagers. The author can associate several resources (files) with the concept *Part_1_1_1* which define its presentation under different conditions.

In the same way as for FD vs. FI cognitive styles the author may specify a "VERBvsIM" attribute of the concept "personal" to indicate this cognitive style. Figure 4 shows that if the value of the attribute is less than 30 (the user is more probably an Imager) a resource which contains more images will be shown to the user. If the value of the attribute is greater than 70 (the user is more likely a verbalizer) then a resource with more textual information is chosen. For any value between 30 and 70 a default resource is shown that should more or less please both styles (Part_1_1_1.xhtml in the figure).

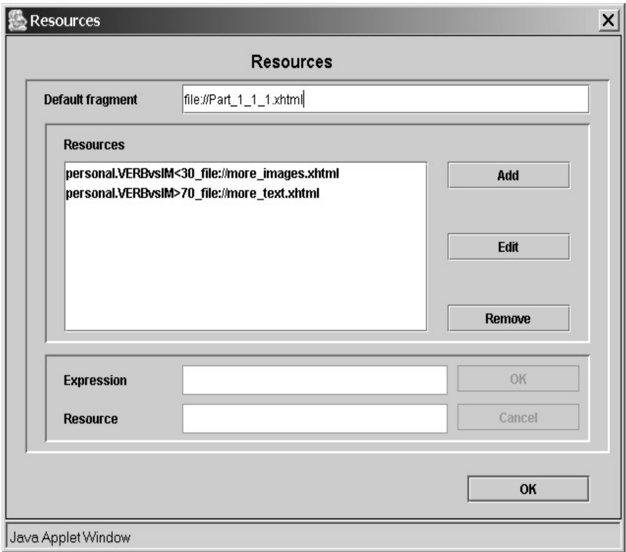


Figure 4. Associating different resources with the concept *Part_1_1_1*.

In an XHTML page which presents concept *Part_1_1_1* the author includes:
<object name="AHA!application.Part_1_1_1" type="aha/text"/>
The "aha/text" type tells the AHA! engine that *AHA!application.Part_1_1_1* is a conditionally included object (concept).

The adaptation to Verbalizer and Imager in AHA! illustrates that an aspect of the user can be used to decide upon the inclusion of certain material. AHA! does not enforces the included material to be of a specific type. The mechanism is thus more general than the example (of Verbalizer vs. Imager) shows.

## 4. Assessing cognitive styles

Currently most adaptive Web-based educational systems collect information about the user's cognitive style by having him/her complete questionnaires. However, filling out long questionnaires is a time consuming process and many users of adaptive hypermedia would not want to do this. Also these questionnaires are not always reliable and valid enough [3]. An important consideration is that users' preferences may change over time. In adaptable systems assumptions about users' styles are acquired through the psychometric questionnaires and these assumptions are not updated during the further interaction between the user and the system. However it is a fact that the user preferences of certain types of multimedia resources or learning activities can change over time (a problem known as concept drift.) [20]. A cognitive style, peculiar to the user, may vary under the influence of the situation or instruction [21]. The effect of the "mobile behavior" of FD/FI cognitive style is described in [22].

One of the ideas in AHA! is to *infer* aspects of a user's cognitive style from his browsing behavior. This may not be possible for all known styles. But for the styles FD/FI and Verbalizer/Imager we propose a way to do it.

In a concept hierarchy we can associate a "level" (attribute) with each concept. The root concept has level 0. Its children have level 1, their children have level 2 and so on. The main information needed to decide on FD/FI is knowing whether users navigate on the same level or go one level deeper. From the examples of Figures 2 and 3, we see that breadth-first navigation involves many "sidesteps" and few "downsteps", whereas depth-first navigation involves many "downsteps" and few "sidesteps". We can store the *current* level in an attribute of the "personal" concept and update it on each page access. This way we can compare the level of an accessed page with that of the previous page and decide whether a step was a "sidestep" or "downstep" (or an "up step" which we ignore). Breadth-first navigation starts with a significant number of sidesteps, which can very quickly tell us that a user is Field Dependent. Depth-first navigation starts with a number of "downsteps", telling us quickly that a user is field-independent. If for instance each step increases or decreases the FDvsFI attribute by 10 until the threshold is reached (and less after that) we quickly obtain a meaningful FDvsFI value without having to ask the user through a questionnaire.

Similarly, we can define a concept relationship that associates access to textual material with an increase of the "VERBvsIM" attribute and pictorial material with decrease the attribute. Therefore we can quickly decide on the Verbalizer/Imager style. If the presentation is such that the "undesired" material is still available through a link we can keep the possibility for users to access the supposedly undesired material and to make the system realize that the verbalizer/visualizer choice was wrong. In this case the system may ask the user if he wants to change an instructional strategy to the one which corresponds to another cognitive style. The same can be done for FD/FI cognitive style, for example, if the browsing behavior of the user who was considered to be FI indicates that he is most probably FD (and vice versa).

AHA! provides a special tool that allows authors to create forms to let the users change values of attributes of concepts in their user model. It is thus possible to create a form that lets users change their "FDvsFI" and "VERBvsIM" values.

Apart from observing the order of following the links the system may also take into account information like:

- does the user follow recommended links?
- number of switches between cognitive styles,
- number of pages read with a chosen style.

## 5. Conclusions

This paper presented the start of our research into adaptation to cognitive styles in AHA!. It showed that AHA! can adapt to field dependence or independence and to Verbalizer vs. Imager. It also showed that this adaptation is always done in a way that leaves authors the choice as to how to adapt these styles. We have suggested the Breadth-first vs. Depth-first navigation for FD/FI but AHA! does not enforce this. Verbalizer vs. Imager is implemented using the conditional inclusion of objects, again without enforcing the use of certain media types. In future articles we will investigate more cognitive styles and their influence on adaptation design.

The paper has also shown some simple ways to infer the cognitive style from the browsing strategy followed by the user. AHA! makes it possible for end-users to explicitly inform the system about their cognitive style if they realize that the system has made the wrong choice.

Many researchers suggest that knowledge about the users cognitive styles may significantly influence users performance in an educational hypermedia system. In this paper we have shown how to implement adaptation to these styles in AHA!. We would like to investigate whether the adaptation to cognitive styles, implemented using AHA!, confirms the findings of these researchers.

## 6. Acknowledgement

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