Towards an Adaptive and Personalized Web Interaction using Human Factors

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Abstract. In recent years, there has been a rapid growth in research and experiments that work on personalizing Web content, according to user needs and the challenges ranging in this area are not few. In this chapter we provide a new comprehensive way of reconstructing Web content; that is creating a comprehensive user profile based on specific metrics of visual, cognitive and emotional processing parameters that have specific impact into the information space. This comprehensive user profile along with the 'traditional' user characteristics (such as age, gender, educational knowledge on computers, profession), and the characteristics of the user's device will serve as the main personalization filter. Based on these considerations, an adaptation and personalization Web-based environment, AdaptiveWeb, has been created and overviewed trying to convey the essence and the peculiarities encapsulated. Finally, this chapter presents a mature experimental evaluation of the system with approximately 500 users, both in an eLearning and eCommerce personalized environment. The results are really encouraging for the future of our work since it has been identified moderation of user's cognitive overload, increasing their performance and satisfaction while interacting with the complicated Web structures.

1 Introduction

We are now witnessing an extensive and gradual increasing use of the World Wide Web space, proved to be the most desirable way of communication, due to its speed, simplicity and efficiency.

Given the exponential growth of new information sources in the Internet[1], the importance of information retrieval and its presentation has become critical. Most Web developers create Web-pages without taking into account the most important entity of the Internet; the user. The plethora of information and services, as well as the complicated nature of most Web structures intensify the orientation difficulties, as users often lose sight of their original goal, look for stimulating rather than informative material, or even use the navigational features unwisely. As the eServices sector is rapidly evolving, the need for such Web structures that satisfy the heterogeneous needs of its users is becoming more and more evident (Germanakos et al., 2005).

To alleviate such navigational difficulties, researchers have to expend increasing amounts of effort to identify the peculiarities of each user group and design methodologies and systems that could deliver an adapted and personalized Web content. The general concept behind all this is called personalization. To date there has not been given a concrete definition of personalization, but we can say that all solutions offering personalization features meet an abstract common goal: to provide users with what they want or need without expecting them to ask for it explicitly (Mulvenna et al., 2000).

Current Web Personalization systems use different kinds of techniques and paradigms and use specific characteristics of the users to create a profile that is used as the primary filtering element for the adaptation and personalization of the Web content with regards to various application fields. Such systems, mostly commercial, are amongst others the Broadvision's One-To-One, Microsoft's Firefly Passport (developed by the MIT Media Lab), the Macromedia's LikeMinds Preference Server, Apple's WebObjects, etc. Other, more research oriented systems, include ARCHIMIDES (Bogonicolos et al., 1999), WBI (Maglio, P. & Barret, R., 2000, Barret, 1997), BASAR (Thomas & Fischer, 1997) and mPERSONA (Panayiotou & Samaras, 2004). Significant implementations have also been developed with regards to the provision of adapted educational content to students using various adaptive hypermedia techniques. Such systems are amongst others, INSPIRE (Papanikolaou et al., 2003), ELM-ART (Weber & Specht, 1997), AHA! (Brusilovsky et al., 1998), Interbook (De Bra & Calvi, 1998), and so on.

Hence, user profile (Germanakos et al., 2008a; Germanakos et al., 2007a) is considered the most vital component of Web Personalization and Adaptation Systems. In this chapter, we refer to the importance of user profiles and we present a comprehensive user profile that incorporates intrinsic user characteristics, such as user perceptual preferences (visual, cognitive and emotional processing parameters), on top of the "traditional" ones. Based on this, we introduce an innovative adaptation and personalization architecture, AdaptiveWeb, emphasizing on the significance and peculiarities of the various user profile aspects it employs, considered necessary for the provision of a most optimized personalization Web-based result.

More specifically, section 2 provides briefly the theoretical background, referring to Adaptive Hypermedia and Web Personalization categories and technologies; it presents the user profile fundamentals and investigates a comprehensive user profile that consists of cognitive processing

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[1] *See Internet Domain Survey Host Count <http://www.isc.org>*

factors; and it depicts a high level correlation diagram showing the relation between the comprehensive user profile and the information space. Section 3 describes the AdaptiveWeb system architecture and gives a brief description of each Web component. Section 4 presents the user profile extraction process, as well as the adaptation process, in two application areas of eLearning and eCommerce, describing actual code instances and pseudo code used (with the use of metadata) as well as the semantics used for achieving content adaptation. Sections 5, 6 and 7 present a mature evaluation of the system in both environments. Finally, section 8 concludes this chapter and presents a number of ideas for opportunities for future work.

2 Theoretical Background

Once considering adaptation and personalization categories and technologies we refer to Adaptive Hypermedia and Web Personalization respectively, due to the fact that they both make use of a user profile to achieve their goal and consequently they can together offer the most optimized adapted content result to the user.

2.1 A Constructive Comparison of Adaptive Hypermedia and Web Personalization

In view of the aforementioned statement it would be essential to highlight their similarities and differences and furthermore, to identify their convergence point which is their objective to develop techniques to adapt what is presented to the user, based on the specific user needs identified in the extracted user profiles (Germanakos et al., 2008a; Tsianos et al., 2008a).

Generally, Adaptive Hypermedia refers to the manipulation of the link or content structure of an application to achieve adaptation and makes use of an explicit user model (Eklund & Sinclair, 2000, Brusilovsky, 2001). Adaptive Hypermedia is a relatively old and well established area of research counting three generations (Brusilovsky & Peylo, 2003). Educational hypermedia and on-line information systems are the most popular, accounting for about two thirds of the research efforts in adaptive hypermedia. Adaptation effects vary from one system to another. These effects are grouped into three major adaptation technologies - adaptive content selection (Brusilovsky & Nejdl, 2004), adaptive presentation (or content-level adaptation) and adaptive navigation support (or link-level adaptation) (Eklund & Sinclair, 2000, Brusilovsky, 2001).

On the other hand, Web personalization refers to the whole process of collecting, classifying and analyzing Web data, and determining based on these the actions that should be performed so that the user is presented with personalized information. Personalization levels have been classified into: Link Personalization, Content Personalization, Context Personalization, and Authorized Personalization (Rossi et al. 2001, Lankhorst et a., 2002). The technologies that are employed in order to implement the processing phases mentioned above as well as the Web personalization categories are distinguished into: Content-Based Filtering, Rule-based Filtering, Collaborative Filtering, Web Usage Mining, Demographic-based Filtering, Agent technologies, and Cluster Models (Pazzani, 2005, Mobasher et al., 2002).

As inferred from its name, Web personalization refers to Web applications solely, and is a relatively new area of research. One could also argue that the areas of application of these two research areas are different, as Adaptive Hypermedia has found popular use in educational hypermedia and on-line information systems (Brusilovsky, 2001), whereas Web personalization has found popular use in eBusiness services delivery. From this, it could be implied that Web personalization has a more extended scope than Adaptive Hypermedia.

The most evident technical similarities of them are that they both make use of a user model to achieve their goal and they have in common two of the adaptation / personalization techniques: the adaptive-navigation support and the adaptive presentation. Last but not least, it is noteworthy to mention that they both make use of techniques from machine learning, information retrieval and filtering, databases, knowledge representation, data mining, text mining, statistics, and human-computer interaction (Mobasher et al., 2007).

2.2 The User Profile Fundamentals

The user profile serves as the core element of most adaptation and personalization systems. According to Merriam-Webster dictionary the term profile means “a representation of something in outline”[1]. User profile can be thought of as being a set of data representing the significant features of the user.

One of the key technical issues in developing personalization applications is the problem of how to construct accurate and comprehensive profiles of individual users and how these can be used to identify a user and describe the user behaviour, especially if they are moving (Panayiotou & Samaras, 2004). The objective of user profile is the creation of an information base that contains the preferences, characteristics, and activities of the user. A user profile can be built from a set of keywords that describe the user preferred interest areas compared against information items.

User profile can either be *static*, when it contains information that rarely or never changes

[1] *See <http://mw1.merriam-Webster.com/dictionary/profile>*

(e.g. demographic information), or *dynamic*, when the data change frequently. Such information is obtained either *explicitly*, using online registration forms and questionnaires resulting in static user profiles, or *implicitly*, by recording the navigational behaviour and / or the preferences of each user (Germanakos et al., 2007a).

2.3 The Comprehensive User Profile used in the AdaptiveWeb System

Based on the abovementioned considerations we will introduce a Comprehensive User Profile, serving as the main raw Web content filtering module, and used in the AdaptiveWeb System developed for personalizing and adapting the users' environment to their individual perceptual characteristics and needs. This module could accept requests from an 'Entry Point' module and after the necessary processing and further communication with a 'Semantic Web-based Content' module, to provide the requested adapted and personalized result as we will describe below. The Comprehensive User Profile is comprised of two main components:

2.3.1 The "Traditional" User Profile

It contains all the information related to the user, necessary for the Web Personalization processing. It is composed of two elements, the (a) *User Characteristics* (the so called "traditional" characteristics of a user: knowledge, goals, background, experience, preferences, activities, demographic information (age, gender), socio-economic information (income, class, sector etc.), and the (b) *Device / Channel Characteristics* (contains characteristics that referred to the device or channel the user is using and contains information like: bandwidth, displays, text-writing, connectivity, size, power processing, interface and data entry, memory and storage capacity, latency (high / low), and battery lifetime. These characteristics are mostly referred to mobile users and are considered important for the formulation of a more integrated user profile, since it determines the technical aspects of it. Both elements are completing the user profile from the user's point of view.

2.3.2 User Perceptual Preference Characteristics

This is the new component / dimension of the user profile. It contains all the visual attention, cognitive and emotional processing parameters that completes the user preferences and fulfils the user profile. User Perceptual Preference Characteristics could be described as a continuous mental processing starting with the perception of an object in the user's attentional visual field and going through a number of cognitive, learning and emotional processes giving the actual response to that stimulus, as depicted in Fig. 1, below. As it can be observed, its primary parameters formulate a three-dimensional approach to the problem.

These characteristics, which have been primarily discussed in (Germanakos et al. 2007a), and formulate a three-dimensional approach to the problem of building a user model that determines the visual attention, cognitive and emotional processing taking place throughout the whole process of accepting an object of perception (stimulus) until the comprehensive response to it (Germanakos et al., 2005).

The first dimension investigates users' *cognitive style*, the second their *visual and cognitive processing efficiency*, while the third captures their *emotional processing* during the interaction process with the information space.

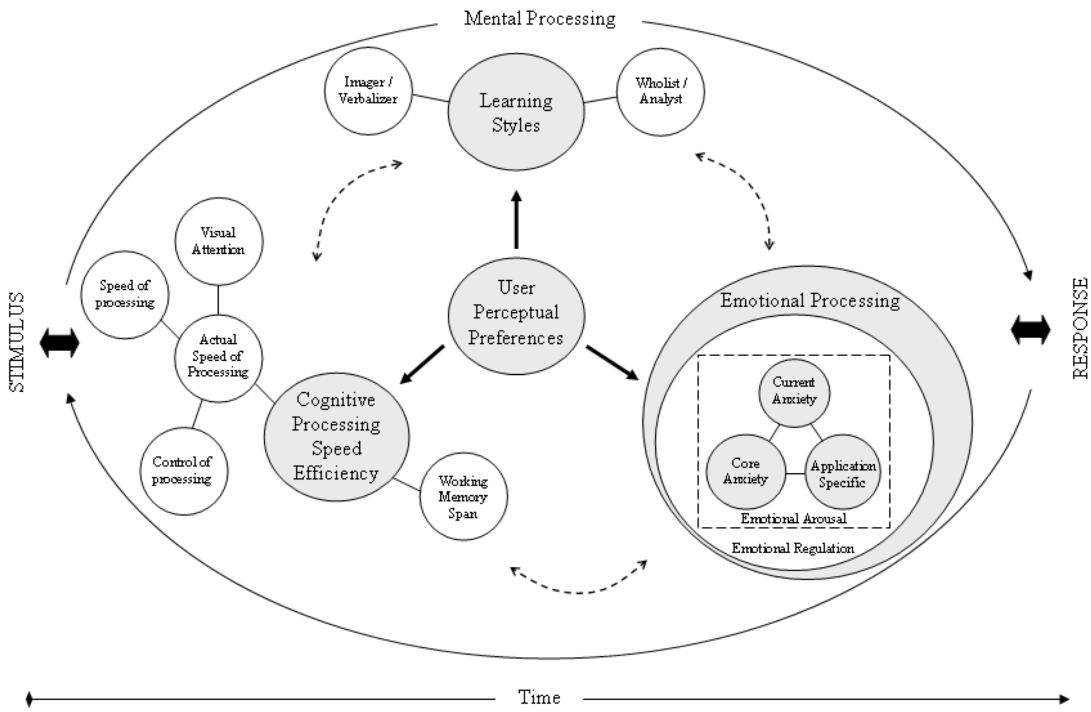

Figure 1. User Perceptual Preference Characteristics – Three-Dimensional Approach

- *Cognitive styles* represent an individual's typical or habitual mode of problem solving, thinking, perceiving or remembering, and "are considered to be trait-like, relatively stable characteristics of individuals, whereas learning strategies are more state-driven…" (McKay et al., 2003). Amongst the numerous proposed cognitive style typologies (Cassidy, 2004; Kolb & Kolb 2005; MyersBriggs et al, 1998) has been selected Riding's Cognitive Style Analysis (Riding, 2001), because it applies in a greater number of information distribution circumstances, since it deals rather with cognitive than learning style. Furthermore, it is considered that its implications can be mapped on the information space more precisely, since it is consisted of two distinct scales that respond to different aspects of the Web. The imager / verbalizer axis affects the way information is presented, whilst the wholist / analyst dimension is relevant to the structure of the information and the navigational path of the user. Moreover, it is a very inclusive theory that is derived from a number of pre-existing theories that were recapitulated into these two axises.

- The *cognitive processing* parameters (Demetriou & Kazi, 2001) that have been included in the model are:
  i. *control of processing* (refers to the processes that identify and register goal-relevant information and block out dominant or appealing but actually irrelevant information),
  ii. *speed of processing* (refers to the maximum speed at which a given mental act may be efficiently executed),
  iii. *working memory span* (refers to the processes that enable a person to hold information in an active state while integrating it with other information until the current problem is solved (Baddeley, 1992), and
  iv. *visual attention* (based on the empirically validated assumption that when a person is performing a cognitive task, while watching a display, the location of his / her gaze corresponds to the symbol currently being processed in working memory and, moreover, that the eye naturally focuses on areas that are most likely to be informative).
- *Emotional processing* is a pluralistic construct which is comprised of two mechanisms:
  i. Emotional Arousal, which is the capacity of a human being to sense and experience specific emotional situations, and
  ii. Emotion Regulation, which is the way that an individual perceives and controls his emotions.

Main focus has been placed on anxiety, as the main indicator of emotional arousal, because it is correlated with academic performance (Cassady & Johnson, 2002), as well as with performance in computer mediated learning procedures (Smith & Caputi, 2007).

The construct of emotional regulation that has been used includes the concepts of Emotional Control (self-awareness, emotional management, self-motivation) (Goleman, 1995), Self - Efficacy (Bandura, 1994), Emotional experience and Emotional Expression (Halberstadt, 2005). By combining the levels of Anxiety with the moderating role of Emotion regulation, it is possible to examine how affectional responses hamper or promote learning procedures (Lekkas et al., 2007).

2.4 Relating the Comprehensive Profile with the Information Space - A high level correlation diagram

For a better understanding of the three dimensions' implications and their relation with the information space a diagram that presents a high level correlation of these implications with selected tags of the information space (a code used in Web languages to define a format change or hypertext link) is depicted in Fig. 2. These tags (images, text, information quantity, links - learner control, navigation support, additional navigation support, and aesthetics) have gone through an extensive optimization representing group of data affected after the mapping with the implications. The main reason we have selected the latter tags is due to the fact that represent the primary subsidiaries of a Web-based content. With the necessary processing and / or alteration we could provide the same content with different ways (according to a specific user's profile) but without degrading the message conveyed.

The particular mapping is based on specific rules created, liable for the combination of these tags and the variation of their value in order to better filter the raw content and deliver the most personalized Web-based result to the user. As it can be observed from the diagram below each dimension has primary (solid line) and secondary (dashed line) implications on the information space altering dynamically the weight of the tags.

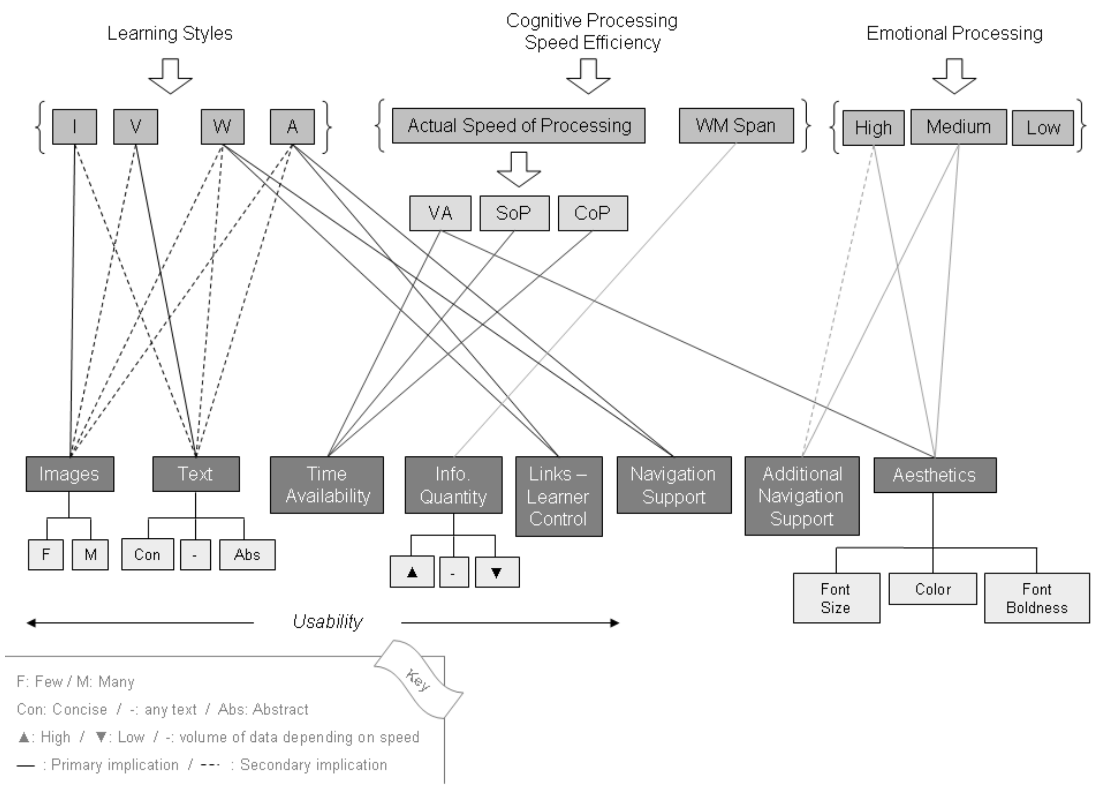

Figure 2. Data - Implications Correlation Diagram

Henceforth, with regards to the learning style, the number of images (few or many) for example to be displayed has a primary implication on imagers, while text (more concise or abstract) has a secondary implication. An analyst may affect primarily the links - learner control and navigation support tag, which in turn is secondary affected by high and medium emotional processing, while might secondary affect the number of images or kind of text to be displayed, consequently. Actual speed of processing parameters (visual attention, speed of processing, and control of processing) as well as working memory span are primarily affecting information quantity. Eventually, emotional processing is primarily affecting additional navigation support and aesthetics, as visual attention does, while secondary affects information quantity.

A practical example of the Data - Implications Correlation Diagram could be as follows, a user might be identified that is: Verbalizer (V) – Wholist (W) with regards to the Learning Style, has an Actual Cognitive Processing Speed Efficiency of 1000 msec, and a fair Working Memory Span (weighting 5/7), with regards to his / her Cognitive Processing Speed Efficiency, and (s)he has a High Emotional processing. The tags affected, according to the rules created and the Data – Implications Correlation Diagram, for this particular instance are the: Images (few images displayed), Text (any text could be delivered), Info Quantity (less info since his / her cognitive speed is moderate), Links – Learner Control (less learner control because (s)he is Wholist), Additional Navigation Support (significant because (s)he has high emotional processing), and high aesthetics (to give more structured and well defined information, with more colours, larger fonts, more bold text, since (s)he has high emotional processing). At this point it should be mentioned that in case of internal correlation conflicts primary implications take over secondary ones.

Additionally, since emotional processing is the most dynamic parameter compared to the others, any changes occurring at any given time are directly affecting the yielded value of the adaptation and personalization rules and henceforth the format of the content delivered.

3 The AdaptiveWeb System's Architecture

Based on the abovementioned considerations an adaptive Web-based environment is overviewed, trying to convey the essence and the peculiarities encapsulated. The current system, AdaptiveWeb[1] (see Fig. 3 – Germanakos et al., 2007b; Germanakos et al., 2007c), is a Web application that can be ported both to desktop computer and mobile devices. It is composed of four interrelated components[2], each one representing a stand-alone Web-based system briefly presented below:

Component 1 - *Profile Construction* - This is the initial step the user makes for the AdaptiveWeb System's personalization process. It is a vital part of the system. At this point the user creates his / her comprehensive profile, which is going to be mapped at a later stage with the personalized content.

Component 2 - *Management / Administration Backend System* - This is the System's backend and is used by the Administrators or other authorized users to manage and analyze the personalized user's profiles. All the AdaptiveWeb personalized members' results from the tests and questionnaires taken during the "User Profiling Construction" are processed and shown.

Component 3 - *Semantic Web Editor* - The third component, the system's "Semantic Web Editor", is still under study. Using this component the provider will be able to create his / her own content by defining objects that will be embodied in a given content. The content structure has to be "well-formatted" and the objects have to be "well-defined" (based on given semantic tags) by the editor in order to give the best results to the end-user. The technology that will be

[1] *See <http://www3.cs.ucy.ac.cy/adaptiveWeb>*
[2] *The technology used to build each Web system's component is ASP .Net <http://asp.net>*

used for creating the personalized content is a more expressive semantic Web language like OWL or RDF used for describing data and to focus on the relation between them.

Component 4 - *Adaptation and Personalization Process (Mapping Rules)* - In this section, all the system's components interact with each other in order to create and give personalized and adapted content to the end user. The author of a page uploads the content on the system's database, which will be mapped after with the system's "Mapping Rules". The system's "Mapping Rules" are functions that run on the AdaptiveWeb server and comprise the main body of the adaptation and personalization procedure of the provider's content, according to the user's comprehensive profile. For experimental purposes, we have authored an eLearning environment with a predefined content for adaptation and personalization.

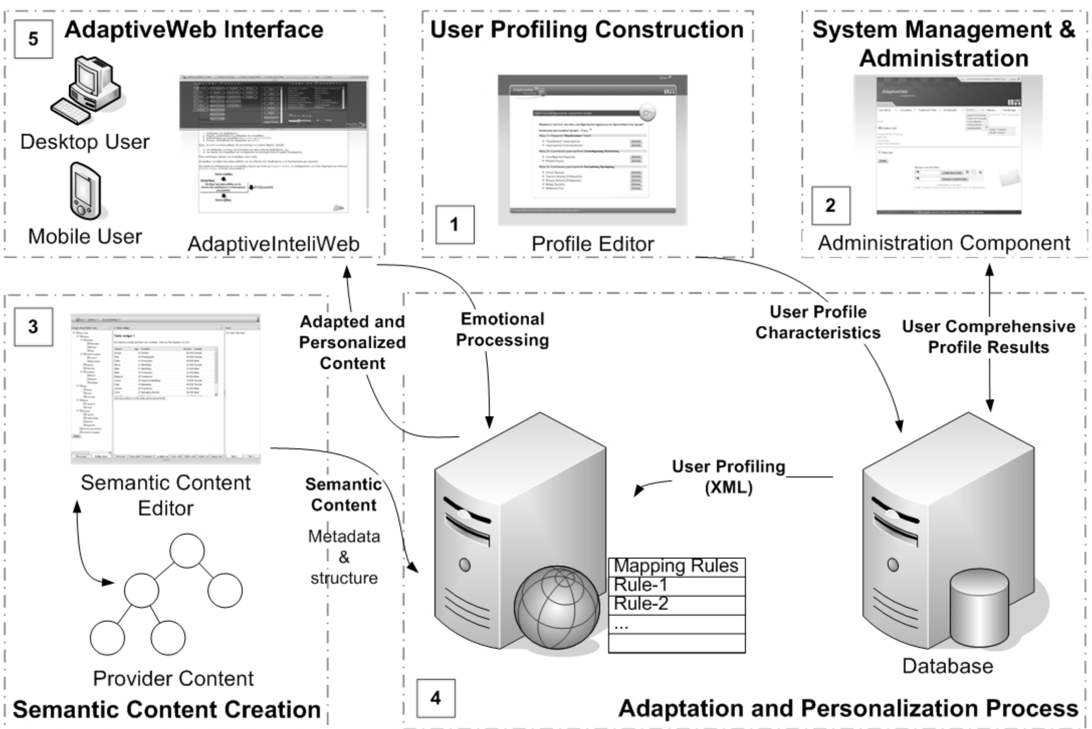

Figure 3. AdaptiveWeb System Architecture

Component 5 - *User's Interface* - AdaptiveWeb User Interface, called AdaptiveInteliWeb (AIWeb) is a Web application used for displaying the raw or personalized and adapted content on the user's device. The main concept of this component is to provide a framework where all personalized Web-sites can be navigated. Using this interface the user will navigate through the provider's content. Based on his / her profile a further support will be provided to him / her with the use of a slide-in panel at the top of the screen, containing all navigation support and learner control attributes adjusted accordingly.

4 The Adaptation Process

4.1 User Profile Construction Process

To get personalized and adapted content, a user has to create his / her comprehensive profile. The "User Profiling Construction" component is responsible for the creation of this content (see Fig. 4).

At this point the user has to provide his "Traditional" and Device / Channel Characteristics and further complete a number of real-time tests (attention and cognitive processing efficiency grabbing psychometric tools) which are preloaded and executed on the client in order to get actual response times of his answers, as well as answer predefined questionnaires for generating his/her cumulative profile.

More specifically, a series of psychometric instruments that reveal users' perceptual characteristics we use include:

- Riding's CSA (2001) for the Learning / Cognitive Styles dimension
- A series of real-time measurements for the Cognitive Parameters (Speed of Processing, Control of Processing, Working Memory and Visual Attention), similar to tests developed on the E-prime platform[1].
- The Emotional Control 27 item questionnaire we have developed (Cronbach's alpha 0.76), and i) the Test Anxiety Inventory (Spielberger & Vagg, 1995) to measure application specific anxiety (educational process in our case) and ii) the State-Trait Anxiety Inventory (Spielberger, 1983) to measure general (core) anxiety.

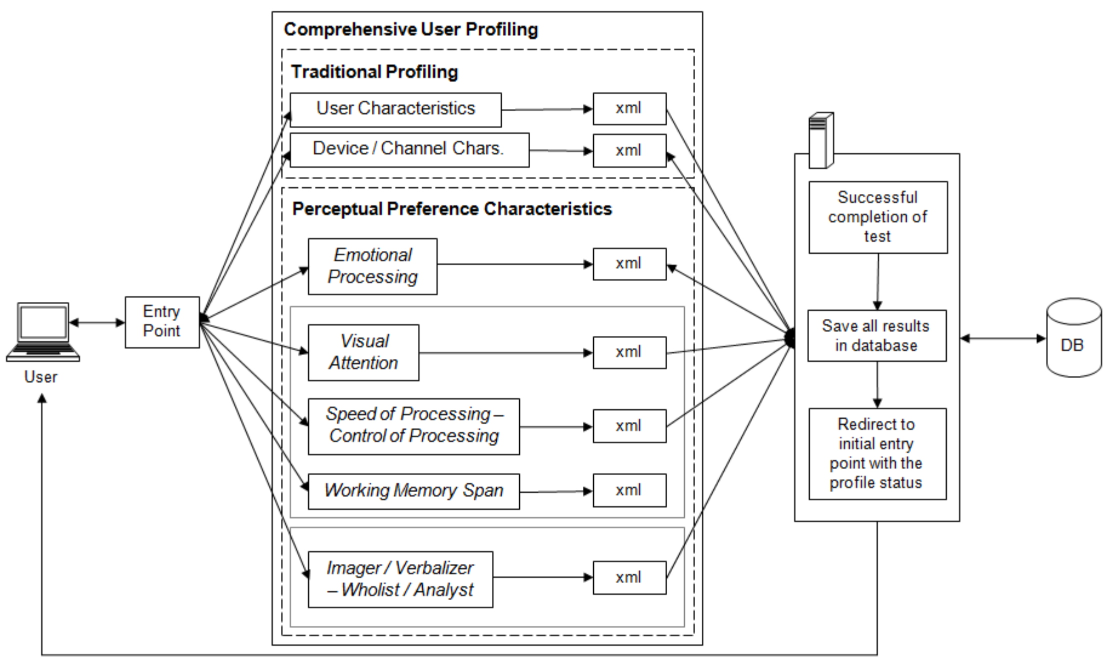

Figure 4. "User Profiling Construction" Data Flow Diagram

Moreover, while users navigate through our application, they can make use of a sliding anxiety bar, which is part of the interface, in order to self-report feelings of inconvenience and high levels of anxiety that burdens their cognitive effort. This self-report measure will be correlated with general (core) and application specific levels of anxiety in order to clarify the extent of their correlation, and the further optimization of the psychometric process.

Our main concern is to ensure openness and interoperability within and between system's components. In case an external component wants to access the user's profile, either for adaptation, for historic or statistical calculations, the system must be able to support extraction of the user's profile. In order to achieve this, the user's profile must be easily extendible and easy to handle. Using XML for implementing the user's profile seems to be the best way to achieve this. Indeed XML[2] enables the extendibility we need and enhances interoperability and integration among systems' components.

We have designed a Web Service (a software system designed to support interoperable Machine to Machine interaction over a network) for retrieving the users' comprehensive profile. Depending on the needs of a third party system that interacts with our system through this middleware; calculations are made and are finally exported in XML. For a better insight, the Tree Structure of the Comprehensive User Profile, giving emphasis on the comprehensive user profile structure, is depicted in Fig. 5.

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[1] *See <http://www.pstnet.com/products/e-prime/>*
[2] *See <http://www.w3.org/XML/>*

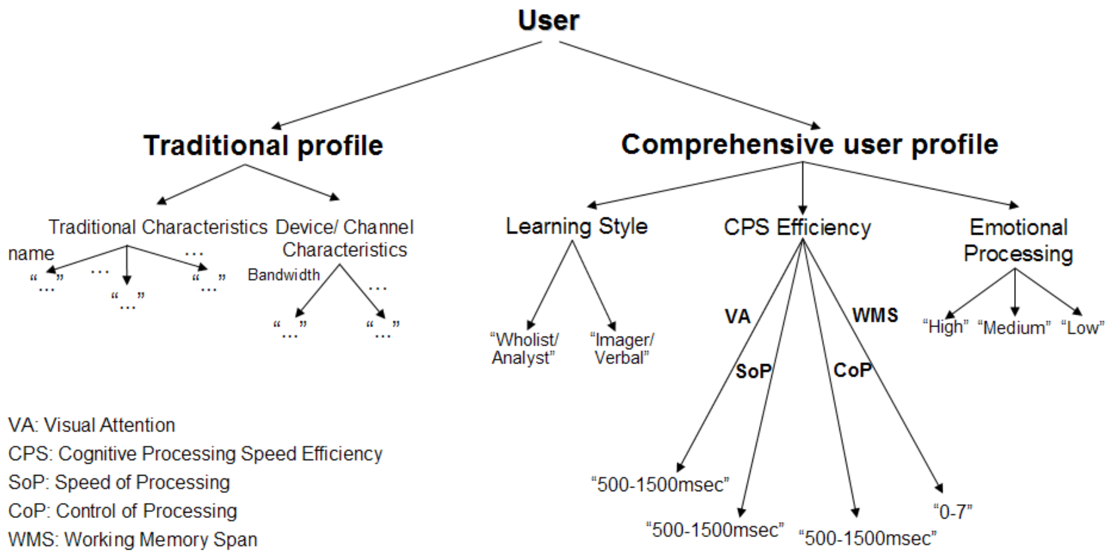

Figure 5. The Tree Structure of the Comprehensive User Profile XML document

4.2 Content Authoring and Mapping Process

In order to evaluate the system's performance as well as the impact of our model's dimensions into the information space, we have designed two experimental settings in the application fields of eLearning and eCommerce, by authoring predefined content for adaptation and personalization.

The eLearning environment includes a course named "Introduction to Algorithms" and is a first year eLearning course environment that aims to provide students with analytic thinking and top-down methodology techniques for further development of constructive solutions to given problems.

On the other hand, the eCommerce (Web) environment that has been developed used the design and information content of an existing commercial Web-site of Sony Style[1]. This Web-site provides products' specifications of the Sony Company. We have developed an exact replica of the Sony Vaio Notebooks section in sonystyle.com.

At this point has to be mentioned that the general methodology and theory behind the content adaptation procedure is the same in both environments with slight differences, based on the peculiarities and constraints underlined by each environment itself, as we will clearly indicate in the following sections.

To get a better insight of the adaptation process and how data flows, we hereafter discuss how the personalized content (the "Introduction to Algorithms" predefined eLearning environment) interacts with the Comprehensive User Profile, using specific mapping rules. In Fig. 6, the Content and Structure Description Schema is shown, while Fig. 7 shows the whole adaptation process.

When users want to interact with the adapted and personalized content they have to give their credentials for retrieving their profile. In this particular example (see Fig. 7), the user happens to be an Imager / Wholist with regards to the Learning Style, has an average knowledge on the subject (computer knowledge) based on his traditional characteristics, has an Actual Cognitive Processing Speed Efficiency of 1200 msec, a fair Working Memory Span (weighting 5/7), and (s)he has a High Emotional processing. Using these preferences the data-implications correlation diagram is evaluated.

Every Web-page is detached into standalone objects, each one having special characteristics. In our example, the user visits the "WebPage_Y" Web-page. First, the main XML document of this Web-page is retrieved which contains all the needed information for building the Web-page;

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[1] *See <http://www.sonystyle.com> (date extracted: September 19, 2007)*

that is, (i) the page details like the url of the page, an abstract description, author's details etc., (ii) the page's layout which is a predefined HTML document (designed from the provider) keeping information of specified divisions/frames in the page for positioning each object and (iii) all objects (text, image, audio, video etc.) that comprise the content of the Web-page (see Fig. 6).

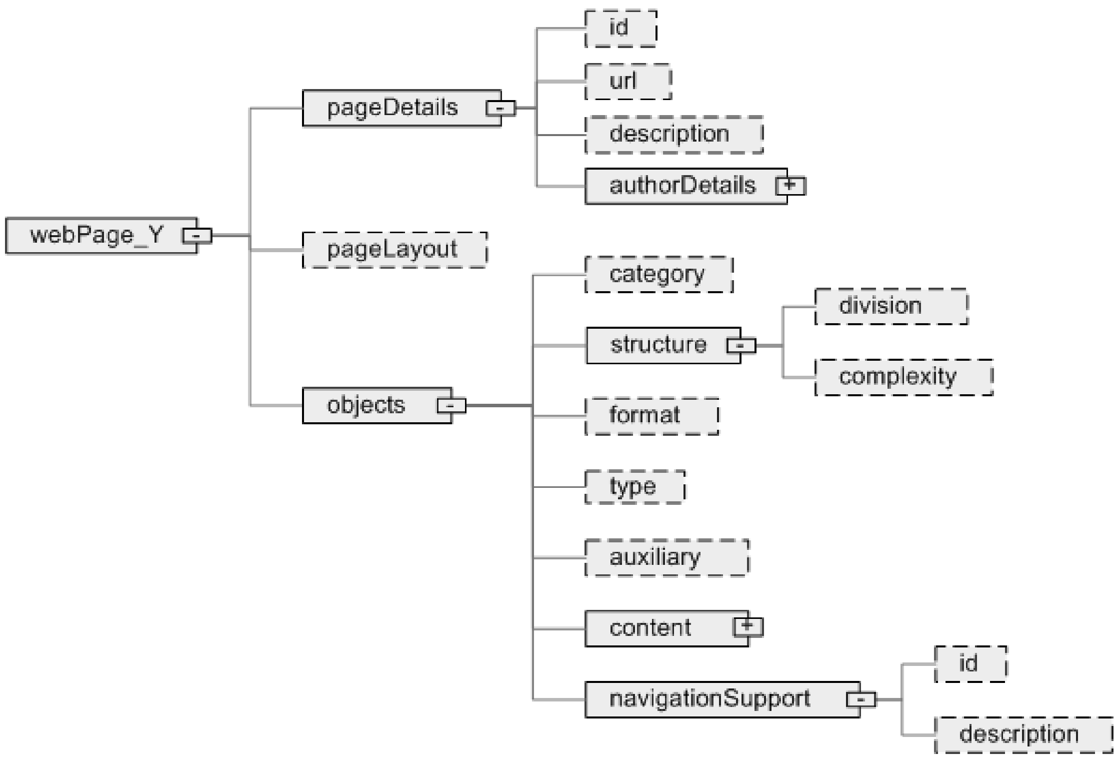

Figure 6. Content and Structure Description Schema (eLearning)

At this point we have all the information we need for adapting the content; the data-implications correlation diagram based on the user's comprehensive profile and the content description of the particular Web-page. The next step is to map the implications with the Web-page's content, for assembling the final version of the provider's content.

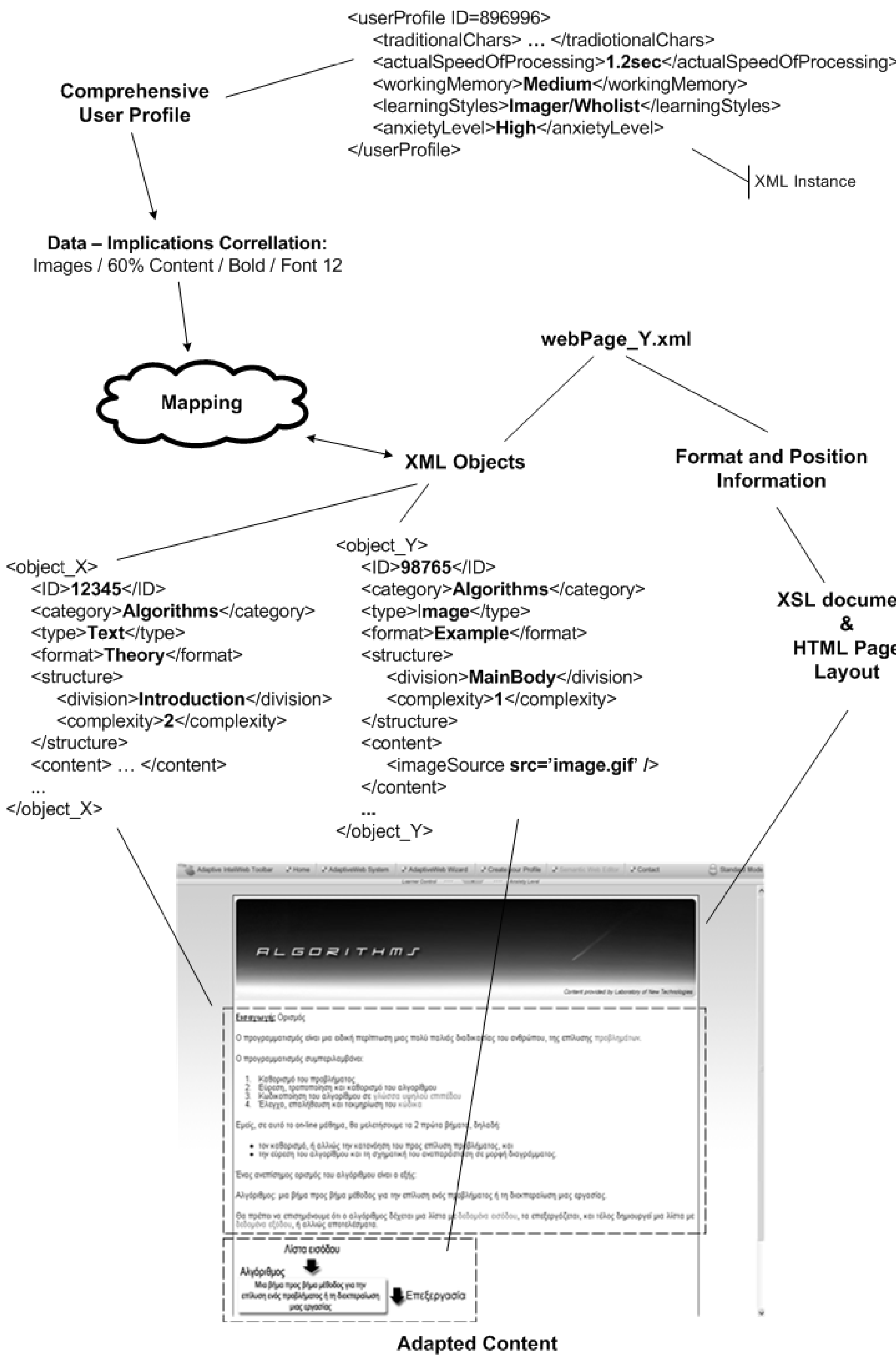

Figure 7. The Adaptation Process

The interpretation of the user's data-implications correlation diagram results in the following conclusions: (a) the user is an Imager, therefore the provision of visual information is predominant (b) gets 60% of the content which has an average complexity because he happens to have a medium cognitive processing speed efficiency, average knowledge of the particular subject (computer knowledge) and a high level of anxiety, (c) the content will be presented in Font-Size 12 and Bold Font-Weight, accordingly to the notion of enhancing clear-cut aesthetics for anxious users.

Fig. 8 shows the mapping process using our example; explained in pseudo code. The XML documents do not provide any formatting information and/or any information about how XML documents should be displayed, unlike HTML documents that carry that information. For this purpose, the author designs the desired page and formats using XSL (eXtensible Stylesheet Language) and puts the objects in a specified subdivision of the Web-page (HTML layout document).

Algorithm : Mapping Process Phase

Input: User's data-implications correlation diagram (contentAmount, fontSize, fontWeight, learningStyles), WebObjects, XSL document, HTML layout

Output: Generate an Adapted and Personalized Web-page

Execute these steps (top-down):

1) For each structure division (Introduction, MainBody, Conclusion)

   Filter out the implication's contentAmount of the WebObjects in ascending order based on their complexity (<complexity>);

2) For each remained object, make a further filtering based on the object's <type> tag

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```
        if (learningStyle1 = Imager)
            Add image objects;
        elseif (learningStyle1 = Verbalizer)
            Add text objects;
        if (object has NavigationSupport Tag){
            var wordDefinitionObject = retrieveWordDefinitions(objectID)
            var navigationSupportType;
            if (learningStyle2 = Analyst)
                getNavigationSupportType(objectID);
                Show description in popup up window;
            elseif (learningStyle2 = Wholist OR learningStyle2 = Intermediate)
                getNavigationSupportType(objectID);
                Show description in tooltip on mouseover;
        }
3) Format each object based on the fontSize and fontWeight and the XSL
   (eXtensive Stylesheet)
4) Position each object in the right structure division based on the HTML layout
   document
```

Figure 8. Mapping Process Example (pseudo code)

The content will be adapted according to the user's preferences and will then be loaded onto the user's device. While navigating, the user will be able to change his anxiety level through a dynamic slide bar on the system's toolbar. By changing his current anxiety level, the server will be alerted and a new data-implications correlation diagram will be generated with a new adaptation process to take place.

In the case of the eCommerce environment, the mapping process between the Web content and the user's profile is the same as previously shown (as in eLearning), but without taking into consideration the emotional characteristics (eg. anxiety – and the anxiety slide-bar) of the user since this factor does not usually apply in generic Web environments (i.e. we can not use the time availability as a constraint to control users' emotional reactions, since the navigation time over these kind of Web structures is liable to users' disposal).

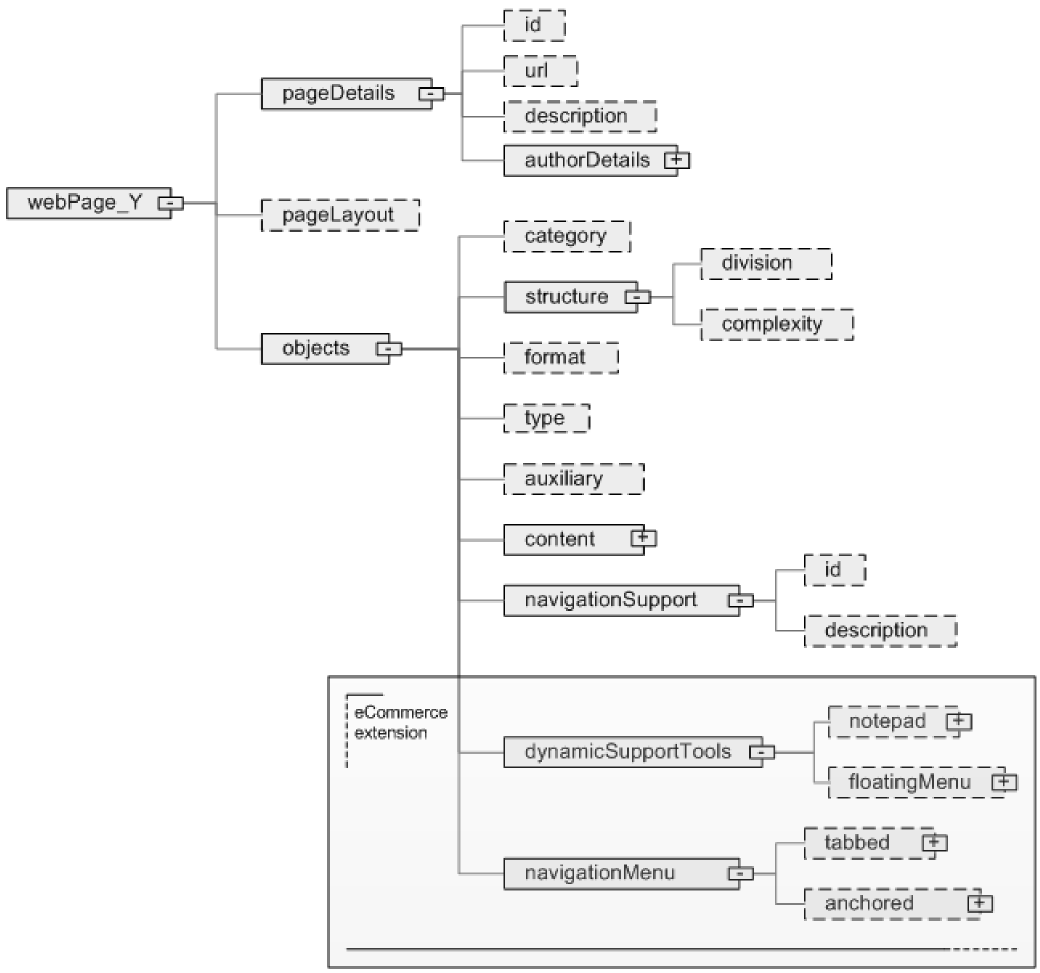

Figure 9. Content and Structure Description Schema (extension for eCommerce)

The main difference is the diagrammatical representation of the content (primarily driven by users' typologies) as well as the provision of extra navigation support tools, devised to be more applicable while interacting with an eCommerce environment. The Content and Structure Description Schema in this environment is therefore extended with additional semantic tags as depicted in Fig. 9.

The subsection below will explain in more detail the AdaptiveWeb Environment, namely AdaptiveInteliWeb, where all personalized content is shown along with the extra navigation support and learner control that differ according to each user's profile and application area.

4.3 Viewing the Adapted Content - The AdaptiveInteliWeb Environment

The last component of the architecture is the AdaptiveWeb User Interface, namely AdaptiveInteliWeb (see Fig. 10), which is a Web application used for displaying the raw and/or personalized and adapted content on the user's device. This can be a home desktop, laptop or a mobile device.

The main concept of this component is to provide a framework where all personalized Web sites can be navigated. Using this interface the users interact with the provider's content and based on their profile further support is provided to them with the use of a slide-in panel at the top of the screen, containing all navigation support and learner control attributes adjusted accordingly. Initially, the interface will show the raw, not personalized content of the provider. When the user wants to personalize and adapt the content according to his / her comprehensive profile he / she will proceed by giving his / her username and password. The corresponding profile will be loaded onto the server and in proportion with his / her cumulative characteristics the content of the provider will be mapped with the "Mapping Rules", as described before.

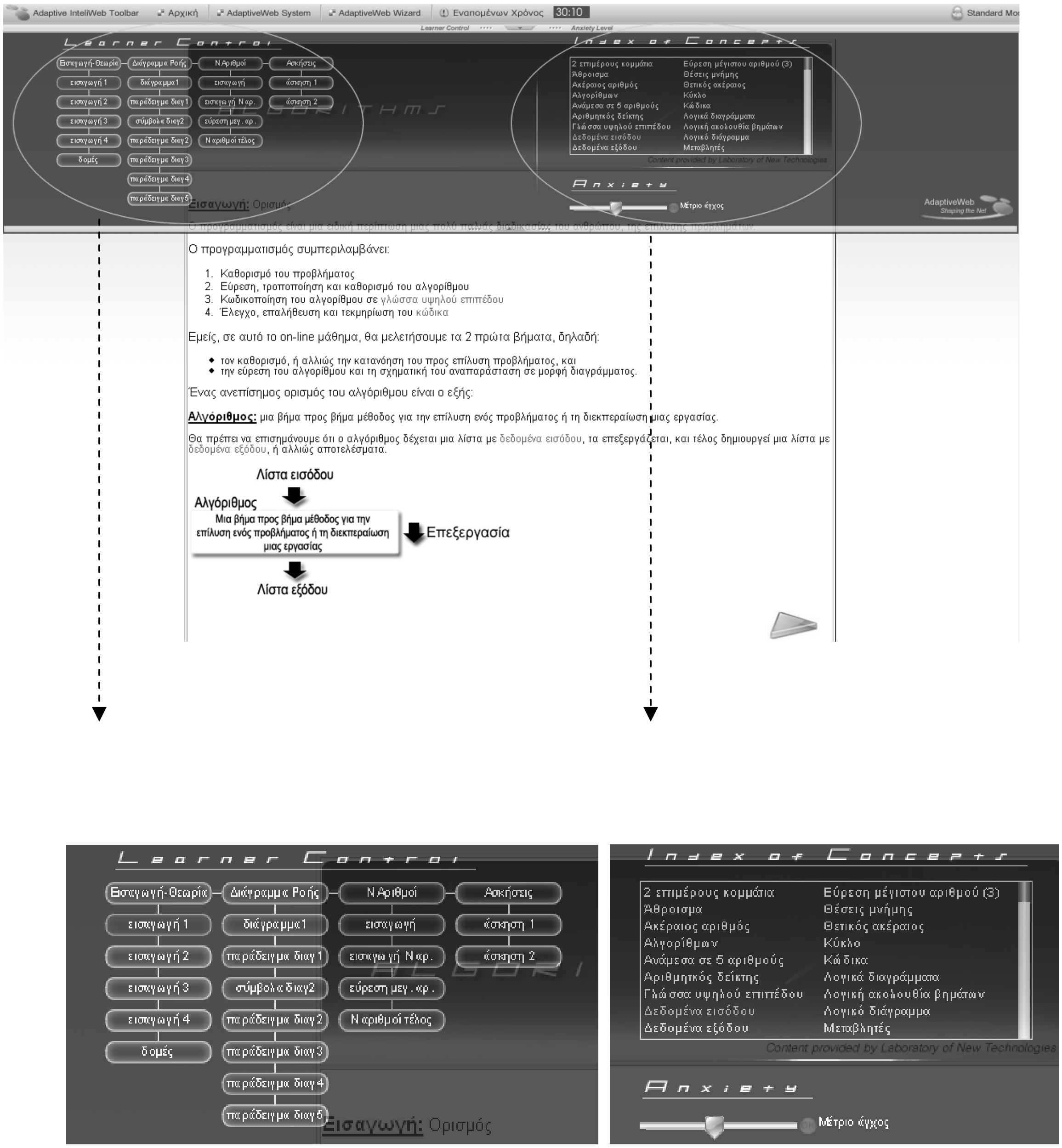

Figure 10. The AdaptiveInteliWeb component

The following two subsections overview the framework, adjusted to both environments (eLearning and eCommerce), showing the main differences regarding the content adaptation and presentation, as well as the additional navigation support tools used in the eCommerce paradigm.

4.3.1 The eLearning environment

Fig.11 shows an example of two users, having a different profile and the raw content adapted accordingly (with different personalization auxiliary tools provided in each case). The matching process in this case is the same as stated previously; all navigation support and learner control information is kept in the content description XML document, as well as the XSL document and the HTML layout document for the objects' formatting and positioning, accordingly.

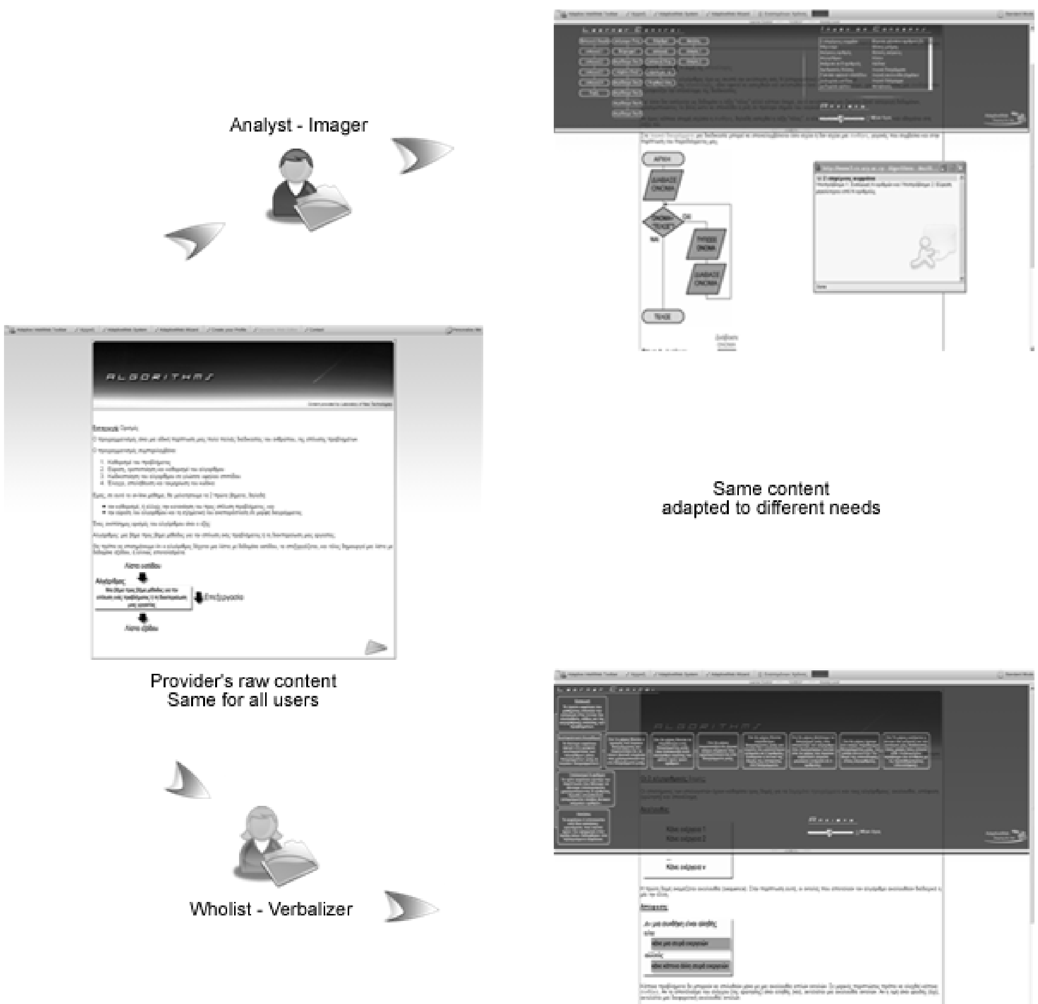

Figure 11. Content adaptation according to user's comprehensive profile (eLearning)

As seen in this figure, the same content has been adapted and a different learner control and navigation support is provided. Based on theory (Sadler-Smith & Riding, 1999), the “Analyst-Imager” has a more analytic diagram with extra description; the navigation support provided (analytic description of definitions) is in popup windows, so (s)he can manage the entire lesson, along with its definitions by him / herself. In the learner control support (that is, the slide-in help panel from the top of the page) is a linkable sitemap of the whole eLearning lesson, plus the entire lesson’s definitions in alphabetic order and an anxiety bar for changing his current anxiety level. On the other hand, the “Wholist-Verbalizer” has more text than images and diagrams; the navigation support and learner control support is more restricted and is specifically provided for guidance. The analytic description of a definition is only shown in a tooltip when (s)he moves his mouse over it and the learner control shows him/her only the current chapter’s pages (s)he learns and lets him / her navigate only to the next and the previous visited pages. As mentioned before, the Wholist user needs more guidance than the Analyst user, who prefers to build the lesson as (s)he wishes.

4.3.2 The eCommerce environment

Accordingly, in the case of the eCommerce environment, the interface altered as follows: Fig. 12a depicts an exact replica of the Sony Web-site without any personalization made, while Fig. 12b and Fig. 12c shows the same Web-site after the personalization and adaptation process has been initiated, with the content to be adapted according to the user’s comprehensive profile.

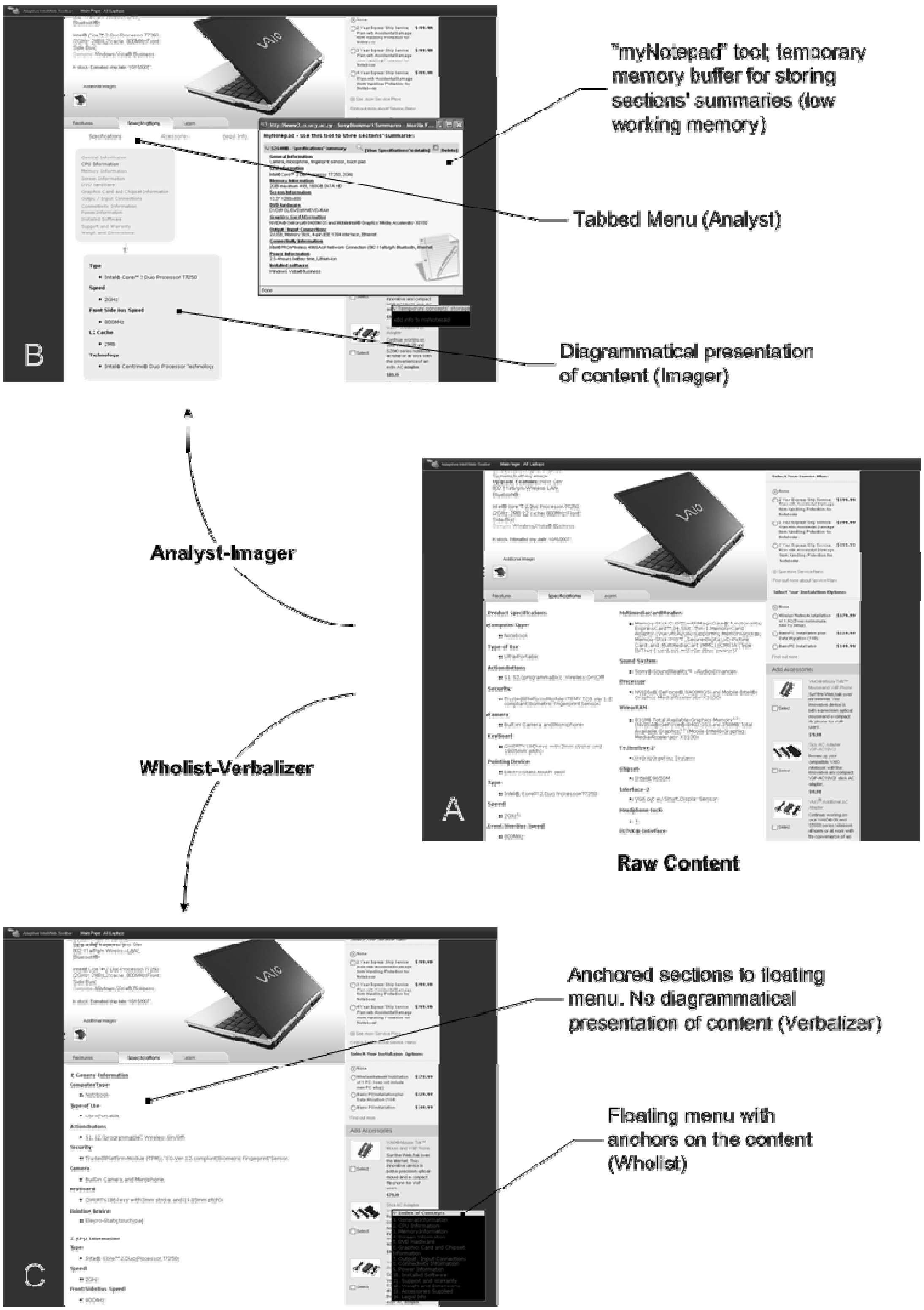

Figure 12. Content adaptation according to user's comprehensive profile (eCommerce)

As we can easily observe, the original environment has been altered based on rules that define the typologies of the users in terms of content reconstruction and supportive tools. For example, a user might be identified as an “Analyst-Imager” with low working memory and therefore the Web environment during interaction time would be as in Fig. 12b. The information will be presented in a diagrammatic form (imager), will be enriched with menu tabs (analyst) to be easier accessible and with the “myNotepad” tool (temporary memory buffer) for storing sections' summaries (low working memory). In case that a user is identified as “Wholist-Verbalizer” the content will be automatically reconstructed as in Fig.12c, where a floating menu with anchors (wholist) have been added so to guide the users on specific parts into the content while interacting. In this case no diagrammatical presentation will be used because the user is a verbalizer.

5 Evaluating System’s Performance

The AdaptiveWeb system is currently at its final stage. All the components, except the Semantic Web Editor as stated above, have been developed and are smoothly running.

To measure system’s performance, functional behaviour and efficiency of our system we have run two different simulations with 100 threads (users) each: (a) users retrieving raw content without any personalization and adaptation taking place and (b) users interacting with adapted and personalized content. In the second scenario, there is a significant increase of functions and modules ran, compared to the first one (raw content scenario), like user profile retrieval, dynamic content adaptation, dynamic learner control tools, navigational support etc. Based on the simulations made (see Table 1) we assume the following: (i) Deviation for raw content is 72ms and for personalized content 110ms. This difference is expected since the system uses more functional components in the case of personalized content like profile loading, dynamic content, etc. Thus, this consumes more network resources causing the deviation of our average to be greater than that of the raw content test.

Table 1: Summary data of each simulation scenario

	Raw Content Scenario	Personalized Content Scenario
Average Response Time	138ms	183ms
Deviation	72ms	110ms
Throughput	14493.17Kb/min	17951.52Kb/min
Median	141ms	172ms
Threads (Users)	100 users	100 users

The deviation is not considered to be significantly greater and thus this metric result is proving the system to be stable and efficient; (ii) the throughput for the raw content scenario was 14493.17Kb/min while for the personalized content was 17951.52Kb/min. Based on the latter results, the system is again considered efficient mainly due to the fact that the difference in throughput between the two scenarios is minimal. Taking in consideration that major component functionality is used in the case of personalized content this small difference suggests the efficiency of the system; (iii) the same arguments are true in the case of the average response times. The average response time for the raw content scenario was 138ms while for the personalized content was 183ms, signifying a discernible difference amongst them. However, the system still appears responsive to the user proving its efficiency.

6 Evaluation of the eLearning paradigm

Due to the fact that there is an increased interest on distant education via the Web, we have decided to implement the first phase of our experiments in an eLearning environment, with the corresponding characteristics and constraints imposed by its nature. In this case, we were able to control factors such as previous knowledge and experience over distributed information, as well as the given interaction time of the users with the system, since learning in the context of a specific course is a far more controlled condition than Web browsing. More specifically, we were seeking to investigate our main research hypotheses drawn:

- Are the cognitive and emotional parameters of our model significantly important in the context of an educational hypermedia application, and
- Does matching the presentation and structure of the information to Users' Perceptual Preferences increase academic performance?

6.1 Sampling and procedure

The experiment consisted of two distinct phases: phase I was conducted at the University of Cyprus, while phase II was conducted at the University of Athens. The aim of the first experiment was to clarify whether matching (or mismatching) instructional style to users' cognitive style improves performance. The second experiment focused on the importance of matching instructional style to the remaining parameters of our model (working memory, cognitive processing efficiency, emotional processing).

All participants were students from the Universities of Cyprus and Athens; phase I was conducted with a sample of 138 students, whilst phase II with 82 individuals. 35% of the participants were male and 65% were female, and their age varied from 17 to 22 with a mean age of 19. The environment in which the procedure took place was an eLearning course on algorithms. The course subject was chosen due to the fact that students of the departments where the experiment took place had absolutely no experience on computer science, and traditionally perform poorly. By controlling the factor of experience in that way, we divided our sample in two groups: almost half of the participants were provided with information matched to their Perceptual Preferences, while the other half were taught in a mismatched way. The match / mismatch factor was their cognitive style (imager / verbalizer, wholist / analyst) at phase I of the experiment, while phase II estimated the effect of matching actual cognitive speed of processing (time availability based on their type, fast / medium / slow), and working memory span (complete or broken content provision depending if they had high / medium / low capacity).We expected that users in the matched condition, both in phase I and phase II, would perform better than those in the mismatched condition.

In order to evaluate the effect of matched and mismatched conditions, participants took an online assessment test on the subject they were taught (algorithms). This exam was taken as soon as the eLearning procedure ended, in order to control for long-term memory decay effects. The dependent variable that was used to assess the effect of adaptation to users' preferences was participants' score at the online exam.

At this point, it should be clarified that matching and mismatching instructional style is a process with different implications for each dimension of our model (see Table 2).

Table 2: Implications for matched/mismatched conditions

	Cognitive Style	**Working Memory**	**Cognitive Processing Speed Efficiency**	**Emotional Processing**
Matched Condition	Presentation and structure of information matches user's preference	Low Working Memory users are provided with segmented information	Each user has in his disposal the amount of time that fits his ability	Users with moderate and high levels of anxiety receive aesthetic enhancement of the content and navigational help
Mismatched Condition	Presentation and structure of information does not coincide with user's preference	Low Working Memory users are provided with the whole information	Users' available amount of time does not coincide with their ability	Users with moderate and high levels of anxiety receive no additional help or aesthetics

6.2 Results

As expected, in both experiments the matched condition group outperformed those of the mismatched group (Tsianos et al., 2008b; Tsianos et al., 2007; Germanakos et al., 2008a;

Germanakos et al., 2008b). Fig. 13 displays the aggregated differences in performance (the dependent variable of exam score), in matched and mismatched conditions.

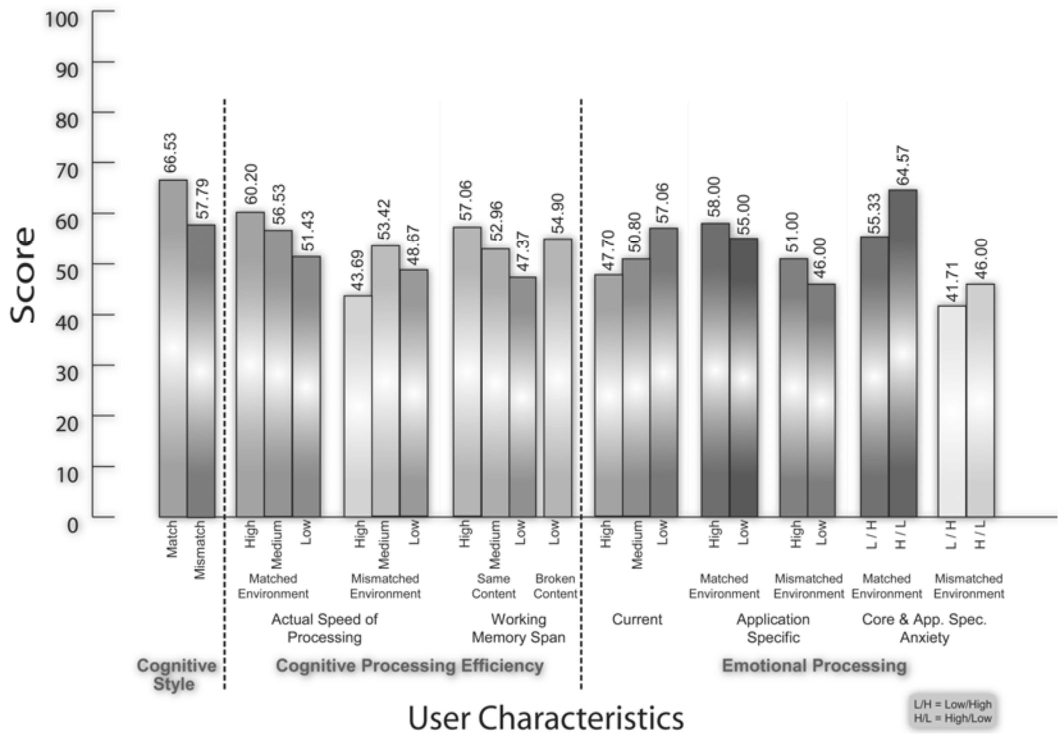

Figure 13. Aggregated differences in matched/mismatch condition

Table 3 shows the differences of means (one way ANOVA) and their statistical significance for the parameters of Cognitive Style, Cognitive Efficiency Speed, and Emotional Processing.

Table 3: Differences of means in the matched/mismatched condition for Cognitive Style and Cognitive Efficiency Speed

	Match Score	Match n	Mismatch Score	Mismatch n	F	Sig.

Cognitive Style	66.53%	53	57.79%	61	6.330	0.013
Cognitive Efficiency Speed	57.00%	41	48.93%	41	5.345	0.023
Emotional Processing	57.91%	23	48.45%	29	4.357	0.042

In the case of Emotional Processing, results show that in case an individual reports high levels of anxiety either at the Core Anxiety or the Specific Anxiety questionnaire, the matched condition benefits his/her performance (Lekkas et al., 2008). Though we have referred above to the construct of Emotional Regulation and the Self-Report tool, which have both shown statistically significant correlation (negative and positive respectively) to anxiety, such an analysis is beyond the scope of this paper.

The relatively small sample that falls into each category and its distribution hamper statistical analysis of the working memory (WM) parameter. In any case, the difference between those with high WM and those with low WM, when both categories receive non-segmented (whole) content, approaches statistical significance: 57.06% for those with High WM, 47.37% for those with Low WM, Welch statistic= 3.988, p=0.054.

This demonstrates that WM has indeed some effect on an eLearning environment. Moreover, if those with low WM receive segmented information, then the difference of means decreases and becomes non-significant (57.06% for High WM, 54.90% for those with Low WM, Welch statistic=0.165, p=0.687).

7 Evaluation of the eCommerce paradigm

The second phase of our research was to apply our evaluated information processing model in a setting (more generic) other than educational. For the purposes of such an empirical validation, we created an adaptive version of a commercial site, in order to investigate users' possible responses to a personalization process as the aforementioned.

7.1 Sampling and procedure

In the case of the eCommerce environment a within participants experiment was conducted, seeking out to explore if the personalized condition serves users better at finding information more accurately and fast. A pilot study that involved a between participants design demonstrated inconsistent effects, suggesting that a within subjects approach would yield more robust results.

All 89 participants were students from the Universities of Cyprus and Athens and their age varied from 18 to 21, with a mean age of 19. They accessed the Web environments using personal computers located at the laboratories of both universities, divided in groups of approximately 12 participants. Each session lasted about 40 minutes; 20 minutes were required for the user-profiling process, while the remaining time was devoted to navigating in both environments, which were presented sequentially (as soon as they were done with the first environment, the second one was presented).

The content was about a series of laptop computers: general description, technical specifications and additional information were available for each model. We consider that the original (raw) version of the environment was designed without any consideration towards cognitive style preferences, and the amount of information was so high and randomly allocated that could increase the possibility of cognitive overload. The personalized condition addressed these issues by introducing as personalization factors both cognitive style and working memory span. The profiling procedure was the same as described above, involving the usage of the same materials.

In each condition, users were asked to fulfill three tasks; they actually had to find the necessary information to answer three sequential multiple choice questions that were given to them while navigating. All six questions (three per condition) were about determining which laptop excelled with respect to the prerequisites that were set by each question. There was certainly only one correct answer that was possible to be found relatively easy, in the sense that users were not required to have hardware related knowledge or understanding.

As soon as users finished answering all questions in both conditions, they were presented with a comparative satisfaction questionnaire; users were asked to choose which environment was better (1-5 scale, where 1 means strong preference for environment A and 5 for environment B), regarding usability and user friendliness factors.

The dependent variables that were considered as indicators of differences between the two environments were:

a) Task accuracy (number of correct answers)

b) Task completion time

c) User satisfaction

At this point a few clarifications about the methodology are necessary:

- Users had no knowledge about which is the personalized condition, nor were they encouraged to use any additional features

- To avoid training effects, half of the users received the raw condition first (considered as environment A), whilst the other half started the procedure with the personalized (again considered as environment A).
- To avoid the effect of differences in difficulty of each set of three questions, they were alternated in both environments. Due to a design error, the division was not in half, but 53 participants received the first combination and 36 the alternated. However there was not observed any effect; all questions were of equal difficulty.
- The within participants design allowed the control of differences and confiding variables amongst users.

7.2 Implications for an e-Commerce setting

In this Web setting, there are some considerable differences in the way our theoretical model was (partially) implemented in the eCommerce environment, as compared to the educational setting. For reasons of increased usability, there was no “learner control” panel. Though it was proven a useful tool for learners, we considered that it would be somehow burdening for the case of browsing laptops in the Web.

Secondly, and most importantly, users with low WMS did not receive segmented content, because that would be impossible considering the absolutely non-sequential pattern of Web-browsing. For that reason, we introduced a “myNotepad” tool that allowed users to make entries of goal-related information; this tool was meant to serve as an additional buffer for participants with low memory span, alleviating disorientation and cognitive load caused by the high amount of information included in the original environment. Users were able to add in this notepad the link and a general description of the section they are visiting, allowing them to code large amounts of information. This approach has of course to be further evaluated with working memory-specific experiments, since there is much depth in the role of working memory and corresponding strategies.

As it concerns cognitive style, table 4 shows the implications for each preference. Intermediates received a balanced between each opposite preference condition, as with the case of the eLearning experiment described in the previous section.

Table 4: Implications for cognitive style preferences in the eCommerce environment

Imager	Verbalizer	Analyst	Wholist
Presentation of information is visually enhanced in order to resemble a diagrammatical form of representation	The usage of text is predominant, unaccompanied by any visual enhancements	The structure of the environment is chunked to clear cut links, as to match the analytical way of thinking	The structure of the environment is less segmented and follows a more holistic pattern. Users are shown where they are, what they have visited, and a more sequential approach is encouraged

7.3 Results

The most robust and interesting finding was the fact that users in the personalized condition were more accurate in providing the correct answer for each task. The same user in the raw condition had a mean of 1 correct answer, while in the personalized condition the mean rose to 1.9. Since the distribution was not normal and the paired samples t-test assumptions were not met, Wilcoxon Signed Ranks Test was performed, showing that this difference is statistically significant at zero level of confidence (Z= -4.755, p=0.000). This is probably a very encouraging finding, implying that personalization on the basis of these factors (cognitive style and WMS) benefits users within an eCommerce environment, as long as there are some cognitive functions involved of course (such as information finding).

Equally interesting is the fact that users in the personalized condition were significantly faster at task completion. The mean aggregated time of answering all three questions was 541 seconds in the raw condition, and 412 in the personalized. A paired samples t-test was performed ($t_{(88)}$=4.668, p=0.000) demonstrating significance at zero level of confidence. Again, this second dependent variable (time) shows that the personalized environment is more efficient (see Fig. 14).

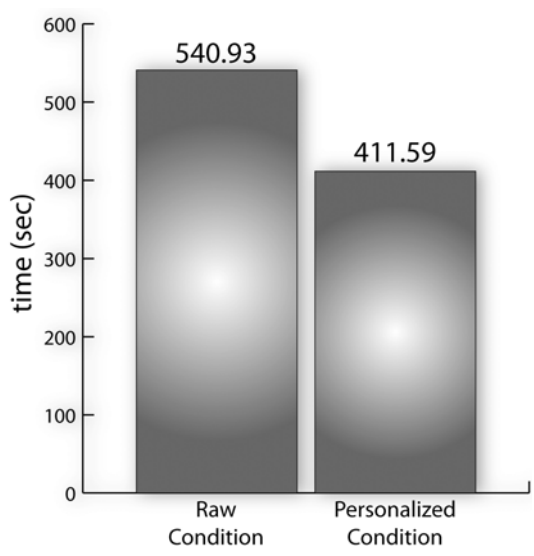

Figure 14. Difference in task completion time between the two conditions

As it concerns the satisfaction questionnaire, 31 users leaned towards the personalized environment, 38 had no preference while 20 preferred the raw. This descriptive statistic is merely indicative of whether participants would consciously observe any positive or negative effects of the personalized condition. A considerable percentage leaned towards that condition (or at least users did not seem somehow annoyed by such a restructuring), but overall it cannot be supported that they were fully aware of their increase in performance, as shown by the abovementioned findings.

In sum, the specific experiment shows in a rather clear way that users performed better within the personalized environment, and these findings are statistically very robust. It could be argued of course that there is no way to be fully aware if information processing was more efficient at a deeper level, or users simply found the personalized condition more of their liking, thus devoting more conscious cognitive effort. Nevertheless, such an increase in performance, which is consistent to the findings of the eLearning experiments, provides support for the further development and application of our theoretical model in a wider than educational level.

8 Conclusions and Future Work

The basic objective of this chapter was to introduce a combination of concepts coming from different research areas all of which focusing upon the user. It has been attempted to approach the theoretical considerations and technological parameters that can provide the most comprehensive user profile, under a common filtering element (User Perceptual Preference Characteristics), supporting the provision of the most apt and optimized user-centered Web-based result. Eventually, this chapter made an extensive reference to the comprehensive user profile construction and presented an overview of the AdaptiveWeb architecture indicating the data flow between its various stand alone components.

Our system, and model, has been evaluated both at system's response time performance and resources consumption, as well as with regards to users' learning performance and satisfaction in two different applications areas of eLearning and eCommerce.

More specifically, we have conducted a number of experiments to load test functional behaviour and measure performance of our system with controlled environments measuring average response times, throughput, deviation and median, ran by 100 threads (users).

The empirical study on the field of eLearning presented above indicates an increase in users' learning performance, while we identified a correlation of cognitive processing speed and visual attention processing efficiency of users as well as intrinsic parameters of emotionality, with the parameters of online content.

Moreover, the evaluation results of the eCommerce environments are consistent to our previous findings, and perhaps are a little more impressive, considering the fact that such an approach in a non-educational setting is rather novel. It was clearly demonstrated that users' information finding was more accurate and efficient, by taking into account their cognitive style preference and working memory span. The implementation of the rest of our theoretical model and the development of corresponding personalization rules is the next step of our experimental approach in generic Web settings, aiming to ground if possible a set of generic personalization guidelines on the basis of human factors- though it is fully understood how challenging such an endeavor is.

Hence, our system, and model, has been proved effective and efficient not only regarding the information flow within and between the various standalone system's components but also in respect to the actual output data gathered. These evaluative results are really encouraging for the future of our work since we found that in many cases there is high positive correlation of matched conditions with performance, as well as between the dimensions of the various factors of our model. This fact reveals that the whole approach turned out to be initially successful with a significant impact of human factors in the personalization and adaptation procedure of Web-based environments.

The next step of our work, besides improving the methodology of our experiments in a commercial / services Web environment, as mentioned, is the integration of the remaining parameters of our proposed model as personalization factors in the Web. With regards to emotional processing, we are setting out a research framework that involves the use of sensors and real-time monitoring of emotional arousal (Galvanic Skin Response and Heart Rate). We will further also investigate constraints and challenges arise from the implementation of such issues on mobile devices and channels. We will extend our study on the structure of the metadata coming from the providers' side, aiming to construct a Web-based personalization architecture that will serve as an automatic filter adapting the received content based on the comprehensive user profile. The final system will provide a complete adaptation and personalization Web-based solution to the users satisfying their individual needs and preferences.

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