Realizing Comprehensive User Profile as the Core Element of Adaptive and Personalized Communication Environments and Systems

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Abstract. Challenges today in the Web personalization and adaptation research area are ranging not only to the heterogeneous user needs and user environment issues such as current location and time, but also on a number of other considerations with respect to multi-channel delivery of the applications concerning Web-based content related to services, educational multimedia, entertainment, commerce etc. Nowadays, most Web personalization systems implement various techniques to extract the user profiles, which serves as the main component of such systems, and based on given user preferences, navigation behaviour and the Web-based content returns the requested personalized result. The main scope of this paper is to present the various techniques employed by such systems with regards to user profiles extraction and introduce a comprehensive user profile, which includes User Perceptual Preference Characteristics. It further analyzes the main intrinsic users’ characteristics like visual, cognitive, and emotional processing parameters incorporated as well as the “traditional” user profile characteristics that together tend to give the most optimized, adapted and personalized outcome. It finally presents a Web adaptation and personalization system that implements the proposed comprehensive user profile as well as initial evaluation results.

1 Introduction

Since 1994, the Internet has emerged as a fundamental information and communication medium that has generated extensive enthusiasm. The Internet has been adopted by the mass market much quicker than any other technology over the past century and is currently providing an electronic connection between progressive businesses and millions of customers and potential customers whose age, education, occupation, interest, and income demographics are excellent for sales. The explosive growth in the size and use of the WWW as well as the complicated nature of most Web structures result in orientation difficulties, as users often lose sight of the goal of their inquiry, look for stimulating rather than informative material, or even use the navigational features unwisely. As the e-Services sector is rapidly evolving, the need for such Web structures that satisfy the heterogeneous needs of its users is becoming more and more evident.

To alleviate such navigational difficulties, researchers have put huge amounts of effort to identify the peculiarities of each user group and analyze and design methodologies and systems that could deliver up-to-date adaptive and personalized information, with regards to products or services. To date, there has not been a concrete definition of personalization. The many adaptive hypermedia and Web personalization solutions offering personalisation features meet an abstract common goal: to provide users with what they want or need without expecting them to ask for it explicitly [1]. Further consideration and analysis of parameters and contexts such as users’ intellectuality, mental capabilities, socio-psychological factors, emotional states and attention grabbing strategies should be extensively investigated. All these characteristics could affect the apt collection of users’ customization requirements and along with the ‘traditional’ user characteristics (i.e. name, age, education, experience, etc.), constitute a comprehensive user profile that serves as the ground element of most of these systems offering in return the best adaptive environments to their preferences and demands.
Some noteworthy, mostly commercial, applications in the area of Web personalization that collect information with various techniques and further adapt the services provided, are amongst others the Broadvision’s One-To-One, a commercial tool for identification of on-line users; Microsoft’s Firefly Passport (developed by the MIT Media Lab); Macromedia’s LikeMinds Preference Server, which identifies behaviours of on-line customers and it further predicts new purchases of a user; Apple’s WebObjects, which adapts the content to user preferences, etc. Other, more research oriented systems, include ARCHIMIDES [2], which adapts the raw content based on the structure reorganization of a Web server. The structure is depicted as a semantic tree through which there is a dynamic selection of the content nodes according to the users’ preferences; Proteus [3], is a system that constructs user models using artificial intelligence techniques and adapts the content of a Web site taking into consideration also wireless connections; WBI [4, 5] and BASAR [6], use static agents for the personalization of the content while other systems employ mobile agents over mobile networks for this purpose, like mPERSONA [7]. Significant implementations have also been developed in the area of adaptive hypermedia, with regards to the provision of adapted educational content to students using various adaptive hypermedia techniques. Such systems are amongst others, INSPIRE [8], ELM-ART [9], AHA! [10], Interbook [11].

Although one-to-one Web-based content provision may be a functionality of the distant future, user segmentation is a very valuable step in the right direction. User segmentation means that the user population is subdivided, into more or less homogeneous, mutually exclusive subsets of users who share common user profile characteristics enabling the possibility of providing them with a more personalized content. The subdivisions could be based on: Demographic characteristics (i.e. age, gender, urban or rural based, region); socio-economic characteristics (i.e. income, class, sector, channel access); psychographic characteristics (i.e. life style, values, sensitivity to new trends); individual physical and psychological characteristics (i.e. disabilities, attitude, loyalty). Moreover, the issue of personalization is a complex one with many aspects and viewpoints that need to be analyzed and resolved. Some of these issues become even more complicated once viewed from a moving user’s perspective, in other words when constraints of mobile channels and devices are involved. Such issues include, but are not limited to: What content to present to the user, how to show the content to the user, how to ensure the user’s privacy, how to create a global personalization scheme. As clearly viewed, user characteristics and needs, determining user segmentation and thus provision of the adjustable information delivery, differ according to the circumstances and they change over time [12]. There are many approaches to address these issues of personalization but usually, each one is focused upon a specific area, i.e. whether this is profile creation, machine learning and pattern matching, data and Web mining or personalized navigation.

This paper overviews adaptive hypermedia and Web personalization, investigating their relationship and presenting techniques used to monitor and extract user profiles which serves as their most essential and common element. Furthermore, it outlines the importance of user profiles and presents 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. Eventually, it introduces 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 presents an overview of Adaptive Hypermedia and Web personalization categories and technologies for extracting user profiles. Section 3 emphasizes the significance of user profiles. Section 4 introduces further intrinsic user considerations to be involved in a comprehensive user profile. Section 5 depicts a high level correlation diagram. Section 6 describes the AdaptiveWeb system and the comprehensive user profile construction and section 7 presents a preliminary evaluation. Finally, section 8 concludes this paper.
2 Adaptive Hypermedia and Web Personalization Techniques and Paradigms

When we are considering adaptation and personalization categories and technologies we refer to Adaptive Hypermedia and Web Personalization respectively, due to the fact that together these can offer the most optimized adapted content result to the user.

2.1 Adaptive Hypermedia Overview

Adaptive Hypermedia is a relatively old and well established area of research counting three generations: The first "pre-Web" generation of adaptive hypermedia systems explored mainly adaptive presentation and adaptive navigation support and concentrated on modeling user knowledge and goals. The second "Web" generation extended the scope of adaptive hypermedia by exploring adaptive content selection and adaptive recommendation based on modeling user interests. The third “New Adaptive Web” generation moves adaptive hypermedia beyond traditional borders of desktop hypermedia systems embracing such modern Web trends as “mobile Web”, “open Web”, and “Semantic Web” [13].

Adaptivity is a particular functionality that alleviates navigational difficulties by distinguishing between interactions of different users within the information space [14]. Adaptive Hypermedia Systems employ adaptivity by manipulating the link structure or by altering the presentation of information, based on a dynamic understanding of the individual user, represented in an explicit user model [14, 15]. In 1996, Brusilovsky identified four user characteristics to which an Adaptive Hypermedia System should adapt. These were user’s knowledge, goals, background and hypertext experience, and user’s preferences. In 2001, further two sources of adaptation were added to this list, user’s interests and individual traits, while a third source of different nature having to deal with the user’s environment had also been identified.

Figure 1. Adaptive Hypermedia Techniques
Generally, Adaptive Hypermedia Systems can be useful in application areas where the hyperspace is reasonably large and the user population is relatively diverse in terms of the above user characteristics. A review by Brusilovsky has identified six specific application areas for adaptive hypermedia systems since 1996 [17]. These are educational hypermedia, on-line information systems, information retrieval systems, institutional hypermedia and systems for managing personalized view in information spaces. 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 [16], adaptive presentation (or content-level adaptation) and adaptive navigation support (or link-level adaptation) [14, 17] and are summarized in Fig. 1.

As mentioned earlier, successful adaptation attempts have been made in the e-Learning research field to provide the students with adapted content according to their different learning styles or knowledge level and goals. A typical case of such a system could be considered the INSPIRE (Intelligent System for Personalized Instruction in a Remote Environment) architecture, see Fig. 2, where throughout its interaction with the learner, the system dynamically generates lessons that gradually lead to the accomplishment of the learning goals selected by the learner [18]. INSPIRE architecture has been designed so as to facilitate knowledge communication between the learner and the system and to support its adaptive functionality.

![Figure 2. INSPIRE’s Components and the Interaction with the Learner](image)

INSPIRE comprises of five different modules: (a) the Interaction Monitoring Module that monitors and handles learner’s responses during his/her interaction with the system, (b) the Learner’s Diagnostic Module that processes data recorded about the learner and decides on how to classify the learner’s knowledge, (c) the Lesson Generation Module that generates the lesson contents according to learner’s knowledge goals, knowledge level, (d) the Presentation Module whose function is to generate the educational material pages sent to the learner and (e) the Data Storage, which holds the Domain knowledge and the Learner’s Model.

### 2.2 Web Personalization Overview

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 information is presented in a personalized manner to the user. As inferred from its name, Web Personalization refers to Web applications solely (with popular use in eBusiness multimedia-based services), and generally is a relatively new area of research. Web personalization is the
process of customizing the content and structure of a Web site to the specific needs of each user by taking advantage of the user’s navigational behaviour. Being a multi-dimensional and complicated area a universal definition has not been agreed to date. Nevertheless, most of the definitions given to Web personalization [19, 20] agree that the steps of the Web personalization process include: (1) the collection of Web data, (2) the modelling and categorization of these data (pre-processing phase), (3) the analysis of the collected data, and the determination of the actions that should be performed. Moreover, many argue that emotional or mental needs, caused by external influences, should also be taken into account.

Web Personalization could be realized in one of two ways: (a) Web sites that require users to register and provide information about their interests, and (b) Web sites that only require the registration of users so that they can be identified [21]. The main motivation points for personalization can be divided into those that are primarily to facilitate the work and those that are primarily to accommodate social requirements. The former motivational subcategory contains the categories of enabling access to information content, accommodating work goals, and accommodating individual differences, while the latter eliciting an emotional response and expressing identity.

Personalization levels have been classified into: Link Personalization (involves selecting the links that are more relevant to the user, changing the original navigation space by reducing or improving the relationships between nodes), Content Personalization (user interface can present different information for different users providing substantive information in a node, other than link anchors), Context Personalization (the same information (node) can be reached in different situations), Authorized Personalization (different users have different roles and therefore they might have different access authorizations) and Humanized Personalization (involves human computer interaction) [22, 23]. 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 [24, 25, 26].

An example of a Web personalization application for the wireless user is the mPERSONA system, depicted in Fig. 3. The mPERSONA system architecture combines existing techniques in a component-based fashion in order to provide a global personalization scheme for the wireless user. The mPERSONA is a flexible and scalable system that focuses towards

![Figure 3. Detailed View of the mPERSONA Architecture](image)
the new era of wireless Internet and the moving user. It avoids tying up to specific wireless protocols (e.g., WAP) by using, as much as possible, autonomous and independent components. To achieve a high degree of independence and autonomy mPERSONA is based on mobile agents and mobile computing models such as the “client intercept model” [7].

3 The User Profile Imperative

As we can clearly understand from above, user profile serves as the core element of most systems and especially the adaptive and personalization ones. This prompts us to have a better insight of the user profile itself and the dimensions incorporated.

The user population is not homogeneous, nor should be treated as such. To be able to deliver quality knowledge, systems should be tailored to the needs of individual users providing them personalized and adapted information based on their perceptions, reactions, and demands. Therefore, a serious analysis of user requirements has to be undertaken, documented and examined, taking into consideration their multi-application to the various delivery channels and devices. Some of the user requirements and arguments anticipated could be clearly distinguished into [28]: (a) General User Service Requirements (flexibility: anyhow, anytime, anywhere; accessibility; quality; and security), and (b) Requirements for a Friendly and Effective User Interaction (information acquisition; system controllability; navigation; versatility; errors handling; and personalization).

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 [29]. 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. Its objective 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 (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. In the case of implicit acquisition of user data, each user can either be regarded as a member of group and take up an aggregate user profile or be addressed individually and take up an individual user profile. The data used for constructing a user profile could be distinguished into: (a) the Data Model which could be classified into the demographic model (which describes who the user is), and the transactional model (which describes what the user does); and (b) the Profile Model which could be further classified into the factual profile (containing specific facts about the user derived from transactional data, including the demographic data, such as “the favorite beer of customer X is Beer A”), and the behavioral profile (modeling the behavior of the user using conjunctive rules, such as association or classification rules. The use of rules in profiles provides an intuitive, declarative and modular way to describe user behavior [29]).

Still, could current user profiling techniques be considered complete incorporating only these dimensions? Do designers and developers of Web-based applications take into consideration the real users’ preferences in order to provide them a really personalized Web-based content? Many times this is not the case. How can a user profile be considered complete, and the preferences derived optimized, if it does not contain parameters related to the user perceptual preference characteristics? We could define User Perceptual Preference Characteristics as all the critical factors that influence the visual, mental and emotional processes liable of manipulating the newly information received and building upon prior

1 http://mw1.merriam-webster.com/dictionary/profile
knowledge, that is different for each user or user group. These characteristics determine 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 [30].

In further support of the aforementioned concepts, one cannot disregard the fact that, besides the parameters that constitute the “traditional” user profile (composed of parameters like knowledge, goals, background, experience, preferences, activities, demographic information, socio-economic characteristics, device-channel characteristics etc.), each user carries his own perceptual and cognitive characteristics that have a significant effect on how information is perceived and processed. Information is encoded in the human brain by triggering electrical connections between neurons, and it is known that the number of synapses that any person activates each time is unique and dependant on many factors, including physiological differences [31]. Since early work on the psychological field has shown that research on actual intelligence and learning ability is hampered by too many limitations, there have been a “number of efforts to identify several styles or abilities and dimensions of cognitive and perceptual processing” [32], which have resulted in what is known as learning and cognitive styles. Learning and cognitive styles can be defined as relatively stable strategies, preferences and attitudes that determine an individual’s typical modes of perceiving, remembering and solving problems, as well as the consistent ways in which an individual memorizes and retrieves information [33]. Each learning and cognitive style typology defines patterns of common characteristics and implications in order to overcome difficulties that usually occur throughout the procedure of information processing. Therefore, in any Web-based informational environment, the significance of the aforementioned users’ differences, both physiological and preferential, is distinct and should be taken into consideration when designing such adaptive environments.

Currently there is no research that moves towards the consideration of user profiles incorporating optimized parameters taken from the research areas of visual attention processing and cognitive psychology in combination. Some serious attempts have been made though on approaching e-Learning systems providing adapted content to the students but most of them relate to the analysis and design of methodologies that consider only the particular dimension of cognitive learning styles, including Field Independence vs. Field Dependence, Holistic-Analytic, Sensory Preference, Hemispheric Preferences, and Kolb’s Learning Style Model [34], applied to identified mental models, such as concept maps, semantic networks, frames, and schemata [35, 36]. In order to deal with the diversified students’ preferences such systems are matching the instructional materials and teaching styles with the cognitive styles and consequently they are satisfying the whole spectrum of the students’ cognitive learning styles by offering a personalized Web-based educational content.

4 Identifying further Intrinsic User Values for Completing User Profiles

Based on the abovementioned considerations we introduce the Comprehensive User Profile that combines the User Perceptual Preference Characteristics described above along with the “Traditional” User Profile Characteristics since they are affecting the way a user approaches an object of perception [37].

The Comprehensive User Profile could be considered as the main raw content filtering module of an Adaptive Web-based Architecture. At this module all the requests are processed, being responsible for the custom tailoring of information to be delivered to the users, taking into consideration their habits and preferences, as well as, for mobile users mostly, their location (“location-based”) and time (“time-based”) of access [12]. The whole processing varies from security, authentication, user segmentation, content identification, user perceptual characteristics (visual, cognitive and emotional processing parameters) and so forth. 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. The Comprehensive User Profile is comprised of two main components:

4.1 **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, (a) the 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 (b) the 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.

4.2 **User Perceptual Preference Characteristics**
This is our proposed new component/dimension of the user profile defined above. It contains all the visual attention and cognitive psychology processes (cognitive and emotional processing parameters) that completes the user preferences and fulfills 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. 4, below. As it can be observed, its primary parameters formulate a three-dimensional approach to the problem. The first dimension investigates the visual and cognitive processing of the user, the second his/her cognitive style, while the third captures his/her emotional processing during the interaction process with the information space.

![Figure 4. User Perceptual Preference Characteristics – Three-Dimensional Approach](image-url)
It is considered a vital component of the user profile since it identifies the aspects of the user that is very difficult to be revealed and measured but, however, might determine his/her exact preferences and lead to a more concrete, accurate and optimized user segmentation. As mentioned above, it is composed of three elements:

(a) Cognitive Processing Speed Efficiency: The Actual Speed of Processing parameters could be primarily determined by (i) the visual Processing, whereby special emphasis is given to the visual attention that is responsible for the tracking of the user’s eye movements and in particular the scanning of his/her eye gaze on the information environment [38]. It is composed of two serial phases: the pre-attentive and the limited-capacity stage. The pre-attentive stage of vision subconsciously defines objects from visual primitives, such as lines, curvature, orientation, color and motion and allows definition of objects in the visual field. When items pass from the pre-attentive stage to the limited-capacity stage, these items are considered as selected. Interpretation of eye movement data is 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; (ii) the control of processing (refers to the processes that identify and register goal-relevant information and block out dominant or appealing but actually irrelevant information); and (iii) the speed of processing (refers to the maximum speed at which a given mental act may be efficiently executed) [38]. The 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. Many researches [39, 40] have identified that the speed of cognitive processing and control of processing it is directly related to a person’s age, as well as to the continuous exercise and experience, with the former to be the primary indicator. Therefore, as it is depicted in Fig. 5a, the processing development speed increases non-linearly in the age of 0 – 15 (1500 msec), it is further stabilized in the age of 15 - 55-60 (500 msec) and decreases from that age on (1500 msec). However, it should be stated that the actual cognitive processing speed efficiency is yielded from the difference (maximum value 0.8 msec) between the peak value of the speed of processing and the peak value of control of processing, as it is depicted in Fig. 5b.

At this point, we have calibrated the psychometric tools that we use to measure these parameters, and we expect to find correlations initially with academic performance. According to theory, if correlation with performance is high, then proper personalizing techniques (like reducing the volume of information in case of low memory and processing abilities) are expected to optimize performance.

(b) Cognitive Styles: They represent the particular set of strengths and preferences that an individual or group of people have in how they take in and process information. By taking into account these preferences and defining specific learning strategies, empirical research has...
shown that more effective learning process can be achieved [41], and that cognitive styles nevertheless correlate with performance in a Web-based environment [42].

Within the context of educational psychology, theories of learning and cognitive styles have been developed, addressing the issue of individual differences in learning, or more specifically, the perception, processing and retaining of information. Cognitive styles have been defined by Messick as “consistent individual differences in preferred ways of organising and processing information and experience” [43], while by Sternberg and Grigorenko as “a bridge between what might seem to be two fairly distinct areas of psychological investigation: cognition and personality” [44]. Learning styles, as a term, are frequently used interchangeably with cognitive styles, but in general are broader concepts that incorporate a greater number of not mutually exclusive characteristics, and focus on learning rather than cognitive tasks [45]. Taking into account individual cognitive and learning styles is of high importance, since such an approach “can lead to new insights into the learning process, a greater knowledge of individual differences, and an expanding repertoire of methods for the teacher” [46].

Regarding the hypermedia information space, amongst the numerous proposed theories of individual style, a selection of the most appropriate and technologically feasible cognitive (and learning) styles (those that can be projected on the processes of selection and presentation of Web-content and the tailoring of navigational tools) has been studied, such as Riding’s Cognitive Style Analysis (CSA) (Verbal-Imager and Wholistic-Analytical) [47], Felder/Silverman Index of Learning Styles (ILS) (4 scales: Active vs Reflective, Sensing vs Intuitive, visual vs Verbal and Global vs Sequential) [48], Witkin’s Field-Dependent and Field-Independent [49], and Kolb’s Learning Styles (Converger, Diverger, Accommodator, and Assimilator) [50], in order to identify how users transforms information into knowledge (constructing new cognitive frames).

We consider that Riding’s Cognitive Style Analysis [47] and Felder/Silverman’s Index of Learning Style [48] implications can be mapped on the information space more precisely, since they consist of distinct scales that respond directly to different aspects of the Web space. Still, one must be cautious about reliability and validity issues of such psychometric tools, since many of them often fail to exhibit satisfactory results; that may be true for the case of Felder/Silverman’s ILS, that perhaps should be further evaluated [51], without of course neglecting the authors’ reliability and validity reports [52].

On the other hand, learning style theories that define specific types of learners, such as Kolb’s Experiential Learning Theory [50], have far more complex implications, since they relate strongly with personality theories, such as the Myers-Briggs Type Indicator (MBTI) [53], and therefore cannot be adequately quantified and correlated easily with Web objects and structures. For example, being a “converger” according to Kolb’s typology or a “judging” person (from a personality psychometric tool aspect) has implications that are more dominant in a traditional social learning environment than in a hypermedia environment. The case of collaborative learning may provide the basis for assessing the role of such learning styles in performance, but is beyond the scope of our present research.

As part of our research, we did find significant correlation between academic performance and adaptation on specific learning style [54], though we now have implemented Riding’s typology implications in our current hypermedia application, rather than Felder’s that we firstly used. Part of our research is to examine whether such results can be repeatedly found, in order to support the importance of learning and cognitive styles.

We use Riding’s CSA since it can be mapped on the information space more precisely (the implications are consisted of distinct scales that respond to different aspects of the Web-space) and can be applied on most cognitive informational processing tasks (rather than strictly educational). The CSA implications are quite clear in terms of hypermedia design (visual/verbal content presentation and wholist/analyst pattern of navigation), and is probably one of the most inclusive theories, since it is actually derived from the common axis of a number of previous theories.

Learning style theories that define specific types of learners, as Kolb’s Experiential Learning Theory, and Felder/Silverman’s ILS (at least the active/reflective and
sensing/intuitive scales) have far more complex implications, since they relate strongly with personality theories, and therefore cannot be adequately quantified and correlated easily with Web objects and structures.

The CSA main characteristics as well as their implication into the information space are summarized in Fig. 6 [43].

![Riding's Cognitive Style Analysis](image)

**Figure 6. Riding's Learning Styles Characteristics and Implications**

(c) Emotional processing: In our study, we are also interested in the way that individuals process their emotions and how they interact with other elements of their information-processing system. Emotional processing is a pluralistic construct which is comprised of two mechanisms: emotional arousal, which is the capacity of a human being to sense and experience specific emotional situations, and emotion regulation, which is the way in which an individual is perceiving and controlling his/her emotions. We focus on these two sub-processes because they are easily generalized, inclusive and provide some indirect measurement of general emotional mechanisms. These sub-processes manage a number of emotional factors like anxiety, boredom effects, anger, feelings of self efficacy, user satisfaction etc. Among these, our current research emphasizes on anxiety, which is probably the most indicative, while other emotional factors are to be examined within the context of a further study.

Accordingly, in order to measure emotional arousal and emotion regulation, we are using the construct of anxiety and the construct of emotional control respectively. An effort to construct a model that predicts the role of emotion, in general, is beyond the scope of our research, due to the complexity and the numerous confiding variables that would make such an attempt rather impossible. However, there is a considerable amount of references concerning the role of emotion and its implications on academic performance (or achievement), in terms of efficient learning [55]. Emotional Intelligence seems to be an
adequate predictor of the aforementioned concepts, and is surely a grounded enough construct, already supported by academic literature.

On the basis of the research conducted by Goleman (1995) [56], as well as Salovey & Mayer (1990) [57], who have introduced the term, we are in the process of developing an EQ questionnaire that examines the 3 out of 5 scales that comprise the Emotional Intelligence construct (according to Goleman), since factors that deal with human to human interaction (like empathy) are not present in our Web-application - at least for the time being. As a result, our variation of the EQ construct, which we refer to as Emotional Control, consists of: (a) The Self-Awareness scale, (b) The Emotional Management scale, and (c) The Self-Motivation scale. While our sample is still growing, Cronbach’s alpha, which indicates scale reliability, is currently 0.714. Revisions on the questionnaire are expected to increase reliability.

Still, there is a question about the role of emotions, and their cognitive and/or neurophysiologic intrinsic origins [58]. Emotions influence the cognitive processes of the individual, and therefore have certain effect in any educational setting. Again, bibliographic research has shown that anxiety is often correlated with academic performance [44], as well with performance in computer mediated learning procedures [59, 60]. Subsequently, different levels of anxiety have also a significant effect in cognitive functions. We believe that combining the level of anxiety of an individual with the moderating role of Emotional Control, it is possible to clarify, at some extent, how emotional responses of the individual hamper or promote learning procedures. Thus, by personalizing Web-based content, taking into account emotional processing, we can avoid stressful instances and take full advantage of his/her cognitive capacity at any time.

Anxiety is a complex term and in order to measure it accurately and validly (measure the kind of anxiety we are interested in), it has to be adapted to our research. For this reason we included in our model not only a general anxiety measure (Stait-Trait Anxiety Inventory (STAI) test [61]) but a situation-specific measure of anxiety as well (i.e. educational). Additionally, we are interested in measuring anxiety as a predisposition (trait-anxiety) and as a generated (state-anxiety) set of emotions as well. This way, we can see the differences between the individual’s evaluation of anxiety and what actually happens during the task.

The concept of general (core) anxiety is indicative of a person’s tendency to exhibit lower performance in information processing tasks, but not all circumstances are the same. For that reason, we measure not only one’s general (core) anxiety, but also application specific anxiety and his current self-reported anxiety. In our experimental case, application specific anxiety is measured by a questionnaire that refers to educational test anxiety, while users can self-report their levels of anxiety using an indicative bar that is embedded in the interface.

We believe that combining the level of anxiety of an individual with the moderating role of Emotional Control, it is possible to clarify, at some extent, how affectional responses of the individual hamper or promote learning procedures. Thus, by personalizing on this concept of emotional processing the educational content that our already developed adaptive system provides, we can avoid stressful instances and take full advantage of his/hers cognitive capacity at any time.

At a practical level, we assume that users with high anxiety levels lacking the moderating role of Emotional Control are in a greater need of enhancing the aesthetic aspects of our system, while users with low anxiety levels focus more on usability issues.

The empirical research we conducted provided us with indications that Emotional Control and Anxiety correlate in a way that supports our assumptions [62]- still, safe conclusions can be drawn only after we have conducted further experiments within the actual learning environment.

5 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. 7. 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 they represent the primary subsidiaries of a Web based content. With the necessary processing and/or alteration we could provide the same content in different ways (according to a specific user’s profile) but without degrading the message conveyed.

![Figure 7. Data–Implications Correlation Diagram](image)

The particular mapping is based on specific rules that are consistent to psychological theory, in order to filter the raw content and deliver the most personalized Web-based result to the user. As it can be observed from the diagram above almost each profiling dimension has primary (solid line) and secondary (dashed line) implications on the information space altering dynamically the weighting of each factor on the creation of the environment.

Riding’s Cognitive Style Analysis has been used in the Learning Style dimension, since the CSA applies in a greater number of information processing circumstances, and deals rather with the broader construct of cognitive, than learning, style. According to theory, for example, the number of images (few or many) to be displayed has a primary implication on imagers, while text (more concise or abstract) has a secondary implication. The analytic preference has a main effect on the links (learner control and navigation support tag), which in turn is secondary affected by high and medium levels of emotional processing. Moreover, levels of emotional processing might secondary affect the number of images or the kind of text to be displayed. Actual speed of processing parameters (visual attention, speed of processing, and control of processing) as well as working memory span primarily affect information quantity. Eventually, emotional processing primarily affects the provision of additional navigation support and aesthetics (which is also the case with visual attention), 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 processing speed efficiency 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 colors, 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.

6 The AdaptiveWeb System and Comprehensive User Profile Construction

Based on the abovementioned considerations an adaptive Web-based environment is overviewed, trying to convey the essence and the peculiarities encapsulated. The current system, AdaptiveWeb² (see Fig. 8), is a Web application that can be ported both to desktop computer and mobile devices. It is composed of four interrelated components³, each one representing a stand-alone Web-based system briefly presented below:

![Figure 8. AdaptiveWeb System Architecture](http://www3.cs.ucy.ac.cy/adaptiveWeb)

6.1 User Profile Construction

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.9).

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

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² http://www3.cs.ucy.ac.cy/adaptiveWeb
³ The technology used to build each Web system’s component is ASP.Net (http://asp.net).
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 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.
- The Emotional Control 27 item questionnaire we have developed (Cronbach’s alpha 0.76), and i) the Test Anxiety Inventory [63] to measure application specific anxiety (educational process in our case) and ii) the State-Trait Anxiety Inventory [61] to measure general (core) anxiety.

Moreover, while users navigate through our application, they can make use of an 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 enables the extensibility 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

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4 http://www.pstnet.com/products/e-prime/
5 http://www.w3.org/XML/
this middleware; calculations are made and are finally exported in XML. For a better insight, the Tree Structure of the Comprehensive User Profiling, giving emphasis on the comprehensive user profile structure, is depicted in Fig. 10.

**Figure 10. The Tree Structure of the Comprehensive User Profiling XML document**

### 6.2 Content Authoring and Adaptation Process

For experimental purposes, we have authored an eLearning environment with a predefined content for adaptation and personalization. This 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.

To get a better insight of the adaptation process and how data flows, we hereafter depict how the personalized content (the “Introduction to Algorithms” predefined environment) interacts with the Comprehensive User Profile, using specific mapping rules. In Fig. 11 the Content and Structure Description Schema is shown, while Fig. 12 shows the whole adaptation process.

When users want to see adapted and personalized content they have to give their credentials for retrieving their profile. In this particular example (see Fig. 12), 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; 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. 11).
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.

Interpreting 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.

Mapping this information with the main content description XML instance of “WebPage_Y.xml”, leads yet to another conclusion, that two objects should be presented on the Web-page; “object_X” and “object_Y”. Each object has special characteristics (tags): an ID which is unique across all the system determined by the Web-site category which it belongs to (i.e. Introduction to Algorithms), the object’s type (text, image, video, audio etc.), the object’s content format (Theory, Description, Example, etc.), the layout structure which defines where the objects should be placed in each division/frame (Introduction, Main Body, Conclusion). Each object, depending on which division it belongs to, is assigned a unique value in the form of a tuple, e.g. (Intro,1), (Intro,2), (Intro,3), where the first attribute represents the division in which the object should be placed while the second represents the complexity of the object. Finally, the XML instance also consists of the object’s actual content for a text object or the source file of an image, audio, video objects. If an object has navigational support (extra description of a definition), we further relate each object’s definition with a navigation support object which has a unique ID and the definition’s content description.
Furthermore, Fig. 13 shows the mapping process using our example; explained in pseudo code. XML documents do not provide any formatting information. They do not provide any information about how XML documents should be displayed, unlike HTML documents that carry that information. For this purpose, the author designs the page and formats it as he wishes 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
   if (learningStyle1 = Imager)
       Add image objects;
   elseif (learningStyle1 = Wholist)
       Add text objects;
   if (object has NavigationSupport Tag){
       var wordDefinitionObject = retrieveWordDefinitions(objectID)
       var navigationSupportType;
       if (learningStyle2 = Analyst)
           getNavigationSupportType(objectID);
           Show description in pop 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 13: Mapping Process Example (pseudo code)

The content will be adapted according to the user’s preferences. The new, adapted content 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.

At this point we should mention that the second component, the system’s “Semantic Web Editor”, is still under study and construction. 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 used for creating the personalized content is a more expressive semantic Web language like OWL\(^6\) or RDF\(^7\) used for describing data and to focus on the relation between them. The author of the page uploads the content on the system’s database, which will be mapped later 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. 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.

So far, we have presented how adaptation of the actual raw content of the Web-page is achieved matching the comprehensive user profile with the content description XML document using specific mapping rules. The next step is to elaborate on how the system’s auxiliary tools (navigation support and learner control) are affected and altered through the adaptation and personalization process. The subsection below will explain in more detail the

\(^7\) http://www.w3.org/RDF/, http://www.ariadne.ac.uk/issue14/what-is/
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.

6.3 Viewing the Adapted Content-The AdaptiveInteliWeb Environment

The last component of the architecture is the AdaptiveWeb User Interface, namely AdaptiveInteliWeb (see Fig. 14), which is a Web application used for displaying the raw or personalized and adapted content on the user’s device. This can be a home desktop, laptop or a mobile device.

![Figure 14. AdaptiveWeb User InteliBar](image)

The main concept of this component is to provide a framework where all personalized Web sites can be navigated. Using this interface the users will navigate through the provider’s content. Based on their profiling further support will be 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 comprehensive profiling 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.

Fig. 15 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 15. Content adaptation according to user’s comprehensive profile

As seen in this figure, the same content has been adapted and a different learner control and navigation support is provided. Based on theory [43], 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.

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. For this reason, all the tests implemented so far to prove components efficiency have been based on a predetermined online content in the field of eLearning multimedia environment, due to the fact mainly that there is an increased interest on distance education via the Web. In this case, we were able to control factors such as previous knowledge and experience over distributed information, by integrating this e-learning procedure into an undergraduate course on Introduction to algorithms in our department.

7 Preliminary Evaluation

7.1 System’s Performance
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, learner control dynamic 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

<table>
<thead>
<tr>
<th></th>
<th>Raw Content Scenario</th>
<th>Personalized Content Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Response Time</td>
<td>138ms</td>
<td>183ms</td>
</tr>
<tr>
<td>Deviation</td>
<td>72ms</td>
<td>110ms</td>
</tr>
<tr>
<td>Throughput</td>
<td>14493.17Kb/min</td>
<td>17951.52Kb/min</td>
</tr>
<tr>
<td>Median</td>
<td>141ms</td>
<td>172ms</td>
</tr>
<tr>
<td>Threads (Users)</td>
<td>100 users</td>
<td>100 users</td>
</tr>
</tbody>
</table>

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.

Furthermore, the evaluation of the system’s positive effect on users’ performance was implemented through an e-learning multimedia environment. Factors such as previous knowledge and experience were controlled by choosing the subject of algorithms, in which students at our department traditionally perform poorly.

7.2 Users’ performance based on parameters used
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).

7.2.1 Sampling and procedure
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 e-learning 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 of computer science, and traditionally perform poorly. By controlling the factor of experience in that way, we divided our sample of the first phase in two groups: almost half of the participants were provided with information matched to their cognitive style, while the other half were taught in a mismatched way. In the second phase, the sample was divided in six, with a matched and mismatched condition for each factor. We expected that users in the matched condition, both in phase I and phase II, would outperform 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 e-learning 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

<table>
<thead>
<tr>
<th></th>
<th>Cognitive Style</th>
<th>Working Memory</th>
<th>Cognitive Processing Speed Efficiency</th>
<th>Emotional Processing</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Matched Condition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Presentation and structure of</td>
<td>Low Working</td>
<td>Each user has</td>
<td>Users with moderate and high levels</td>
<td></td>
</tr>
<tr>
<td>information matches user’s</td>
<td>Memory users are</td>
<td>his disposal</td>
<td>of anxiety receive aesthetic enhancement</td>
<td></td>
</tr>
<tr>
<td>preference</td>
<td>provided with</td>
<td>the amount of</td>
<td>of the content and navigational help</td>
<td></td>
</tr>
<tr>
<td></td>
<td>segmented</td>
<td>time that fits</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>information</td>
<td>his ability</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mismatched Condition</strong></td>
<td></td>
<td>Low Working</td>
<td>Users with moderate and high levels</td>
<td></td>
</tr>
<tr>
<td>Presentation and structure of</td>
<td>Memory users are</td>
<td>have less time</td>
<td>of anxiety receive no additional help</td>
<td></td>
</tr>
<tr>
<td>information does not coincide</td>
<td>provided with</td>
<td>in their disposal (the same with</td>
<td>or aesthetics</td>
<td></td>
</tr>
<tr>
<td>with user’s preference</td>
<td>the whole</td>
<td>“medium” users).</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>information</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

7.2.2 Questionnaires
In this specific e-learning setting, Users’ Perceptual Preferences were the sole parameters that comprised each user profile, since demographics and device characteristics were controlled for. In order to build each user profile according to our model, we used a number of questionnaires that address all theories involved.

- **Cognitive Style**: Riding’s Cognitive Style Analysis, standardized in Greek and integrated in .NET platform
- **Cognitive Processing Speed Efficiency**: Speed and accuracy task-based tests that assess control of processing, speed of processing, visual attention and visuospatial working memory. Originally developed in the E-Prime platform, we integrated them into the .NET platform.
- **Core (general) Anxiety**: Spielberger’s State-Trait Anxiety Inventory (STAI) – 10 items (Only the trait scale was used) [58].
• **Application Specific Anxiety:** Cassady’s Cognitive Test Anxiety scale – 27 items [61].
• **Current Anxiety:** Self-reported measures of state anxiety taken during the assessment phase of the experiment, in time slots of every 10 minutes – 6 Time slots.
• **Emotion Regulation:** This questionnaire was developed by us; cronbach’s $\alpha$ that indicates scale reliability reaches 0.718.

### 7.2.3 Results

As expected, in both experiments the matched condition group outperformed those of the mismatched group. Fig. 18 displays the differences in students’ mean performance (the dependent variable of exam score), in all matched and mismatched conditions.

![Figure 18. Mean differences of scores in all matched/mismatch conditions](image)

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

As hypothesized, the mean score of those that received matched to their cognitive style environments is higher than the mean score achieved by those that learned within the mismatched condition ($F_{2,113}=6.330$, $p=0.013$). This supports the notion that cognitive style is of importance within the context of web-education and that this construct has a practical application in hypermedia instruction. The same applies with the case of Cognitive Processing Speed Efficiency: $F_{2,81}=5.345$, $p=0.023$). It should at least be of some consideration the fact that in case designers’ teaching style mismatched learners’ preference, performance may be lowered.

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

<table>
<thead>
<tr>
<th>Cognitive Style</th>
<th>Match Score</th>
<th>Match n</th>
<th>Mismatch Score</th>
<th>Mismatch n</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive Style</td>
<td>66.53%</td>
<td>53</td>
<td>57.79%</td>
<td>61</td>
<td>6.330</td>
<td>0.013</td>
</tr>
<tr>
<td>Cognitive Processing</td>
<td>57.00%</td>
<td>41</td>
<td>48.93%</td>
<td>41</td>
<td>5.345</td>
<td>0.023</td>
</tr>
<tr>
<td>Speed Efficiency</td>
<td>57.91%</td>
<td>23</td>
<td>48.45%</td>
<td>29</td>
<td>4.357</td>
<td>0.042</td>
</tr>
</tbody>
</table>

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 e-learning 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).

9 Conclusion and Future Trends

Adaptive Hypermedia and Web personalization are two distinct well established areas of research both investigating methods and techniques to move conventional static systems beyond traditional borders to more intelligent, adaptive and personalized implementations. A common goal is to alleviate navigational difficulties and satisfy the heterogeneous needs of the user population by adapting according to user-specific characteristics. In order to do that, the user profile construction is considered necessary.

The basic objective of this paper was to make an extensive reference of a combination of concepts and techniques coming from different research areas, Adaptive Hypermedia and Web personalization, 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-centred Web-based result. It further underpinned the significance of the comprehensive user profile, that incorporates not only the “traditional” user characteristics (i.e. name, age, education, experience, profession, etc.), but other intrinsic values of the user such as user perceptual preferences (visual, cognitive and emotional processing parameters). Eventually, this paper introduced the comprehensive user profile construction and presented an overview of the AdaptiveWeb system indicating the data flow between its various stand alone components.

The current system has been initially evaluated both at system’s response time performance and resources consumption, as well as with regards to users’ learning performance. 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). With regards to the users’ learning performance, 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. The system 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 which reveals that the whole approach turned out to be initially successful with a significant impact in the Personalization and Adaptation Procedure.

The initial evaluative results were 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 demonstrates the effectiveness of incorporating human factors in Web-based personalized environments. To further evaluate and support the current results we are currently constructing an experiment in the field of eServices measuring the satisfaction levels of the users while interacting with a personalized as opposed to a non-personalized environment. We more specifically devise a Web content aligned to users’ specific cognitive styles and working memory span capabilities, since cognitive performance as well as emotional processing it is very difficult to be measured and put under a corresponding control environment at this stage. We will further also investigate constraints and challenges arising 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 profiling. The final system will provide a complete adaptation and personalization Web-based solution to the users satisfying their individual needs and preferences.

References

[34] Yuliang, L. and Dean, G. (1999). Cognitive Styles and Distance Education, Online Journal of Distance Learning Administration, Volume II, Number III.


