NEW FUNDAMENTAL PROFILING CHARACTERISTICS FOR DESIGNING ADAPTIVE WEB-BASED EDUCATIONAL SYSTEMS

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ABSTRACT

There is a growing body of empirical evidence to suggest that users tend to make poor decisions in traditional educational systems as the navigational freedom given to the user leads to comprehension and orientation difficulties in the sense that users may become spatially disoriented, lose sight of educational objectives, skip important content, choose not to answer questions, look for stimulating rather than informative material or simply use the navigational features unwisely. Since the user population is relatively diverse, such traditional static hypermedia applications suffer from an inability to satisfy the heterogeneous needs of the many users. Moreover, with the growth of mobile and wireless communication allowed service providers to develop for users new ways of interactions through a variety of channels in an anyhow, anytime and anywhere manner, but developing also more demanding requirements. This paper makes an extensive reference to user profiling considerations. It underpins the emergence of the mobile and wireless technology and the "new" user profiling requirements that arise, with visual, emotional and cognitive processing parameters incorporated. Eventually, it proposes an adaptive Web-based educational environment based on the user perceptual preference characteristics identified.

KEYWORDS

Adaptation, User Profiling, Cognition, Visual Attention, Emotions

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 more quickly than any other technology over the past century and is currently providing an electronic connection between progressive entities and millions of users whose age, education, occupation, interest, and income demographics vary significantly. The explosive growth in the size and use of the World Wide Web as well as the complicated nature of most Web structures may very well 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. Adaptivity is a particular functionality that alleviates navigational difficulties by distinguishing between interactions of different users within the information space. Over the last 10 years, researchers in adaptive hypermedia and Web systems have put huge amounts of effort, exploring many user modeling and adaptation methods, to identify the peculiarities of each user group and design methodologies and systems that could deliver an adapted and personalized Web-based educational content. With the emergence of wireless and mobile technologies new devices and communication platforms, other than PC-based Internet access are becoming available making the delivery of knowledge feasible through a variety of media. Inevitably, the user requirements are elevated to an "anytime, anywhere and anyhow" basis, and adaptation must not only take into account the explicit user model, but also the context (location, time, computing platform, bandwidth) of their work, as well as other user perceptual preference characteristics, like visual attention, cognitive and emotional processing parameters. A comprehensive user profile should

include parameters and contexts such as user intellectuality, mental capabilities, socio-psychological factors, emotional states and attention grapping strategies, since these could affect the apt collection of users' customization requirements, offering in return the best adaptive environments to the user preferences and demands.

The aim of this paper is to introduce the "new" user profiling dimensions that incorporates other than the "traditional" user characteristics (like user perceptual preference characteristics). It will discuss some primary mobility and adaptive hypermedia cross-road design considerations and will emphasize on vital adaptivity characteristics and implications in the information space. Lastly, it will define an Adaptive Web-based Educational System incorporating the aforementioned "new" user profiling, and the semantic Web-based educational content that includes amongst others the perceptual provider characteristics.

The paper is structured in 4 sections. Section 2 refers to adaptivity and mobility considerations analyzing the "new" user profiling notion. Section 3 proposes an Adaptive Web-based Educational System, and section 4 concludes this paper.

2. INNOVATIVE ADAPTIVITY CONSIDERATIONS – BEYOND THE "TRADITIONAL" USER PROFILING

Adaptivity is a particular functionality that alleviates navigational difficulties by distinguishing between interactions of different users within the information space [Eklund and Sinclair, 2000; Brusilovsky and Nejdl, 2004]. Adaptive Hypermedia Systems employ adaptivity by manipulating the link structure or by altering the presentation of information, based on a basis of a dynamic understanding of the individual user, represented in an explicit user model [Eklund and Sinclair, 2000; De Bra *et al*., 1999; Brusilovsky, 2001; Brusilovsky, 1996a; Brusilovsky, 1996b]. In the 1997 discussion forum on Adaptive Hypertext and Hypermedia, an agreed definition of adaptive hypermedia systems was reached after Brusilovsky [Eklund and Sinclair, 2000] as follows: "By Adaptive Hypermedia Systems we mean all hypertext and hypermedia systems which reflect some features of the user in the user model and apply this model to adapt various visible and functional aspects of the system to the user." [Eklund and Sinclair, 2000; Brusilovsky, 1996b]. A system can be classified as an Adaptive Hypermedia System if it is based on hypermedia, has an explicit user model representing certain characteristics of the user, has a domain model which is a set of relationships between knowledge elements in the information space, and is capable of modifying some visible or functional part of the system based on the information maintained in the user model [Eklund and Sinclair, 2000; Brusilovsky and Nejdl, 2004; Brusilovsky, 1996b].

The "Mobile" generation is now extending the basis of the adaptation in a multi-channel and multi-device accessibility by adding models of context such as location, time, computing platform and bandwidth to the classic user model and exploring the use of known adaptation technologies to adapt to both an individual user and a context of their work [Brusilovsky, 2004]. User interfaces must now be friendlier enabling active involvement (information acquisition), giving control to the user and provide easier means of navigation supported by the small screens of the mobile devices and enable adaptation of hypermedia, multi-media, and multi-modal user interfaces. Adding to the challenges of classic hypermedia applications the fact that these devices are handled in a more 'personal' basis by the user, other characteristics like the user perceptual preference characteristics must be taken into consideration in order to deliver a more comprehensive adapted result. Consequently, user profiling is becoming more and more important considering different users with different needs and expectations. This means that they may probably want better personalized services to save them time and trouble, or that they may require different level of entrance according to different levels of group awareness, or that they may probably need multiple profiles according to their status. Therefore, capabilities like bandwidth, displays, and text-writing must be taken into account when developing such educational-based services.

User profiling 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 favourite beer of customer X is Beer A"), and the *behavioural profile* (modeling the behaviour 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 behaviour [Adomavicious and Tuzhilin, 1999]). Additionally, in the case of a mobile user, by user needs it is implied both, the *thematic preferences* (i.e., the traditional notion of profile) as well as the characteristics of their personal device called *"device profile"*. Therefore, here, adaptive personalization is concerned with the negotiation of user requirements and device abilities. As Web developers regard personalization as the best way to filter out unnecessary or irrelevant information for their users, some argue on issues like it may restrict the extent and the variety of information users receive, that people often do not have well-defined preferences, they need to answer detailed questions to personalize their Web pages, that the recommendation process is a black box for end users and so on [Wang and Lin, 2002].

But, could the user profiling be considered complete incorporating only these dimensions? Do the designers and developers of Web-based educational applications take into consideration the real users preferences in order to provide them a really personalized Web-based educational content? Many times this is not the case. How can a user profiling 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 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. It has to be noted at this point that the user perceptual preference characteristics are directly related to the "traditional" user characteristics since they are affecting the way a user approaches an object of perception.

In further support of the aforementioned concepts, one cannot disregard the fact that, besides the parameters that constitute the traditional user profile, 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 [Graber, 2000]. 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" [McLoughlin, 1999], 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 [Pithers, 2002]. 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 knowledge distributing environment, the significance of the fore mentioned users' differences, both physiological and preferential, is distinct and should be taken under consideration when designing such adaptive environments.

It is true that nowadays, there are not researches that move towards the consideration of user profiling incorporating optimized parameters taken from the research areas of visual attention processing and cognitive psychology. Some serious attempts have been made though on approaching e-Learning systems providing adapted content to the students but most of them are lying to restricted analysis and design methodologies considering particular cognitive learning styles, including Field Independence vs. Field Dependence, Holistic-Analytic, Sensory Preference, Hemispheric Preferences, and Kolb's Learning Style Model [Yuliang and Dean, 1999], applied to identified mental models, such as concept maps, semantic networks, frames, and schemata [Ayersman and Reed, 1998; Reed et al., 1996]. 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.

The issue of adaptive personalization, and consequently user segmentation is a complex one. User segmentation divides the user population into heterogeneous, mutually exclusive subsets who share common

user profile characteristics (i.e. demographic, psychographic, and individual and psychological characteristics). Some of these issues become even more complicated once viewed from a mobile user's perspective, when wireless communication media and mobile device constraints are involved, like small size, bandwidth constraints, processor computing power, memory and storage space, small screen, high latency and data entry constraints [Freire et al., 2001; Brusilovsky and Nejdl, 2004; Panayiotou et al., 2005]. 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*. Consequently, having researchers in mind the continuous rising of complexity with regards to the design and implementation of Web-based educational applications should develop more advanced adaptation and personalization techniques that would take advantage of these constraints to the broader benefit of the more comprehensive user profiling characteristics identified.

3. IMPLEMENTATION IMPLICATIONS OF AN ADAPTIVE WEB-BASED EDUCATIONAL SYSTEM

Based on the abovementioned considerations, an adaptive Web-based educational environment is overviewed trying to convey the essence and the peculiarities encapsulated, placing special emphasis on the "New User Profiling" module. The current system, depicted in Fig. 1, is composed of four main interrelated modules. Each *module* for the purpose of the infrastructure functionality may be composed of *components* and each component may be broken down into *elements*, as detailed below:

3.1 Entry Point and Content Reconstruction Module

It is the primary module and the user access interface of the system and is called 'Entry Point and Content Reconstruction'. It accepts multi-device (enables the attachment of various devices on the infrastructure, such as mobile phones, PDAs, desktop devices etc. identifying the characteristics of the device and the preferences as well as the location of the user (personalization / location based) and multi-channel (due to the variety of multi-channel delivery i.e. over the Web, telephone, interactive kiosks and so on, this module will identify the different characteristics of the channels) requests. It is directly communicating with the '"New" User Profiling' and 'Semantic Web-based Educational Content' modules exchanging multi-purpose data. It consists of two components each one assigned for a different scope:

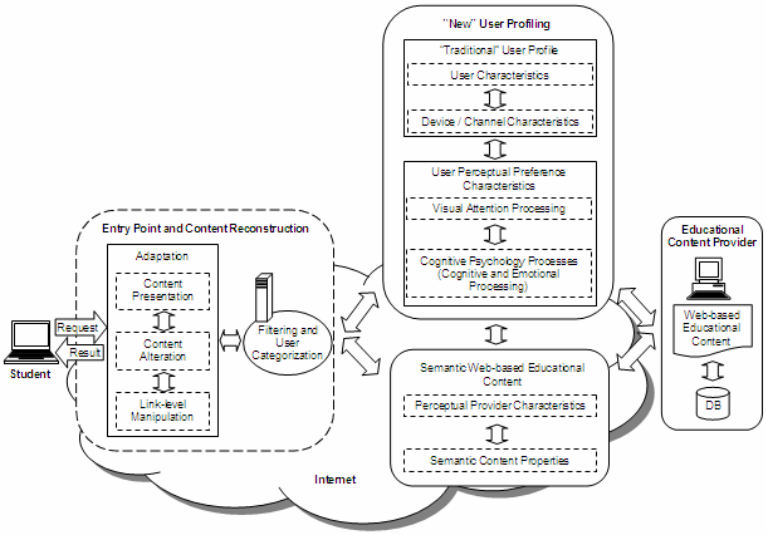

Figure 1. Adaptive Web-based Educational Content Architecture

- *Adaptation*: This component comprises of all the access-control data (for security reasons) and all the information regarding the user profile. These might include user preferences, geographical data, device model, age, business type, native language, context, etc. It is the enter point for the user enabling the login to the architecture. This component is directly communicating with the '"New" User Profiling' module where the actual verification and profiling for the user is taking place. Once the whole processing has been completed it returns the adapted results to the user. It is comprised of three elements: (a) *Content Presentation* (or Adaptive Presentation): It adapts the content of a page to the characteristics of the user according to the user profile and personalization processing. The content is individually generated or assembled from pieces for each user, to contain additional information, pre-requisite information or comparative explanations by conditionally showing, hiding, highlighting or dimming fragments on a page. The granularity may vary from word replacement to the substitution of pages to the application of different media; (b) *Content Alteration* (or Adaptive Content Selection): When the user searches for a particular content, that is, related information to his / her profile, the system can adaptively select and prioritize the most relevant items; and (c) *Link-level Manipulation* (or Adaptive Navigation Support): It provides methods that restrict the user's interactions with the content or techniques that aid the user in their understanding of the information space, aiming to provide either orientation or guidance (i.e. adaptive link, adaptive link hiding / annotation). Orientation informs the user about his / her place in the hyperspace while guidance is related to a user's goal.
- *Filtering*: This component is considered the main link of the 'Entry Point and Content Reconstruction' module with the '"New" User Profiling' and 'Semantic Web-based Educational Content' modules of the architecture. It actually transmits the data accumulated both directions and it makes the low-level reconstruction and filtering of the content, according to the Web personalization processing characteristics, delivering the content for adaptation according to the user segmentation.

3.2 "New" User Profiling Module

This is the main module of the architecture and it is called '"New" User Profiling' module. At this module all the requests are processed. This module is 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 [Panayiotou et al., 2005]. The whole processing varies from security, authentication, user segmentation, educational content identification, user perceptual characteristics (visual, cognitive and emotional processing parameters) and so forth. This module accepts requests from the 'Entry Point and Content Reconstruction' module and after the necessary processing and further communication with the 'Semantic Web-based Educational Content' module, either sends information back or communicates with the next module ('Educational Content Provider') accordingly. This module is comprised of the following two components:

- *"Traditional" User Profile*: It contains all the information related to the user, necessary for the Web Personalization processing. It is directly related to the User Perceptual Preference Characteristics component and is composed of two elements: (a) *User Characteristics*: This element is directly related to the Device / Channel Characteristics element and provides 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 so forth. Both elements are completing the user profiling from the user's point of view; and (b) *Device / Channel Characteristics*: This element is referring to all the 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 space, 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.
- *User Perceptual Preference Characteristics*: This is the new element / dimension of the user profile. 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. 2, below. As it can be observed, its primary parameters formulate a three-dimensional approach to the problem.

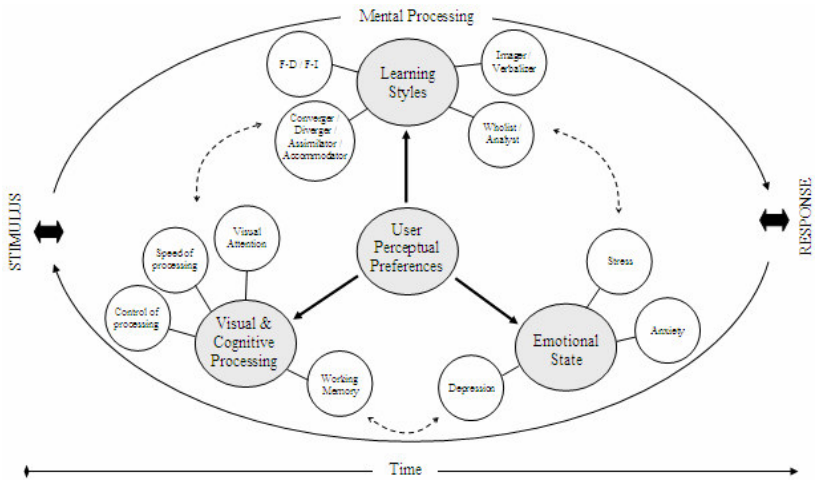

Figure 2. User Perceptual Preference Characteristics – Three-Dimensional Approach

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. It is composed of three elements: (a) *Visual & Cognitive Processing*: From the *Visual Processing* 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. 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. *Cognitive Processing* parameters could be primarily determined by (i) 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), (ii) the speed of processing (refers to the maximum speed at which a given mental act may be efficiently executed), and (iii) the working memory (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 [Demetriou et al., 1999; Demetriou and Kazi, 2001] have identified that the speed of cognitive processing and control of processing it is directly related to the human'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. 3a, the processing development speed increases non-linearly in the age of 0 – 15 (1500 m/sec), it is further stabilized in the age of 15 - 55-60 (500 m/sec) and decreases from that age on (1500 m/sec). However, it should be stated that the actual cognitive processing speed efficiency is yielded from the difference (maximum value 0.8 m/sec) between the peak value of the speed of processing and the peak value of control of processing, as it is depicted in Fig. 3b. (b) *Learning 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. A selection of the most appropriate and technologically feasible learning styles are taken into consideration, such as Witkin's Field-Dependent and Field-Independent, Riding's Cognitive Style Analysis (Verbal-Imager and Wholistic-Analytical), and Kolb's Learning Styles (Converger, Diverger, Accomodator, and Assimilator), being in a position to identify how users transforms information into knowledge (constructing new cognitive frames).

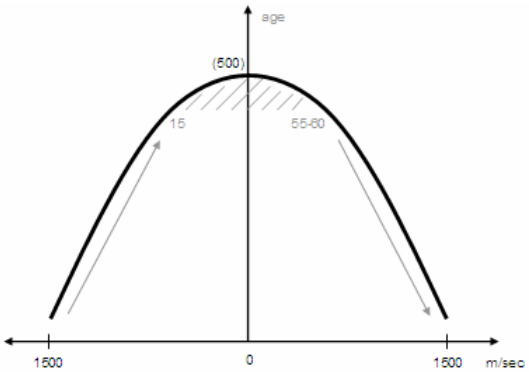

Figure 3a. Speed of Processing

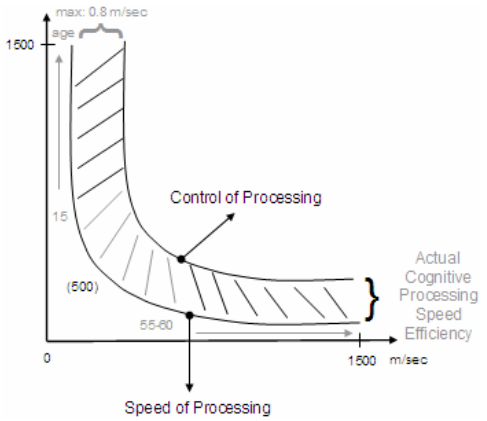

Figure 3b. Actual Cognitive Processing Speed Efficiency

Their main characteristics as well as their implication into the information space are summarized in Fig. 4a, b [Henke, 2001; Sharp, 1998; Parkinson and Redmond, 2002; Liu and Ginther, 1999]. Note that for the scope of this research, Witkin's Field Dependent and Field Independent characteristics and implications are considered to be the same as those of the Riding's Cognitive Style Analysis due to their significant similarities.

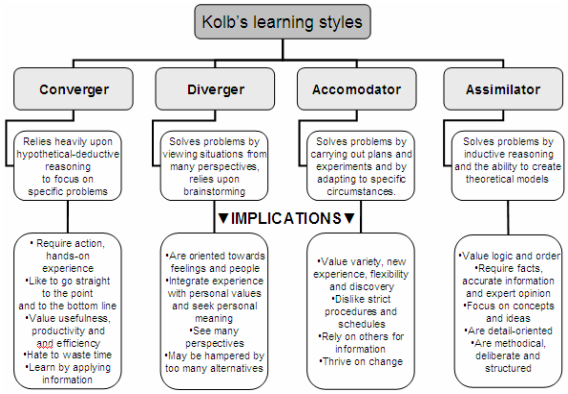

Figure 4a. Kolb's Learning Styles Characteristics and Implications

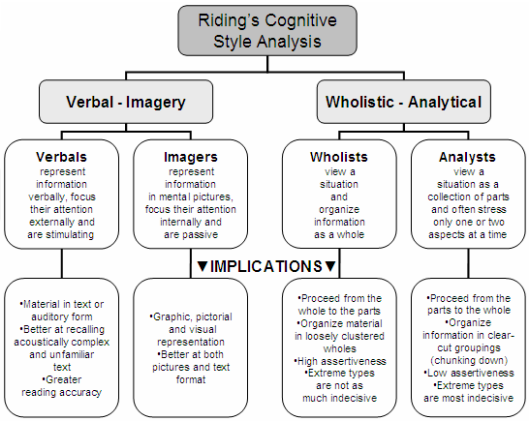

Figure 4b. Riding's Learning Styles Characteristics and Implications

(c) *Emotional State*: The whole emotional processing of a user's interaction with the information space consists of these parameters that could determine his / her emotional state during the response process. This is vital so as to determine the level of adaptation (user needs per time interval) during the interaction process. Significant characteristics as well as adaptation design implications are summarized in Fig. 5 [Psychology Foundation of Australia].

3.3 Semantic Web-based Educational Content Module

This module is based on metadata describing the content (data) available from the 'Educational Content Provider' module. In this way a common understanding of the data, i.e. semantic interoperability, openness, is achieved. The data manipulated by the system / architecture is described using metadata that comprises all needed information to unambiguously describe each piece of data and collections of data. This provides

semantic interoperability and a human-friendly description of data. This module is also directly related to the '"New" User Profiling' module providing together the most optimized adaptive Web-based educational content result. It is consisted of two components:

- *Perceptual Provider Characteristics*: It identifies the provider characteristics assigned to the Web-based educational content. They are involving all these perceptual elements that the provider has been based for the design of the content.
- *Semantic Content Properties*: This element performs the identification and metadata description of Web-based educational content based on predetermined ontologies. It is implemented in a transparent manner removing data duplication and the problem of data consistency.

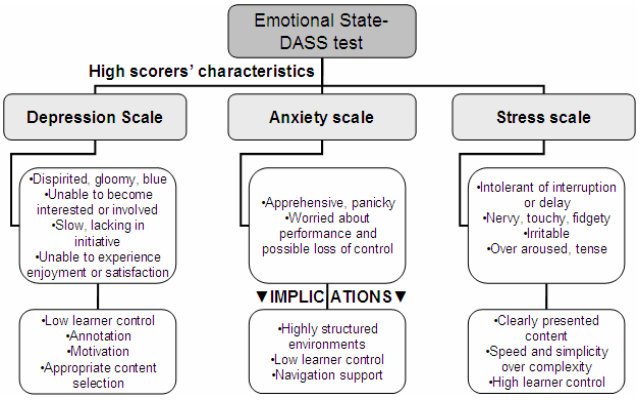

Figure 5. Emotional State Characteristics and Implications

3.4 Educational Content Provider Module

This is the last module of the architecture and is directly connected to the '"New" User Profiling' and 'Semantic Web-based Educational Content' modules. It contains transition mechanisms and the databases of Web-based educational content as supplied by the provider without been through any further manipulation or alteration.

4. CONCLUSION

When referring to adaptive Web-based educational content provision it is implied that the content adaptation and personalization is based on a concrete and comprehensive user profile that covers all the dimensions and parameters of the users' preferences. However, there is still the view that if a provider knows the users "traditional" characteristics and channel / device capabilities can design and offer an apt personalized result. Most of the times though the providers tend to design educational applications based on their own preferences and what they think should be offered. The proposed Adaptive Web-based Educational Content Architecture will allow users to receive the Web-based educational content in an adapted style according to their perceptual preference characteristics, increasing that way efficiency and effectiveness of use.

Indisputably, in order for the latter consideration to be accomplished, a further filtering of the aforementioned parameters, and especially of the "New" User Profiling module, has to take place so that the final optimized model is achieved. Once this established, a series of tests (others in the form of questionnaires and others with real time interaction metrics) will be constructed which will attempt to reveal user perceptual preference characteristics. These features along with the "traditional" user characteristics could complete the "New" User Profile and therefore adaptation schemes could be adjusted to deliver even more personalized Web-based educational content accordingly. The next step is to identify what is the correlation between the various users and / or user groups and if it would be feasible to refer to the term 'users' segmentation' (users sharing similar "new" user profiling characteristics) providing them with

predetermined personalized content or treat users separately and adjust content as the adaptation processing evolves. In either case, personalization mechanisms will be based upon these parameters and considering users' device / channel characteristics and the semantic content will provide them with the corresponding adapted result. Eventually, this methodology will be implemented with adaptation and personalization algorithms and paradigms so to automatically gather all the related information and construct the "new" user profiling giving the users the adapted result without their actual intervention.

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