Towards a Human Factors Ontology for Computer-Mediated Systems

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Abstract. Adapting to user context, individual features and behavior patterns is a topic of great attention nowadays in the field of Web-based and mobile mediated platforms, such as eTraining, eCommerce, eLearning and so on. A challenge is to design an expressive ontology that is composed of human factors that can be used in any application, whether that is the WWW or any other embedded information system. Based on that ontology, engineers will design and develop personalized and adaptive interfaces and software. This will enable easy access to any content while being sufficiently flexible to handle changes in users' context, perception and available resources, optimizing the content delivery while increasing their comprehension capabilities and satisfaction. Therefore, this paper describes a human factors ontology that has been positively evaluated, called UPPC (User Perceptual Preference Characteristics), and could be used in any computer mediated application for returning an optimized adaptive result to the user.

Keywords: Web Personalization, Adaptation, User Profiling, Cognitive Processes, Ontology, eLearning

1 Introduction

1.1 Motivation

The usage of computer-mediated systems over the Web has increased rapidly over the past few decades, applied in a variety of domains such as Training, Learning, Commerce and so on. Computer-mediated platforms have been adopted by the mass market much quicker than any other technology / platform over the past century and are currently providing convenience and have changed our lifestyle.

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However the plethora of information and services as well as the complicated nature of most Web structures intensify the orientation difficulties, as users often lose sight of their original goal, look for stimulating rather than informative material, or even use the navigational features unwisely. As the 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 [1].

In recent years, there has been a rapid growth in research and experiments that work on personalizing computer-mediated platforms, according to user needs and indeed, the challenges ranging in this area are not few.

Indisputably, the user population is not homogeneous. To be able to deliver quality knowledge, systems should be tailored to the needs of individual users providing them personalized and adapted information.

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. The objective of user profiling is the creation of an information base that contains the preferences, characteristics and activities of the user.

1.2 Proposing a Human Factors Ontology

This paper introduces a new model in the field of Web Personalization, which integrates cognitive, mental and emotional parameters and attempts to apply them on a Web-based learning environment. Our purpose is to improve learning performance in terms of information assimilation and comprehension capabilities and, most importantly, to personalize web content to users' needs and preferences, eradicating known difficulties that occur in traditional approaches.

User Profiling is considered the main filtering element for Web Personalization Systems. Therefore, the main scope of this paper is to further enhance current user profiles by creating an ontology that will be based on a theoretical three-dimensional model incorporating the latter cognitive concepts that has already been proposed by the authors and positively evaluated into the information space [2, 3]. This ontology will contain an optimized series of parameters related to human factors that could be used in any computer-mediated platform in order to return a more enhanced user-centric result.

Using this ontology as the main filtering component we have developed an adaptive Web-based system that could be used to reconstruct (adapt) any content coming from the provider.

Such approach may be proved to be very useful in assisting and facilitating a user to understand better web content and therefore increase his / her satisfaction and navigation performance.

In the remaining sections, we present the theoretical model that the ontology has been based upon, describe its terms and we show the ontology itself. In section 3, we show the implications of each dimension onto the information space. In section 4, we evaluate the ontology's concept in an eLearning domain through a computer-mediated system (Web-based adaptation and personalization system), AdaptiveWeb, since this

ontology figures as its core component. Finally, section 5 presents our conclusions and future trends of our work.

2 Describing the UPPC Ontology

We introduce the new component / dimension of the user profile. It contains all the visual attention, cognitive and emotional processing parameters that enhances the user preferences and fulfils the user profile. User Perceptual Preference Characteristics could be described as a continuous mental processing starting with the perception of an object in the user's attentional visual field and going through a number of cognitive, learning and emotional processes giving the actual response to that stimulus, as depicted in Fig. 1, below.

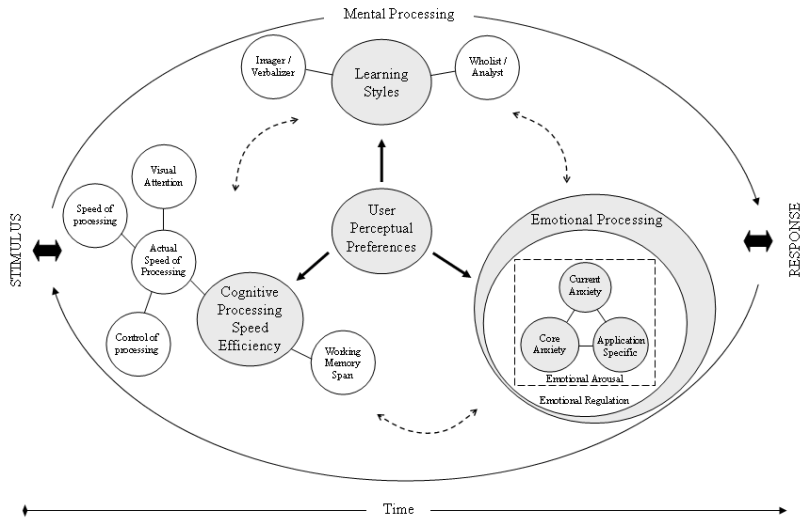

Fig. 1. User Perceptual Preference Characteristics - Three-Dimensional Approach

As it can be observed, its primary parameters formulate a three-dimensional approach to the problem.

These characteristics, which have been primarily discussed in [3], and formulate a three-dimensional approach to the problem of building a user model that determines the visual attention, cognitive and emotional processing taking place throughout the whole process of accepting an object of perception (stimulus) until the comprehensive response to it [4]. The first dimension investigates users' *cognitive style*, the second their *visual and cognitive processing efficiency*, while the third captures their *emotional processing* during the interaction process with the information space [3].

Based on the abovementioned considerations, we present the User Perceptual Preference Characteristics Model that is proposed to identify the main impact of human factors in the information space. Its primary objective is to give a semantic

description of each dimension in the UPPC theoretical model as well as the impact in the information space.

2.1 Cognitive processing efficiency

The cognitive processing parameters [5, 6] that have been included in our model are:

i. *control of processing* (refers to the processes that identify and register goal-relevant information and block out dominant or appealing but actually irrelevant information)

ii. *speed of processing* (refers to the maximum speed at which a given mental act may be efficiently executed), and

iii. *working memory span* (refers to the processes that enable a person to hold information in an active state while integrating it with other information until the current problem is solved)

iv. *visual attention* (based on the empirically validated assumption that when a person is performing a cognitive task, while watching a display, the location of his / her gaze corresponds to the symbol currently being processed in working memory and, moreover, that the eye naturally focuses on areas that are most likely to be informative).

We measure each individual's ability to perform control/speed of processing and visual attention tasks in the shortest time possible, with a specific error tolerance, while the working memory span test focuses on the visuospatial sketch pad sub-component [7], since all information in the web is mainly visual.

2.2 Cognitive style

Cognitive styles represent an individual's typical or habitual mode of problem solving, thinking, perceiving or remembering, and "are considered to be trait-like, relatively stable characteristics of individuals, whereas learning strategies are more state-driven…" [8]. Amongst the numerous proposed cognitive style typologies [9] we favor Riding's Cognitive Style Analysis [10], because we consider that its implications can be mapped on the information space more precisely, since it is consisted of two distinct scales that respond to different aspects of the Web. The imager / verbalizer axis affects the way information is presented, whilst the wholist / analyst dimension is relevant to the structure of the information and the navigational path of the user. Moreover, it is a very inclusive theory that is derived from a number of pre-existing theories that were recapitulated into these two axises.

We prefer the construct of cognitive rather than learning style because it is more stable [11], and to the extent that there is a correlation with hemispherical preference and EEG measurements [12, 8], the relationship between cognitive style and actual mode of information processing is strengthened.

2.3 Emotional Processing

In our study, we are 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 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 concerning emotional arousal emphasizes on anxiety, which is probably the most indicative, while other emotional factors are to be examined within the context of a further study.

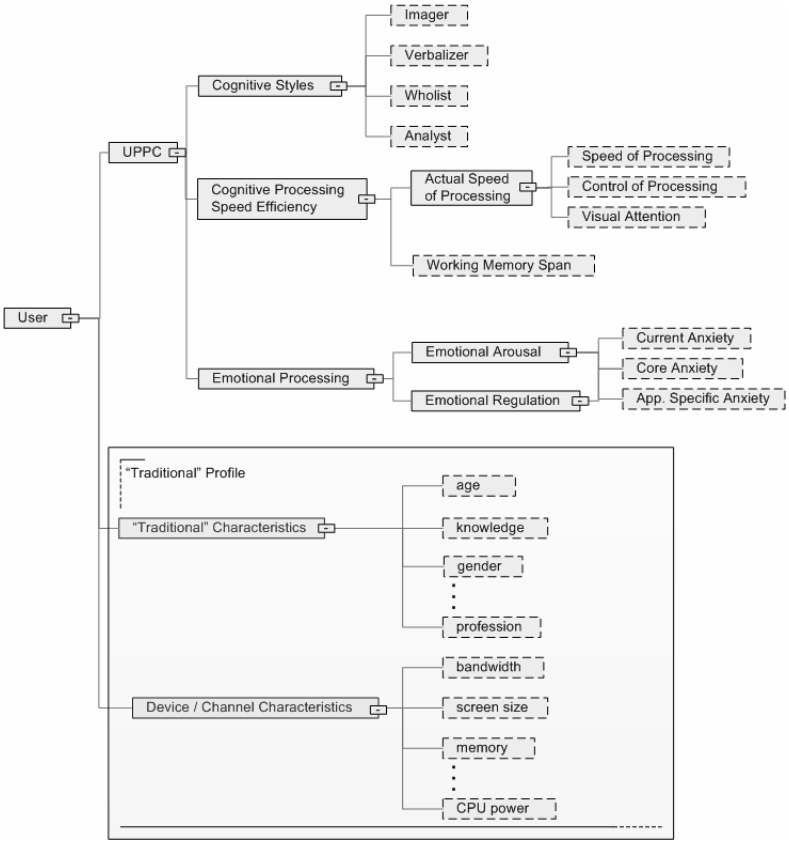

Fig. 2. User Perceptual Preference Characteristics Ontology

Anxiety is an unpleasant combination of emotions that includes fear, worry and uneasiness and is often accompanied by physical reactions such as high blood pressure, increased heart rate and other body signals [13] [14].

Accordingly, in order to measure emotion regulation, we are using the cognominal construct of emotion regulation. 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 confounding 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 [15]. Emotional intelligence seems to be an adequate predictor of the aforementioned concepts, and is a grounded enough construct, already supported by academic literature [16, 17]. Additional concepts that were used are the concepts of self-efficacy, emotional experience and emotional expression [18].

After the presentation of the above findings, we hereafter depict (Fig. 2) the UPPC ontology that uses the main elements of the human factors conceptualization.

The main uses of this ontology [19] are: 1) to enable consistent implementation (and interoperation) of all computer-mediated systems that use human factors as their main filtering element, based on a shared background vocabulary, 2) to play the role of a domain ontology that encompasses the core human factors elements for computer-mediated systems and that can be extended by any other individual or group.

As we will see later, we evaluated the UPPC ontology's concept in an eLearning domain. Although the results are really encouraging for the validity and integrity of the relation within and between the UPPC model dimensions, this model can only be considered as a proposal. Main goal is to initiate and drive this research to a concrete human factors ontology that can be used in any computer-mediated system.

3 Relating the UPPC Ontology with the Information Space - A high level correlation diagram

For a better understanding of the three dimensions' implications and the UPPC ontology as well as 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. 3. These tags (images, text, information quantity, links - learner control, navigation support, additional navigation support, and aesthetics) have gone through an extensive optimization representing group of data affected after the mapping with the implications. The main reason we have selected the latter tags is due to the fact that represent the primary subsidiaries of a Web-based content. With the necessary processing, mapping and / or alteration we could provide the same content with different ways (according to a specific user's profile) but without degrading the message conveyed.

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

secondary (dashed line) implications on the information space altering dynamically the weight of the tags.

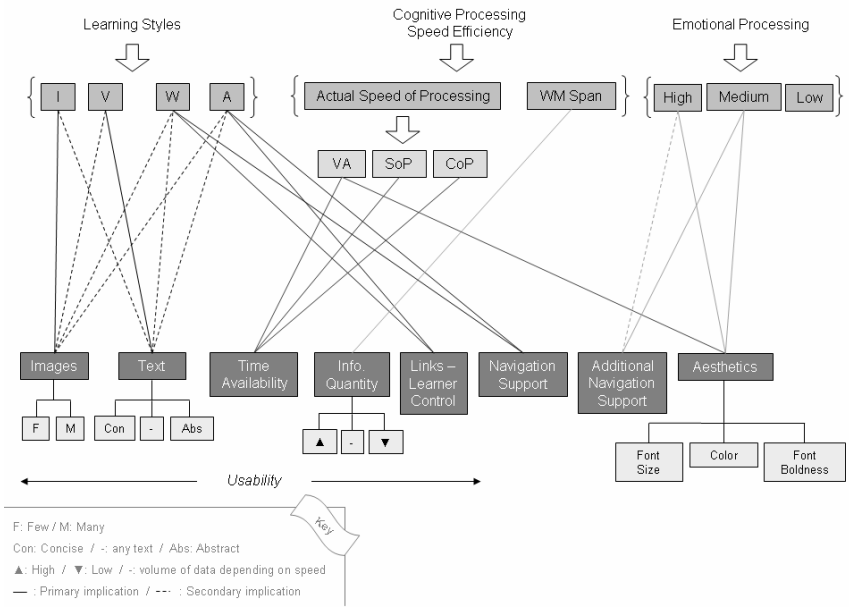

Fig. 3. Data - Implications Correlation Diagram

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

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.

The intended impact of this research is the future initiation of the use of human factors in the information space. In this respect, the ontology is intended to become the basis for a future core human factors ontology in the domain of computer-mediated systems.

4 Evaluation

The UPPC ontology has been evaluated in the eLearning domain through a computer-mediated application (Web-based adaptation and personalization system), AdaptiveWeb, since it figures as its core component. A total number of five hundred BETA testers participated in the experimentation phases. The concept of the ontology has been proven effective and efficient not only regarding the relation within and between its various human factor elements 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.

More specifically we have implemented a number of experiments in controlled environments with regards to the three dimensions giving match and mismatch environments, depending on the factor we were controlling each time. Our main hypothesis was that students in matched environment perform better than those in mismatched conditions. 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 [20].

Initial indications show a significant correlation between the Cognitive Processing factors used, not only amongst them but also with regards to the performance of the subjects. Subjectively, with regards to the cognitive learning styles it has been shown that Imagers, Verbalizers, Wholists and Analysts are greatly performed in environments of their type whereby it has been identified significant correlation with the second dimension and more specifically with the Working Memory Span parameter (Working Memory Capacity is more important for Analysts than Wholists).

Regarding the second dimension, Cognitive Processing Speed Efficiency results have preliminary showed that could be used effectively in controlled mostly learning environments where time span / availability is an issue. With regards to the Working Memory, high significance has been found to low Working Memory subjects whereby broken content is considered necessary for their better comprehension of the Web-based content.

Regarding the third dimension, it has been proven that the medium anxiety level of the subject is more beneficial for their learning performance. For users with high anxiety levels it has been shown that the aesthetics and extra navigation support are considered necessary assistive tools and techniques for their adequate comprehension of the content. Furthermore the emotional regulation of a subject acts reversely with the trait anxiety (mostly with the application specific than the core) and current anxiety. It has been preliminary also found a noteworthy correlation between the anxiety levels and the CPSE of the user. More specifically, users with high CPSE have shown decreased levels of application specific anxiety.

It has to be mentioned that this is a high level preliminary analysis that however indicates initial validity of the proposed model and the positive impact of the AdaptiveWeb System.

In due time further experiments will be conducted enabling us to analyze in more depth the parameter significance and correlation with regards to the information space

and therefore prove validity of our research argument and the proposed UPPC ontology

5 Conclusions and Future Trends

The basic objective of this paper was to present a conceptualization of a human factors ontology, namely UPPC, for computer-mediated systems.

It has been attempted to approach the theoretical considerations and technological parameters that can provide the most comprehensive user profiling, under a common filtering element (User Perceptual Preference Characteristics), supporting the provision of the most apt and optimized user-centered Web-based result. We further underpinned the significance of the user profiling, introducing the comprehensive user profiling, which incorporates intrinsic user characteristics such as user perceptual preferences.

Furthermore, a data - implications correlation diagram has been identified showing the impact of human factors and more specifically of the UPPC parameters onto the information space.

An evaluation with approximately 500 users has been conducted with the results to be highly promising and encouraging for the continuation of our research, since using the proposed human factors ontology as a main filtering element of a computer-mediated system can really increase students' academic performance.

Future and emerging trends include further analysis and testing of the current ontology in different domains and contexts. A more detailed analysis of the current model as well as the relationship between its different sub-dimensions; further investigation of constraints and challenges arise from the implementation of such issues on mobile devices and channels; study on the structure of the metadata coming from the providers' side, aiming to construct a Web-based personalization architecture that will be based on the UPPC ontology and will serve as an automatic personalization filter.

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