Embracing a Human Factors' Ontology in the eCommerce Context

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Abstract. This paper[1] focuses on integrating theories of individual differences in information processing within the context of eCommerce Web-sites. Accordingly, a design of a human factors' ontology has been proposed, called UPPC (User Perceptual Preference Characteristics), and could be used in any Web-based application for returning an optimized adaptive result to the user. An existing commercial Web-site was filtered through an adaptive mechanism based on that ontology. This mechanism is described by a proposed Web browser extension set of custom xml tags for the imminent automatic transformation and enhancement of the Web-based content. The expected impact of the content reconstruction lies in the increase of users' satisfaction and efficiency of information processing (both in terms of accuracy and task completion time), while users navigating in the personalized condition rather than the original one.

1. Introduction

Advances in Web-based oriented technologies and services are taking place with a considerable speed around the world. As communications and IT usage become an integral part of many people's lives and the available products and services become more varied and sophisticated, users expect to be able to personalize a service to meet their individual needs and preferences.

Due to the heterogeneous users' needs and requirements, user profiling could be considered as a successful step towards the identification and collection of users' preferences. However, there are some crucial issues that should be further investigated and analyzed, such as whether user profiles could nowadays be

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considered complete, and more extensively whether all the vital parameters of users' characteristics are taken into account in order for the Web-based systems to provide users with the most user-centric result.

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. In this respect, an objective is to design an expressive ontology that is composed of human factors that can be used in any hypertext computer-mediated application. Based on that ontology, engineers will design and develop personalized and adaptive interfaces. 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, called UPPC (User Perceptual Preference Characteristics) that could be used in any hypertext computer-mediated application for returning an optimized adaptive result to the user. It further analyzes the main intrinsic users' characteristics like visual and cognitive processing parameters that together tend to give the most optimized, adapted and personalized result. In the remainder of the paper an adaptation paradigm of an existing commercial Web-site is presented. The Web-site's content was filtered through an adaptive mechanism based on the UPPC Ontology. This mechanism is described by a proposed Web browser extension set of custom xml tags for the imminent dynamic transformation and enhancement of the Web-based content. An evaluation of the expected impact of the content reconstruction concludes the paper.

2. Proposing a Human Factors Ontology

The proposed human factors ontology is based on the theoretical conceptualization of a comprehensive model in the field of Web personalization and adaptation, which integrates cognitive parameters and attempts to apply them on a Web-based environment. The particular cognitive concepts have already been proposed by the authors and positively evaluated in the information space (Germanakos et al., 2007, Germanakos et al., 2008). This ontology consists of an optimized series of these parameters and tends to further enhance the current user profiles (considered the main filtering elements for Web personalization systems), that could be used in any hypertext computer-mediated platform in order to return a more enhanced user-centric result by reconstructing (adapting) any content coming from the provider.

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 methods. Such an 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.

2.1 Theoretical Implications of the UPPC Ontology

The theoretical implications of the proposed ontology constitute an enhancement / component of the user profile, called User Perceptual Preference Characteristics (UPPC). The UPPC theoretical model formulates a three-dimensional approach to the problem of building a user profile determining these mental, cognitive and emotional factors that take place throughout the whole process of accepting an object of perception (stimulus) until the comprehensive response to it (Germanakos et al., 2008). 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 (Germanakos et al., 2007).

For the scope of this paper, only the cognitive styles and the working memory span of the UPPC model are considered. Our primary objective is to identify the main impact of these characteristics in the information space, and specific content meta-characteristics, and to give a semantic description of these dimensions in the UPPC theoretical model utilized by the proposed ontology.

Cognitive styles represent an individual's typical or habitual mode of problem solving, thinking, perceiving or remembering, and "are considered to be trait-like, relatively stable characteristics of individuals, whereas learning strategies are more state-driven…" (McKay, 2003). Among the proposed cognitive style typologies (Cassidy, 2004) we favor Riding's Cognitive Style Analysis (Riding, 2001), 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 axes.

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.

We measure each individual's ability to perform working memory tasks based on the Visio spatial sketch pad sub-component (Baddeley, 1992), since all information in the Web is mainly visual.

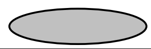
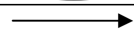
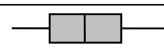
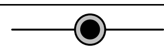
2.2 The UPPC Ontology

Based on the abovementioned considerations, findings and the described cognitive characteristics we hereafter depict (Fig. 1) at a high level point of view the UPPC ontology that uses the main elements of the human factors conceptualization.

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

The semantics behind the ontology (Fig. 1) are depicted in Table 1. The user entity in the ontology (Fig. 1) is the main entity. Specializations of the user are the Cognitive Styles and the Working Memory.

Table 1. Semantics of the Ontology

Ontology figures	**Semantics**
	Entity / Class
	Specialization
	Binary relation
	Total constraint (at least one)
●	Mandatory constraint
{ n }	Value constraint

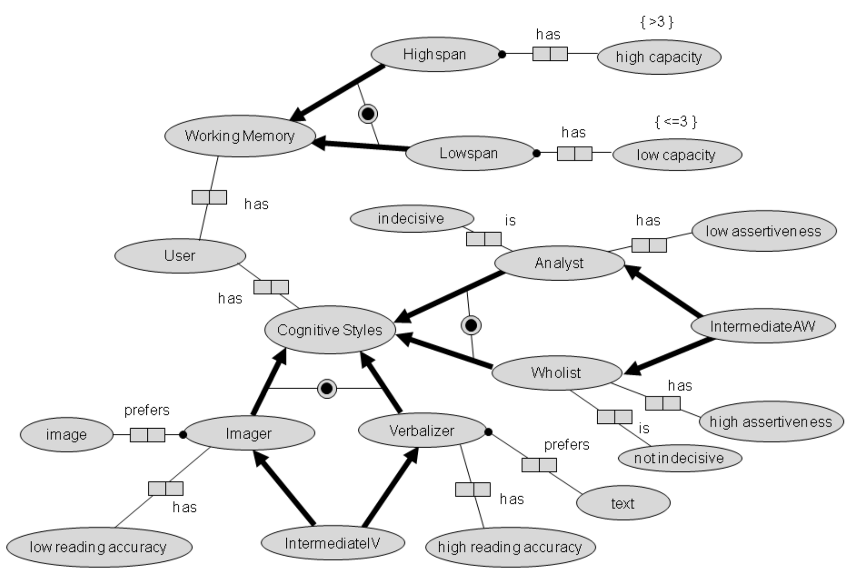


Fig. 1. User Perceptual Preference Characteristics Ontology (represented using the ORM graphical notation (Lukichev and Jarrar, 2009))

Cognitive Styles is distinguished between Imager, Verbalizer, Wholist and Analyst. The Imager prefers image and has low reading accuracy. On the other hand, the Verbalizer prefers text and has high reading accuracy. The Analyst has low assertiveness and is indecisive. The Wholist has high assertiveness and is not indecisive.

Working Memory is distinguished between Highspan and Lowspan. The Highspan and the Lowspan entity have high and low working memory span capacity, respectively.

Even though the evaluation of the UPPC ontology's concept in the eCommerce domain, described in section 5, is really encouraging for the validity and integrity of the relation within and between these cognitive dimensions and their effective impact in the information space, this ontology 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 hypertext computer-mediated system enhancing one-to-one services delivery based on an efficient user-centric dynamic content reconstruction (adaptation).

3. Web Content Transformation based on the UPPC Ontology

As mentioned in previous sections the given UPPC ontology's cognitive dimensions have a specific influence into the information space and to specific structural content meta-characteristics. Based on this impact, we hereafter introduce a method of transforming and adapting Web-based content into users' unique characteristics. The validation and accuracy of the content transformation based in this ontology has been achieved with the use of an innovative Adaptation and Personalization Web-based System, namely, AdaptiveWeb[2] that has been developed and positively evaluated in the Web domain (Germanakos et al., 2009).

```
<csl>
    <csli name="General Information">
        <h2 style="...">Sony Vaio SZ791</h2>
        <p>Notebook</p>
        <p>Ultra Portable</p>
    </csli>
    <csli name="CPU Information">
        <p>Intel Core 2 Duo</p>
        <p style="...">2.5 GHz</p>
    </csli>
    <csli name="Memory Information">
        <p>4GB Ram Memory</p>
        <p>250 GB Hard Disk (7200 rpm)</p>
    </csli>
</csl>
```

Fig. 2. Sample code extension with the new <csl> tag

The proposed methodological approach is related to the mapping process mechanism (that is, rules responsible for the content's transformation based on the correlation of the cognitive implications and the actual raw (provider's) data) and the

[2] See http://www3.cs.ucy.ac.cy/adaptiveWeb

imminent adaptation of any content based on the specific human factors, that is in the particular case the cognitive styles and working memory.

3.1 Web Browser Extension

A suggested precondition for the mapping process to work properly at this stage is to extend the well known html model with a new set of tags; <csl> (cognitive style list) and <csli> (cognitive style list item). A Web Browser (Mozilla Firefox) Extension has been therefore developed in order for the browser to recognize and implement the set of tags. Fig 2 shows a sample code that is extended with the new set of tags.

This set of custom xml tags is interpreted by the Web browser extension for reconstructing a given Web content when mapped with a user's cognitive factors.

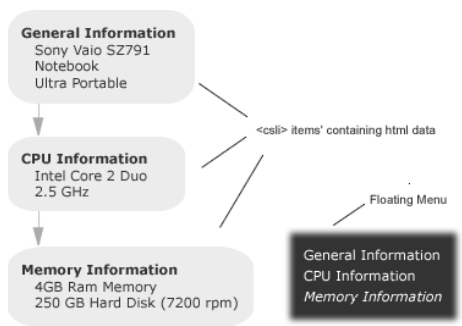


Fig. 3a. Browser content interpretation based on user's profile (Wholist / Imager)

Based on the sample code depicted in Fig. 2, the corresponding browser's extension interpretation and content presentation is shown in Fig. 3a and 3b.

In case a user is a Wholist / Imager (with regards to his cognitive style – see Fig. 3a), the browser will enhance each <csli> item, along with its containing data, with a diagram box (Imager) and will also create a floating menu (Wholist) that contains each <csli> item's name so to help the user navigate through the items by clicking on the corresponding link.

Fig. 3b. Browser content interpretation based on user's profile (Analyst / Verbalizer)

In Figure 3b, the user happens to be an Analyst / Verbalizer. In this case, the browser shows the <csli> item's containing data in a textual form (Verbalizer) and will also enhance the Web-page with a tabbed menu for each <csli> item (Analyst).

Each time the user clicks on a link of the tabbed menu, the corresponding data of the <csli> item is shown on the Web-page.

3.2 Mapping the <csl> tag with the User's Cognitive Characteristics

Our main goal in this section is to show in a more detail how the web browser extension interprets the <csl> tag and adapts the containing information based on the user's profile and consequently the abovementioned cognitive factors. The adaptation process involves the transformation and / or enhancement of a given raw Web-based content (provider's original content) based on the impact the specific human factors have on the information space (Germanakos et al., 2009, Germanakos et al., 2008) (i.e., show a more diagrammatical representation of the content in case of an Imager user, as well as provide the user with extra navigation support tools). Fig. 4 shows the possible Web content transformations / enhancements based on the mapping process that take place during adaptation process, the influence of the human factors and the theory of individual differences.

According to Fig. 4, the meta-characteristics of a user profile are deterministic (at most 3); Imager or Verbalizer, Analyst or Wholist and Working Memory level (considered only when low).

For a better understanding, a user that happens to be an Imager gets as mentioned above a diagrammatical representation of the containing information of the <csl> tag. The <csli> tag is used by the web browser extension to distinguish the logical meaning of a sentence when creating the diagrammatical representation. In other words, the <csli> tag is used for a new paragraph sentence in the <csl> division. As we will see later, the <csli> tag is interpreted differently by the browser when the user types change. On the other hand, when a user is a Verbalizer (prefers text instead of diagrammatical representations), no changes are made to the containing custom xml tags of <csl>.

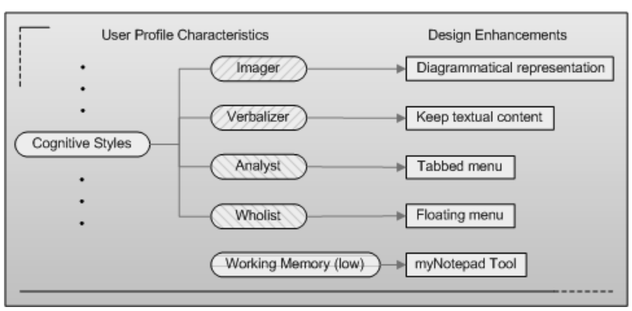


Fig. 4. Web design enhancements / transformations

Furthermore, if a user is an Analyst, the information will be enriched with a tabbed menu to be easier accessible. The menu will consist of the <csl> element's containing <csli> tags. The <csli> tags along with the "name" attribute (see Fig. 2) are used in this case to create the tabbed menu with the name of each <csli> element comprising an item of the menu. Each <csli> element is added to the tabbed menu and is used as a dynamic link to the containing information of the particular tag. The same logic of transformation is used when mapping the <csl> with a Wholist user. In this case, a dynamic floating menu with anchors is created so to guide the users on specific parts into the content while interacting. Again, the <csli> elements comprise the menu's items.

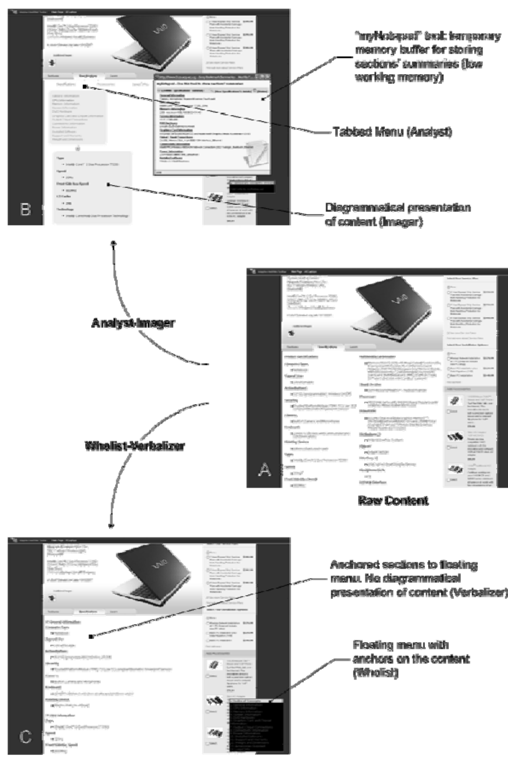


Fig. 5. Content adaptation according to user's comprehensive profile

Finally, when users happen to have a low working memory level, the browser will provide them with the "myNotepad" tool (temporary memory buffer) for storing a section (<csli> element content) of the page and keep active information that is interested in until the completion of a cognitive task at hand.

3.3 An eCommerce Adaptation Paradigm

We have designed and authored an experimental environment in the application field of eCommerce using the <csl> tags. The eCommerce (Web) environment that has been developed used the design and information content of an existing commercial

Web-site of Sony[3]. This Web-site provides products' specifications of the Sony Company. We have developed an exact replica of the Sony Notebooks' section in sonystyle.com using the <csl> tags. Fig. 5a depicts the Sony Web-site without any personalization made, while Fig. 5b and Fig. 5c shows the same Web-site after the personalization and adaptation process has been initiated, with the content to be adapted according to the user's comprehensive profile and consequently the UPPC ontology.

As we can easily observe, the original environment has been altered based on rules that define the typologies of the users in terms of content reconstruction and supportive tools. For example, a user might be identified as an "Analyst-Imager" with low working memory and therefore the Web environment during interaction time would be as in Fig. 5b. The information will be presented in a diagrammatic form (imager), will be enriched with menu tabs (analyst) to be easier accessible and with the "myNotepad" tool (temporary memory buffer) for storing sections' summaries (low working memory). In case that a user is identified as "Wholist-Verbalizer" the content will be automatically reconstructed as in Fig.5c, where a floating menu with anchors Wholist) have been added so to guide the users on specific parts into the content while interacting. In this case no diagrammatical presentation will be used because the user is a Verbalizer.

4. Experimental evaluation using an eCommerce setting

The following section overviews the experimental design of Sony and the results that support the notion of personalization in Web-sites using the UPPC ontology as the main influential factor irrespective of the reconstruction mechanism (automatic or predefined).

4.1 Methodology and Design Implications

In order to evaluate such an approach a within participants experiment was conducted, seeking out to explore if the personalized condition based on the UPPC ontology serves users better at finding information more accurately and fast.

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

The content was about a series of Sony Notebooks: general description, technical specifications and additional information were available for each model. We considered that the original (raw) version of the environment was designed without

[3] See http://www.sonystyle.com (date extracted: September 19, 2007)

any consideration towards cognitive style preferences, and the amount of information was so high and randomly allocated that could increase the possibility of cognitive overload. The personalized condition addressed these issues by introducing as personalization factors both cognitive style and working memory span. The psychometric materials that were used are the following: i) Cognitive Style: Riding's Cognitive Style Analysis, ii) Working Memory Span: Visuospatial working memory test (Demetriou et al., 1993, Demetriou and Kazi, 2001).

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

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

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

a) Task accuracy (number of correct answers)
b) Task completion time
c) User satisfaction

The within participants design allowed the control of differences and confiding variables amongst users.

Regarding the design implications in this eCommerce setting, the content enhancements and transformation considerations discussed in previous sections regarding users' particular typologies were followed. More specifically, users with low working memory received a "myNotepad" tool that allowed them to make entries of goal-related information

4.2 Results

The most robust and interesting finding (Germanakos et al., 2009) was the fact that users in the personalized condition were more accurate in providing the correct answer for each task. The same user in the raw condition had a mean of 1 correct answer, while in the personalized condition the mean rose to 1.9.

Since the distribution was not normal and the paired samples t-test assumptions were not met, Wilcoxon Signed Ranks Test was performed, showing that this difference is statistically significant at zero level of confidence ($Z = -4.755$, $p=0.000$). This is probably a very encouraging finding, implying that personalization on the basis of these factors (cognitive style and working memory span) benefits users within an eCommerce environment, as long as there are some cognitive functions involved of course (such as information seeking).

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

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

In sum, the specific experiment shows in a rather clear way that users performed better within the personalized environment, and these findings are statistically very robust. It could be argued of course that there is no way to be fully aware if information processing was more efficient at a deeper level, or users simply found the personalized condition more of their (perhaps unconscious) liking, thus devoting more conscious cognitive effort.

Nevertheless, such an increase in performance, which is consistent to the findings of previously conducted experiments in the field of eLearning (Germanakos et al., 2008), provides support for the further development and application of our UPPC ontology in different Web-based application environments.

5. Conclusions

The basic objective of this paper was to present a conceptualization of a human factors ontology, namely UPPC, for hypertext computer-mediated systems. It has been attempted to approach the theoretical considerations and technological parameters that can provide the most comprehensive user profiling and further supporting the provision of the most apt and optimized user-centered Web-based result.

We further proposed a Web-based content adaptation design methodology according to the ontology's impact into the information space, and described the mechanism that is based on a proposed Web browser extension set of custom xml tags for the imminent automatic transformation and enhancement of the Web-based content. The specific influence and the Web design enhancements and content transformations have been overviewed and positively evaluated in the eCommerce domain.

It was clearly demonstrated that users' information finding was more accurate and efficient, both in terms of providing correct answers to the task questions and in task completion time. These findings reveal that our approach turned out to be initially successful, with a significant impact of the UPPC ontology and the given human factors in the personalization and adaptation procedure of Web-based environments.

Future and emerging trends include a more extensive study on the structure of the metadata coming from the providers' side as well as a fully detailed technical description of the UPPC ontology, implemented and tested in different domains and contexts.

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