Proposing Web Design Enhancements based on Specific Cognitive Factors: An Empirical Evaluation

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***Abstract*—The research that is described in this paper focuses on incorporating theories of individual differences in information processing within the context of generic Hypertext and Hypermedia Environments. The main objective of this paper is to introduce a framework for the automatic reconstruction of Web content based on human factors. It is supported that human factors may be used in order to enhance the design of generic hypertext (or hypermedia) content in a measurable and meaningful way. A Web Browser extension set of custom xml tags has been therefore developed in order for the browser to recognize and implement these set of tags for the imminent transformation and enhancement of Web content. An increase on users' satisfaction as well as more efficient information processing (both in terms of accuracy and task completion time), has been observed in the personalized condition than the original one. Consequently, it is supported that human factors may be used in order to enhance the design of generic hypertext (or hypermedia) content in a measurable and meaningful way.**

Keywords-human factors; cognitive styles; smart web objects; web personalization; web adaptation

I. INTRODUCTION

Finding and presenting information on the World Wide Web (WWW) has become a challenging and urgent problem [6]. The vast number of Websites makes it hard, or indeed impossible, to find the appropriate site [7]. Similarly, the growing size and complexity of Websites makes it very difficult to locate information within specific Web-pages. This problem of finding and presenting information in a site has become an important area of research, with several solutions currently being pursued. Web adaptation and personalization techniques and paradigms are employed in order to alleviate such problems by presenting information based on the needs and preferences of users, by dynamically adapting the user's view according to the task at hand.

Furthermore, since the WWW is by definition a huge resource of information, it would make much sense that individuals' information processing characteristics should be taken into consideration. To that direction, our efforts are focused on improving the effectiveness of Websites by employing methods of personalization.

As part of our previous research, it has been demonstrated that the incorporation of human information processing factors in eLearning environments leads to better comprehension on behalf of the users [5]. Based on this experimental evaluation, our next step was to apply such individual differences theories in a context other than educational, namely the Web in general and the imminent hypertext/hypermedia content that is composed. From such a wide perspective that emphasizes on information processing and not strictly learning, the constructs of cognitive style and working memory were opted for as personalization parameters, considering that their effect in the case of our eLearning experiments was highly significant. Moreover, these factors address the issue of processing in a wider than the educational area, while the corresponding implications are viable for implementation on the Web.

As a result, we developed a Web Browser extension set of custom xml tags, as design enhancements and content transformation in generic hypertext environments, based on the incorporation and mapping of these human factors with the information space, in order to optimize the effectiveness of information distribution in the Web. The expected outcome can be summarized in the increase of the levels of efficiency and satisfaction of the users by facilitating information comprehension and retaining. This filtering of the Web-content ultimately aims to match individuals' preferences and abilities in a measurable way, possibly proving that Web designers should also focus on individual differences in cognitive factors.

II. BACKGROUND THEORY

Riding and Cheema's Cognitive Style Analysis (CSA) has been used as a very representative theory of cognitive (not learning) style; additionally, the two independent scales of the CSA (Verbal/Imager and Wholist/Analyst) correspond ideally to the structure of hypertext environments. A personalized environment that is supported by an automated mechanism can be altered mainly at the levels of content selection and hypermedia structure; the content is essentially either visual or verbal (or auditory), while the manipulation of links can lead to a more analytic and segmented structure, or to a more holistic and cohesive environment. These are actually the differences in the preferences of individuals that belong to each dimension of the CSA scales [10].

The concept of working memory [2] also fits very well into our rationale of personalizing Websites on the basis of

users' cognitive abilities and preferences. "The term working memory refers to a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning" [1]; Baddeley also refers to individual differences in the working memory (digit) span of the population, thus providing a very good argument for using this concept as a personalization factor.

Nevertheless, in order to substantiate the need of personalization in commercial Websites, it is necessary to:

a) Identify whether the existing hypertext structure and method of presentation of commercial sites fits users' cognitive preferences.

b) Experimentally evaluate the effect of personalization.

III. Dynamic Hypertext Transformation based on given Cognitive Factors

In our previous work, as mentioned above, we have introduced a new way of transforming and adapting Web-based learning content based on a comprehensive user model that employs specific metrics of visual and cognitive parameters. The validation and accuracy of the content transformation based in these factors has been achieved with the use an innovative Adaptation and Personalization Web-based System, namely, AdaptiveWeb (www3.cs.ucy.ac.cy/adaptiveweb) that has been developed and positively evaluated in the eLearning domain [6].

Since the so far results of the proposed model are really encouraging for the future, we propose in this section a design methodological approach for the mapping process and adaptation of any Web-based hypertext content (rather than learning) based on the specific human factors, that is cognitive styles and working memory.

```
<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>
```

Figure 1. Sample code extension with the new <csl> tag

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. Figure 1 shows a sample code that is extended with the new set of tags.

This set of tags should be interpreted by any Web browser for reconstructing a given Web-based content when mapped with a user's human factors' model.

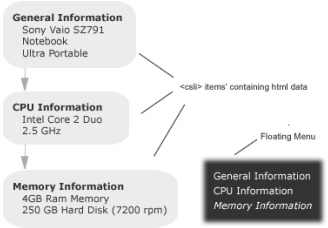

Figure 2. Browser content interpretation based on user's profile (Wholist / Imager)

Based on the sample code depicted in Figure 1, the corresponding browser's interpretation and hypertext content presentation is shown in Figure 2 and 3.

In case a user is a Wholist/Imager (see Figure 2), 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.

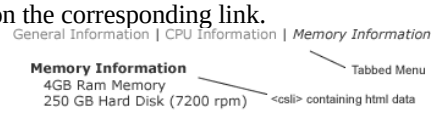

Figure 3. Browser content interpretation based on user's profile (Analyst / Verbalizer)

In Figure 3, 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 Webpage with a tabbed menu for each <csli> item. Each time the user clicks on a link of the tabbed menu, the corresponding data of the <csli> item is shown on the Webpage.

A. *Mapping the <csl> tag with the User's Cognitive Style Characteristics*

Our main goal in this section is to show in a more detail how a Web browser should interpret the <csl> tag and adapt the containing information based on the user's profile and consequently the abovementioned cognitive factors. We assume that the Web browser has fully knowledge of the user's profile, which based on Figure 1, it combines it with the containing information of the <csl> tag, adapting the content. The adaptation process involves the transformation and/or enhancement of a given raw Web-based hypertext content (provider's original content) based on the impact the specific human factors have on the information space [5] (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). Figure 4 shows the possible Web-based hypertext content transformations/enhancements based on the mapping process that take place during adaptation process based on the influence of the human factors and the theory of individual differences.

Based on the following figure, 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).

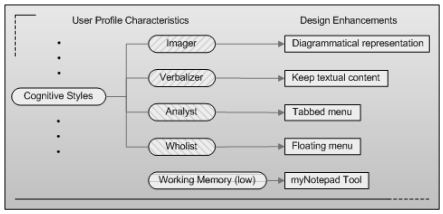

Figure 4. Hypertext Content Transformations / Enhancements

For a better understanding, a user that happens to be an Imager gets a diagrammatical representation of the containing information of the <csl> tag. The <csli> tag is used by the Web browser 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 furthermore, 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>. 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 Figure 1) 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 hypertext content while interacting. Again, the <csli> elements comprise the menu's items.

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.

IV. Experimental Evaluation using an eCommerce Setting

The following section describes the experimental design and the results that support the notion of personalization in generic Web-based hypertext environments other than educational.

A. *Methodology & Design Implications*

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

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-based hypertext 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 hypertext environments, which were presented sequentially (as soon as they were done with the first environment, the second one was presented).

The hypertext content was about a series of Sony laptop computers: general description, technical specifications and additional information were available for each model. As stated in the introductory section, we considered that the original (raw) version of the environment was designed without any consideration towards cognitive style preferences, and the amount of information was so high and randomly allocated that could increase the possibility of cognitive overload. The personalized condition addressed these issues by introducing as personalization factors both cognitive style and working memory span.

The psychometric materials that were used are the following:

Cognitive Style: Riding's Cognitive Style Analysis, standardized in Greek, assessing the Imager/Verbalizer and Wholist/Analyst dimensions.

Working Memory Span: Visuospatial working memory test, examining participants' ability to temporarily store visual figures.

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 hypertext 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 hypertext environments were:

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

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

- Users did not know which the personalized condition was, nor were they encouraged to use any additional features.
- To avoid training effects, half of the users received the raw condition first (considered as environment A), whilst the other half started the procedure with

the personalized (again considered as environment A).

- To avoid a possible effect of differences in difficulty of each set of three questions, they were alternated in both environments. Due to a design error, the division was not in half, but 53 participants received the first combination and 36 the alternated. However there was not observed any effect; all questions were proven of equal difficulty- to the extent that this is possible of course.

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

B. Results

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

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

V. CONCLUSIONS

The basic objective of this research paper was to introduce a combination of human factors, namely cognitive styles and working memory, and to propose a Web-based content adaptation design methodology based on their impact into the information space. Their specific influence and the Web design enhancements and hypertext content transformations have been described 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 human factors in the personalization and adaptation procedure of Web-based hypertext and hypermedia environments.

The implementation of the rest of our three dimensional theoretical model and the development of corresponding personalization rules is the next step of our experimental approach in Web-based hypertext settings, aiming to ground if possible a set of generic personalization guidelines on the basis of human factors- though it is fully understood how challenging such an endeavor is.

Finally, at a technical level, 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 hypertext/hypermedia content based on the comprehensive user profile. The final system will provide a complete adaptation and personalization Web-based solution to the users satisfying their individual needs and preferences.

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