Adaptivity Considerations for Enhancing User-Centric Web Experience

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Abstract **- User Experience (UX) design relates to the creation of models that affect user experiences during interaction with a system, while the incorporation of cognitive factors in the personalization process of Web systems might provide a more user-centric approach. This paper explores the influence specific cognitive factors may have on UX qualities to be used as adaptivity factors for personalizing and improving users' experiences in commercial Web-sites. A user experience evaluation was conducted where 96 students navigated in an existing commercial Web-site for a problem-based task. A user experience measurement was performed so as to assess users' perceptions regarding the pragmatic, hedonic and attraction qualities of the environment. It has been observed that specific cognitive factors have considerable influence on specific qualities of user experience. To this end, such findings are encouraging for further investigation of the possible impact of cognitive factors in terms of enhancing the personalization process of commercial Web-sites so as to achieve better user experience.**

Keywords - User-adaptive systems; User Modeling (UM); User Experience (UX); Cognitive Factors

I. Introduction

User-adaptive systems [1] have become progressively popular in the last decade due to the exponential increase of users and availability of digital information, mainly on the World Wide Web (WWW). Since its early days, research on User-adaptive systems focused on the weaknesses presented in traditional "one-size-fits-all" systems [2] that were unable to satisfy the heterogeneous needs and preferences of users.

By User-adaptive systems we mean all computer-mediated systems that are able to (semi) automatically adapt their structure and presentation by learning from data about their users; implicitly (i.e., observing user's interactions) and/or explicitly (i.e., direct input from the user). All User-adaptive systems, from research-oriented to industrial systems, and from educational hypermedia systems to commercial Web systems, they all share a common goal, i.e., to increase the *functionality* of the system and improve the *users' experiences* by making it personalized.

Research on User-adaptive systems straddles the boundaries of User Modeling (UM) [3] and User Experience (UX) [4]. UM in User-adaptive systems deals with what information is important about the user and how to learn and represent this information, while UX studies the feelings and thoughts of an individual about a product (e.g., interactive system). UX mainly takes the affective consequences on the human side as opposed to the computer side. It focuses on positive emotional outcomes such as joy, fun and pride and deals with hedonic and affective (e.g., surprise, diversion, intimacy) aspects of HCI design and evaluation.

The work presented in this paper lies on previous research [5] that has shown that individual traits (i.e., specific cognitive factors) may have significant impact in the adaptation and personalization process of User-adaptive systems. Furthermore, current advances in User Experience (UX) reveal that there is still enough space for research by combining UM and UX strategies for providing a more user-centric approach in User-adaptive systems.

In this respect, this work is an attempt to study a possible association between specific cognitive factors of a cognitive-based user model [5] and UX qualities of a valid UX measurement (AttrakDiff) [12]. The main aim is to identify possible relationships between these cognitive factors and UX qualities that will generate new research possibilities; personalizing commercial Web-sites based on cognitive factors in order to improve users' experiences (focused on hedonic and affective aspects) during interaction with a product.

The remainder of the paper is organized as follows: Sections 2 and 3 briefly discuss the research areas related with this work; User Modeling (UM) in User-adaptive system and User Experience (UX), respectively. Section 4

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formulates the basis for the investigation of the relationship between cognitive factors and UX qualities. Section 5 presents the experimental methodology of a study with 96 participants, followed by a discussion on its results. The paper concludes with some future prospects.

II. User Modeling In User-Adaptive Systems

Adaptation decision in User-adaptive systems is based on taking into account any vital information about the user, represented in the user model, in order to provide adaptation effects (i.e., the same system can look different to users with different models). The data kept in the user model can be distinguished (according to [6]) to *user data*, *usage data*, and *environment data*. User data comprise various characteristics about the user, usage data comprise data about user's interactions with the system that are utilized to infer knowledge about the user, and environment data comprise all aspects of the user's environment (i.e., context, device's or network's characteristics).

The work presented in this paper focuses on modeling *user data*. Among the five most popular user features (i.e., user's knowledge, interests, goals, background, and individual traits) of user data applied in User-adaptive systems [3], this study focuses on users' individual traits (i.e., cognitive factors) for modeling the user.

The user's individual traits are features that define the user as an individual. Examples are personality factors, cognitive factors and learning styles. Unlike other features, that are extracted through interviews or based on user's interactions, individual traits are traditionally extracted using psychometric tests. Individual traits are stable user features that might change only over a long period of time or might not change at all, in contrast with other user features, such as user's goals, knowledge, interests that are rather dynamic features and change frequently over time.

Recently, a considerable amount of research efforts have been undertaken focusing on modeling and utilizing cognitive factors for personalization in User-adaptive systems. Several User-adaptive systems [5][28][29][30] have distinguished users based on their cognitive styles and learning styles and provided different adaptation effects accordingly. In a study, Germanakos et al. [5] have distinguished imager and verbal users, and wholist users and analyst users based on Riding's Cognitive Style Analysis [16]. Each user was provided with adaptive presentation of content and different navigation organization. In a similar approach, Triantafillou et al. [28] distinguished field-dependent and field-independent users based on Witkin et al. [18] and provided different navigation organization, amount of user control, and navigation support tools for these groups. Results in both studies indicate that cognitive styles have significant impact in the adaptation and personalization process of Web environments by increasing usability and user satisfaction during navigation and learning performance.

Such findings suggest that individual traits are important user features to take into account in the personalization process of a User-adaptive system.

III. User Experience (UX)

ISO 9241-210 [7] defines User Experience (UX) as "a person's perceptions and responses that result from the use or anticipated use of a product, system or service". UX is dynamic, because it changes over time as the circumstances change [8]. Being a multi-dimensional and complicated area a universal definition has not been agreed to date. Nevertheless, most of the definitions given to UX [9, 10] agree that UX focuses on the hedonic and affective aspects of HCI, but it also includes a person's perceptions of the practical aspects such as utility, ease of use and efficiency of a system.

Effective HCI design and evaluation involves two important qualities: i) usability (i.e., traditional HCI), and ii) hedonic, beauty and affective [10]. Based on Jordan [11], the latter complements traditional HCI qualities (i.e., pragmatic) by suggesting a fixed hierarchical structure of qualities that contribute to positive experience. That is, a product has to provide functional and usability qualities before hedonic aspects can take effect. In contrast to Jordan, Karapanos et al. [8] assume the importance of these different qualities to vary with several contextual factors, i.e., individual differences, type of product, situation the product is used in, and change of experience over time.

Regarding UX evaluation, one of the most influential models is the one proposed by Hassenzahl [12]; according to this model each interactive product has a pragmatic (related to usability) and hedonic quality that contribute to the UX. Based on this model a well-known and widely used measurement instrument has been developed, the AttrakDiff [12], which has been employed in our empirical study (version AttrakDiff2). It is composed of four main constructs with seven anchor scales (total 28 items). Within each item a word-pair spans a scale between two extremes. The scales consist of seven stages (-3,-2,-1,0,1,2,3) between the word-pairs. The oppositional word-pairs consist of two conflictive adjectives like “bad” – “good”, or “technical” – “human”.

The constructs are [12][13]: Pragmatic Quality (PQ), which is related to traditional usability issues (such as, effectiveness, efficiency, learnability, etc.); Hedonic Quality Stimulation (HQ-S), which is about personal growth of the user and the need to improve personal skills and knowledge; Hedonic Quality Identification (HQ-I), which focuses on the human need to be perceived by others in a particular way; and Attraction (ATT), which is about the global appeal of an interactive product.

IV. Relationship Analysis Between Cognitive Factors and UX Qualities

This section presents specific cognitive factors that could influence UX qualities (based on the AttrakDiff analysis) in User-adaptive systems. The goal is to initially investigate and formulate a cognitive-based user model for User-adaptive systems in relation to the UX perspective (Figure 1).

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A. Cognitive Styles

Cognitive styles represent the particular set of strengths and preferences that an individual or group of people have in how they take in and process information. By taking into account these preferences and defining specific strategies, empirical research has shown that cognitive styles correlate with performance in a Web-based environment [14][21]. Cognitive styles have been defined by Messick as "consistent individual differences in preferred ways of organizing and processing information and experience, a construct that is different than learning style" [15].

Regarding the hypermedia information space, amongst the numerous proposed theories of individual style, a selection of the most appropriate and technologically feasible cognitive (and learning) styles (those that can be projected on the processes of selection and presentation of Web-content and the tailoring of navigational tools) has been studied, such as Riding's Cognitive Style Analysis (CSA) (Verbal-Imagery, and Wholistic-Analytic) [16], Felder/Silverman Index of Learning Styles (ILS) (4 scales: Active vs. Reflective, Sensing vs. Intuitive, Visual vs. Verbal, and Global vs. Sequential) [17], Witkin's Field-Dependent, and Field-Independent [18], and Kolb's Learning Styles (Converger, Diverger, Accommodator, and Assimilator) [19], in order to identify how users transform information into knowledge (constructing new cognitive frames).

TABLE I. RIDING COGNITIVE STYLE SCALE

CSA Scale	*Typology*	*Description*	*Web Implications*
Imagery-Verbal	Imager	Represents information in mental pictures	Prefers graphic, pictorial/visual representation
Imagery-Verbal	Interme diate	No specific preference	Combination of graphics and text
Imagery-Verbal	Verbal	Represents information verbally	Prefers material in text/auditory form
Wholistic-Analytic	Wholist	Organizes information as whole	Needs more guidance, serial navigation approach
Wholistic-Analytic	Interme diate	No specific preference	Combination of scattered and serial navigation
Wholistic-Analytic	Analyst	Organizes information in parts	Independent and scattered navigation

Riding and Cheema's CSA [20] has been used as a reference theory of cognitive style in previous research [21] due to the fact that the two independent scales (Table 1) of the CSA (Imagery-Verbal, and Wholistic-Analytic) correspond at a considerable extend to the structure of hypermedia (i.e., Web) 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 scale [22].

This study utilizes Riding's Cognitive Style Analysis (CSA) [16] because its implications can be mapped on the information space more precisely, since they consist of distinct scales that respond directly to different aspects of the Web space. The CSA implications (Table 1) are quite clear in terms of hypermedia design (visual/verbal content presentation and wholistic/analytic pattern of navigation).

In this respect, the following research assumptions could be formulated: The Imagery-Verbal factor, which mainly influences the presentation of content (visual/textual), might primarily affect the Attraction (ATT) and Hedonic Quality Stimulation (HQ-S) constructs that relate to the overall appeal of a Web-site and stimulation and attention through inspiring and supportive content as well as interaction/presentation techniques. Furthermore, the Wholist-Analyst factor might primarily affect Pragmatic Quality (PQ) that is related to traditional usability issues (i.e., instrumental efficiency and effectiveness) because this factor has high impact on the navigation and instrumental functionality (e.g., navigation support, supportive tools) of a Web-site.

B. Working Memory Span

The concept of Working Memory Span (WMS) [23] also fits very well into our rationale [21] of personalizing Web content 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" [24]; Baddeley also refers to individual differences in the WMS (digit) of the population, thus providing a very good argument for using this concept as a personalization factor.

We are mainly interested in the notion of the WMS; since it can be measured and the implications on information processing are rather clear (Table 2). Each WMS instance (i.e., low/medium/high), indicating the working memory capacity of a person, has implications on the navigation, quantity of content and aesthetics of a Web environment. Due to the visual form of presentation in the Web, we have focused especially on the measurement of visual WMS [25] in terms of psychometrics.

TABLE II. WORKING MEMORY SPAN SCALE

WMS	*Description*	*Web Implications*
Low	Low working memory capacity	Needs more guidance in Web-sites, navigation support tools, less content, emphasize content
Medium	Medium working memory capacity	Prefers navigation support tools, emphasize content
High	High working memory capacity	More complex structure of Web-sites, more content

The idea of exploring the role of working memory in hypermedia environments has indeed generated research. DeStefano and LeFevre [26] reviewed 38 studies that address mainly the issue of cognitive load in hypertext reading, and working memory is often considered as an individual factor of significant importance, even at the level of explaining differences in performance. Lee and Tedder [27] examine the role of working memory in different computer texts, and their results show that low WMS learners do not perform equally well in hypertext environments.

The research assumption in this case is that WMS might significantly affect Pragmatic Quality (PQ), Hedonic Quality Stimulation (HQ-S) and Attraction (ATT), since WMS has implications on the navigation, quantity of content and aesthetic appeal of a Web-site.

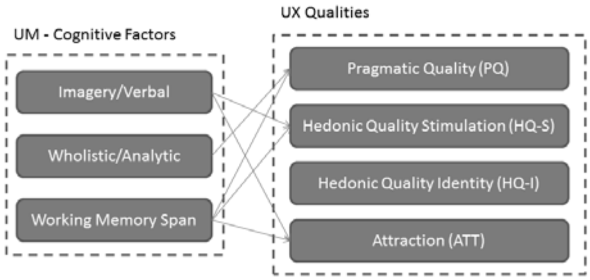

Figure 1. Relationship Between Cognitive Factors and UX Qualities

Concluding, Hedonic Quality Identity (HQ-I) might not significantly affect any of the cognitive factors in the current context since it is essentially intended for evaluation of hedonic qualities of products, rather than software (i.e., Web-based environments). Thus, the HQ-I construct is not included in the current analysis.

V. STUDY

In this section, we describe a preliminary study that aims to evaluate the experiences users had in a commercial Web-site based on their cognitive factors and support the aforementioned possible relationship between UX qualities. A UX measurement (AttrakDiff2) was performed so as to assess their perceptions regarding the pragmatic and hedonic qualities of the environment.

A. Methodology and Sampling

The study was carried out at the University of Cyprus during the whole month of March 2011. Our sample included 96 students of the Computer Science department. The participation was voluntarily. All participants' ages varied from 18 to 21, with a mean age of 19. All users accessed a commercial Web-site using personal computers located at the laboratories of the university, divided in groups of approximately 20 participants. Each session lasted about 40 minutes; 20 minutes was required for the user modeling process, while the remaining time was devoted to navigate in an existing commercial Web-site and evaluate their experiences using AttrakDiff2.

During the user modeling process, students provided their demographic characteristics (i.e., name, age, education, etc.) and performed a number of interactive tests using attention and cognitive processing efficiency grabbing psychometric tools [31] in order to quantify their cognitive characteristics.

Furthermore, the students were asked to navigate in a replica of the official Web-site of HTC Corp. (www.htc.com, derived on March 1, 2011) that was developed for the purpose of this experiment. The Web-site's content was about a series of mobile phones; general description, technical specifications and additional information were available for each model.

The students were asked to fulfill three tasks; they had to find the necessary information to answer three sequential multiple choice questions that were given to them while navigating and which were referring to a particular type of mobile phone. There was certainly only one correct answer that was possible to be found relatively easy, in the sense that the students were not required to have hardware related knowledge or understanding.

As soon as they completed the three tasks, they were presented with an online version of AttrakDiff2 to express their opinion regarding the hedonic and pragmatic qualities of the environment they just navigated.

B. Results

In order to assess the significance and possible impact cognitive factors may have on UX qualities, a comparison has been performed between the cognitive factor's instances per UX construct.

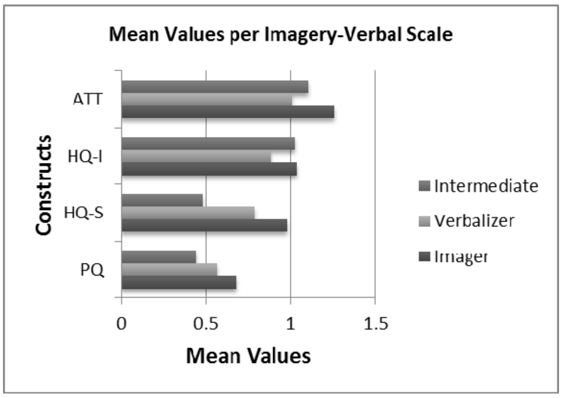

Figure 2. Mean UX Values per Imagery-Verbal Scale

Figure 2 illustrates the mean values of the UX dimensions per Verbal-Imagery scale. According to the results, we observe considerable deviation between the instances in Hedonic Quality Stimulation (HQ-S) and Attraction (ATT). In HQ-S, mean scores of Imagers were 0.98, Verbalizers 0.79 and Intermediates 0.48, and in ATT, mean scores of Imagers were 1.26, Verbalizers 1.01 and Intermediates 1.1, indicating that users based on this cognitive factor perceived differently the hedonic quality (stimulation) and overall appeal (attraction) of the environment. In addition, based on an empirical observation of the environment, it can be easily revealed that the environment is rich with graphical/visual representations.

To this end, the Imagery-Verbal factor primarily influences the HQ-S and ATT constructs and that Imagers find the environment more stimulating and attractive since the environment contains a lot of graphical representations.

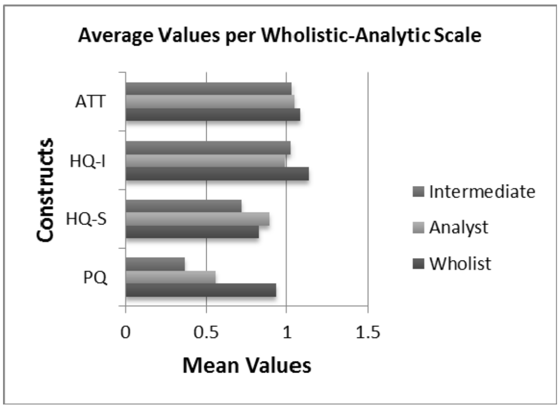

Figure 3. Mean UX Values per Wholistic-Analytic Scale

Figure 3 illustrates the mean values of the UX dimensions per Wholistic-Analytic scale. According to the results, we observe considerable deviation between the instances in Pragmatic Quality (PQ). In PQ, mean scores of Wholists were 0.93, Analysts 0.79 and Intermediates 0.36 indicating that users based on this cognitive factor perceived differently the pragmatic quality (i.e., usability) of the environment. Regarding the Attraction (ATT), marginal deviation has been observed, with Wholists having mean scores of 1.08, Analysts 1.05 and Intermediates 1.03, indicating that the Wholistic-Analytic factor does not significantly influence ATT. This is in accordance with the implications the Wholistic-Analytic factor has on the Web space; it primarily influences usability of a Web-site (i.e., different navigation, support tools for different user models).

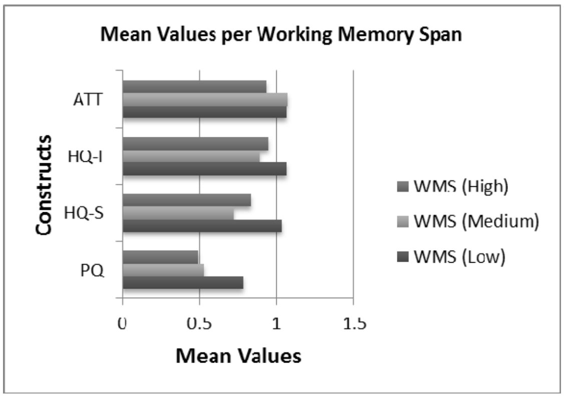

Figure 4. Mean UX Values per Working Memory Span

Figure 4 illustrates the mean values of the UX dimensions per Working Memory Span. According to the results, we observe considerable deviation between the instances in Hedonic Quality Stimulation (HQ-S) and Pragmatic Quality (PQ). In HQ-S, users with low working memory span (WMS) had mean scores of 1.03, with medium WMS 0.72 and with high WMS 0.84, and in PQ, mean scores of low WMS users were 0.78, medium WMS users 0.53 and high WMS users 0.49, indicating that users based on these cognitive factors perceived differently the hedonic quality (stimulation) and usability of the environment. In Attraction (ATT), minor deviation of ratings has been observed, indicating that this construct is not primarily influenced by this cognitive factor.

In conclusion, the WMS factor primarily influences the HQ-S and PQ constructs and that users with low WMS find the environment more stimulating and “usable” since the environment contains supportive content and a lot of graphical indications.

VI. Conclusion And Future Work

In conclusion, this empirical work focused on the influence specific cognitive factors may have on UX constructs. A UX measurement was performed so as to assess users’ perceptions regarding the pragmatic and hedonic qualities of a commercial Web-site.

Initial findings indicate that incorporating specific cognitive factors in the personalization process of commercial Web-sites may affect users’ experiences. Results reveal that the Imagery-Verbal factor primarily affects Hedonic Quality Stimulation (HQ-S) and Attraction (ATT), the Wholistic-Analytic factor primarily affects Pragmatic Quality (PQ), and the WMS factor primarily affects Hedonic Quality (HQ-S) and Pragmatic Quality (PQ). In addition, results indicate that Hedonic Quality Identity (HQ-I) does not primarily affect any of the cognitive factors in the current context, which is in accordance with theory [12], since HQ-I is essentially intended for evaluation of hedonic qualities of products, rather than software (i.e., Web environments).

The relevant research is in its infancy and further empirical studies are needed to investigate UX issues in such context. A future research prospect is to employ personalization methods [5] in order to assess the impact cognitive factors may have in the personalization process of commercial Web-sites, in terms of amplifying users’ experiences during navigation session. In this respect, an experimental study with real users will be conducted in the future (similar experimental approach to Germanakos et al. [5]), where specific adaptation and personalization techniques will be employed in the same commercial Web-site used in this study. The main aim is to adapt and personalize the original environment based on each individual’s cognitive factors in such a way (e.g., remove some graphical representations of the Web content for Verbal users or enhance navigation support for Wholist users) to achieve positive experience. In order to assess the approach, users will evaluate the original and personalized version of the commercial Web-site utilizing AttrakDiff2. A statistical analysis will be performed in order to compare the user experience evaluations between the two different environments. Based on the influence specific cognitive instances may have on UX qualities, we assume that the personalized version will lead to better emotional outcomes and that the UX qualities will have better ratings than the original version.

Even though the evaluation of this concept in the eCommerce domain is encouraging for our work, there is

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still a lot room of investigation in order to shed light on this complex and dynamic research area. Main goal is to initiate and drive this research to a concrete cognitive factors' framework that can be used in any hypermedia system proposing a new set of design guidelines for the enhancement of one-to-one Web services' delivery.

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