PERSONALIZING WEB ENVIRONMENTS ON USER INTRINSIC CHARACTERISTICS

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Abstract

Individual differences in information processing, as derived from an approach that takes into account cognitive and emotional parameters, serve as a basis for setting a theoretical framework that addresses user profiling issues in web environments. This paper presents empirical results of two distinct efforts to built and evaluate personalized applications in the field of education and commercial web-sites respectively. In the educational context, this approach is shown to optimize learners' performance; the case of commercial environments seems more complex and elusive in measuring actual benefits. The theories involved in constructing a comprehensive information processing model are presented, and the adaptation rules and changes within the environment are discussed, in relation to the empirical results that were gathered throughout the development of the proposed model. It is argued that individual differences are nevertheless present during users' interactions within the information space and that web environments should be adapted on such intrinsic characteristics.

1 Introduction

Within certain web applications the notion of personalization may contribute to a more efficient adaptation on users' or/and context characteristics, thus providing flexibility as a property of the web environment. These systems are mainly referred as adaptive hypermedia, and according to a review by Brusilovsky six specific application areas for adaptive hypermedia systems have been identified since 1996 [1]. These are educational hypermedia, on-line information systems, information retrieval systems, institutional hypermedia and systems for managing personalized view in information spaces. Educational hypermedia and on-line information systems are the most popular, accounting for about two thirds of the research efforts in adaptive hypermedia. Adaptation effects vary from one system to another. These effects are grouped into three major adaptation technologies - adaptive content selection [2], adaptive presentation (or content-level adaptation) and adaptive navigation support (or link-level adaptation) [1, 3].

The function of adaptivity may as well be considered as a level of intelligence embedded in a web (or virtual in general) environment, whether emphasis is placed upon users' or interface/technical characteristics. A certain form of mapping rules and corresponding implications on the information space is required, in order for a system to alter visible to the user aspects of the environment. Therefore, a serious analysis of user requirements has to be undertaken, documented and examined, taking into consideration their multi-application to the various delivery channels and devices.

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 [4]. According to Merriam-Webster dictionary the term profile means "a representation of something in outline" [5]. User profile can be thought of as being a set of data representing the significant features of the user. Its objective is the creation of an information base that contains the preferences, characteristics, and activities of the user. A user profile can be built from a set of keywords that describe the user preferred interest areas compared against information items.

Our psychometrically based research focuses on user cognitive and emotional characteristics that have an effect on real-time information processing. We approach the issue of personalization from the perspective of individual differences, aiming to maximize the performance of users within the context of information distributing web environments. We are in the process of building, evaluating and validating a user profiling model that could be applied in various web-based settings, since our first efforts in the field of educational applications have been fruitful [6]. In this paper, we present a comparison analysis of different implementation fields of our model, in an educational and a commercial web environment respectively.

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2 Theoretical Background

Our proposed new component / dimension of the user profiling contains cognitive and emotional processes that could be described as user "perceptual preferences", aiming to enhance information learning efficacy.
User Perceptual Preferences could be described as a continuous mental process, which starts with the perception of an object in the user's attentional visual field, and involves a number of cognitive, learning and emotional processes that lead to the actual response to that stimulus [6].
This model's primary parameters formulate a three-dimensional approach to the problem. The first dimension investigates the visual and cognitive processing of the users, the second their cognitive style, while the third captures their emotional processing mechanism during the interaction with the information space.

2.1 Cognitive Processing Efficiency

The cognitive processing parameters [7, 8] 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. *visual working memory span (VWMS)* (refers to the processes that enable a person to hold visual 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 [9], 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…" [10]. Amongst the numerous proposed cognitive style typologies [11] we favour Riding's Cognitive Style Analysis [12], 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 [13], and to the extent that there is a correlation with hemispherical preference and EEG measurements [10, 14], 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.
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 like shortness of breath, nausea and increased sweating. The anxious person is not able to regulate his emotional state since he feels and expects danger all the time [15].
Barlow [16] describes anxiety as a cognitive-affective process in which the individual has a sense of unpredictability, a feeling of uncertainty and a sense of lack of control over emotions, thoughts and events. This cognitive and affective situation is associated as well with physiological arousal and research has shown that an individual's perception is influenced in specific domains such as attentional span, memory, and performance in specific tasks. In relation to performance, the findings are controversial but there is a strong body of research which supports that anxiety is strongly correlated to performance and academic achievement. [17, 18]
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 [19]. Emotional intelligence

seems to be an adequate predictor of the aforementioned concepts, and is surely a grounded enough construct, already supported by academic literature [20, 21]. Additional concepts that were used are the concepts of self-efficacy, emotional experience and emotional expression.

Self-efficacy is defined as people's beliefs about their capabilities to produce and perform. Self-efficacy beliefs determine how people feel, think, motivate themselves and behave. Such beliefs produce these diverse effects through four major processes. They include cognitive, motivational, affective and selection processes. *Emotional experience* is the conceptualization of an emotion, the way in which the individual is dealing with it and how he perceives it. *Emotional expression* is the way in which the individual is reacting after an emotion triggers. It is his behaviour after an affective stimulus. It can be argued that emotional expression is the representation of an emotion. [22]

3 Empirical evaluation of the proposed model in an educational environment

This section presents the results from experiments that were conducted in the context of an educational web-setting, which support our approach in terms of optimizing users' performance in the sense of information comprehension.

3.1 Sampling and procedure

All participants were students from the Universities of Cyprus and Athens; phase I was conducted with a sample of 138 students, whilst phase II with 82 individuals. 35% of the participants were male and 65% were female, and their age varied from 17 to 22 with a mean age of 19. The environment in which the procedure took place was an e-learning course on algorithms. The course subject was chosen due to the fact that students of the departments where the experiment took place had absolutely no experience of computer science, and traditionally perform poorly. By controlling the factor of experience in that way, we divided our sample of the first phase in two groups: almost half of the participants were provided with information matched to their cognitive style, while the other half were taught in a mismatched way. In the second phase, the sample was divided in six, with a matched and mismatched condition for each factor. We expected that users in the matched condition, both in phase I and phase II, would outperform those in the mismatched condition.

In order to evaluate the effect of matched and mismatched conditions, participants took an online assessment test on the subject they were taught (algorithms). This exam was taken as soon as the e-learning procedure ended, in order to control for long-term memory decay effects. The dependent variable that was used to assess the effect of adaptation to users' preferences was participants' score at the online exam.

At this point, it should be clarified that matching and mismatching instructional style is a process with different implications for each dimension of our model. These are described below:

- Matched Cognitive Style: Presentation and structure of information matches user's preference
- Mismatched Cognitive Style: Presentation and structure of information does not coincide with user's preference
- Matched VWMS: Low VWMS users are provided with segmented information
- Mismatched VWMS: Low VWMS users are provided with the whole information
- Matched CPSE: Each user has in his disposal the amount of time that fits his ability
- Mismatched CPSE: Users' with low speed of processing have less time in their disposal (the same with "medium" users
- Matched Emotional Processing: Users with moderate and high levels of anxiety receive aesthetic enhancement of the content and navigational help
- Mismatched Emotional Processing: Users with moderate and high levels of anxiety receive no additional help or aesthetics

3.2 Questionnaires

In this specific e-learning setting, Users' Perceptual Preferences were the sole parameters that comprised each user profile, since demographics and device characteristics were controlled for. In order to build each user profile according to our model, we used a number of questionnaires that address all theories involved.

- Cognitive Style: Riding's Cognitive Style Analysis, standardized in Greek and integrated in .NET platform
- Cognitive Processing Speed Efficiency: Speed and accuracy task-based tests that assess control of processing, speed of processing, visual attention and visuospatial working memory. Originally developed in the E-prime platform, we integrated them into the .NET platform
- Core (general) Anxiety: Spielberger's State-Trait Anxiety Inventory (STAI) – 10 items (Only the trait scale was used)
- Application Specific Anxiety: Cassady's Cognitive Test Anxiety scale – 27 items [23]
- Current Anxiety: Self-reported measures of state anxiety taken during the assessment phase of the experiment, in time slots of every 10 minutes – 6 Time slots
- Emotion Regulation: This questionnaire was developed by us; cronbach's α that indicates scale reliability reaches 0.718

3.3 Results

As expected, in both experiments the matched condition group outperformed those of the mismatched group.

Table 1 shows the differences of means (one way ANOVA) and their statistical significance for the parameters of Cognitive Style (CS), Cognitive Processing Speed Efficiency (CPSE), and Emotional Processing (EM).

As hypothesized, the mean score of those that received matched to their cognitive style environments is higher than the mean score achieved by those that learned within the mismatched condition ($F_{(2,113)}$=6.330, p=0.013). This supports the notion that cognitive style is of importance within the context of web-education and that this construct has a practical application in hypermedia instruction. The same applies with the case of Cognitive Processing Speed Efficiency: $F_{(2, 81)}$=5.345, p=0.023). It should at least be of some consideration the fact that in case designers' teaching style mismatched learners' preference, performance may be lowered.

In the case of Emotional Processing, results show that in case an individual reports high levels of anxiety either at the Core Anxiety or the Specific Anxiety questionnaire, the matched condition benefits his/her performance ($F_{(2, 81)}$=4.357, p=0.042).

Table 1. Differences of means for Cognitive Style and Cognitive Processing Speed Efficiency

	Match Score	Match n	Mis-match Score	Mis-match n	F	Sig.
CS	66.53%	53	57.79%	61	6.330	0.013
CPSE	57.00%	41	48.93%	41	5.345	0.023
EP	57.91%	23	48.45%	29	4.357	0.042

The relatively small sample that falls into each category and its distribution hamper statistical analysis of the working memory (WM) parameter. In any case, the difference between those with high WM and those with low WM, when both categories receive non-segmented (whole) content, approaches statistical significance: 57.06% for those with High WM, 47.37% for those with Low WM, Welch statistic= 3.988, p=0.054.

This demonstrates that WM has indeed some effect on an e-learning environment. Moreover, if those with low WM receive segmented information, then the difference of means decreases and becomes non-significant (57.06% for High WM, 54.90% for those with Low WM, Welch statistic=0.165, p=0.687).

3.4 Correlations and statistics of emotional processing constructs

The emotional processing factor is discussed further due to the fact that it can be applied in various environments that relate to performance but do not require extended use of cognitive resources.

It is observed in table 2 that all types of anxiety are positively correlated with each other and are negatively correlated with emotion regulation. These findings support our hypothesis and it can be argued that our theory concerning the relationship between anxiety and regulation has a logical meaning. In tables 3 and 4 we can see an even stronger relationship between emotion regulation and core and specific anxiety respectively. A statistically significant analysis of variance for each anxiety type shows that if we categorize the participants according to their emotional regulation ability, then the anxiety means vary significantly with the high regulation group scoring much higher than the low one. Finally, in table 6 we can see that the two conditions (matched aesthetics/mismatched aesthetics) are differentiating the sample significantly always in relation with performance. Participants in the matched category scored higher than the ones in the mismatched and additionally lower anxious (core or specific or both) scored higher than high anxious, always of course in relation to match/mismatch factor.

We also found that participants with low application specific anxiety perform better than participants with high specific anxiety in both matched and mismatched environments. Additionally, In categories that a certain amount of anxiety exists, match-mismatch factor is extremely important for user performance. Participants with matched environments scored highly while participants with mismatched environments had poor performance. Emotion regulation is negatively correlated with current anxiety. High emotion regulation means low current anxiety and low emotion regulation means high current anxiety. Finally, current anxiety is indicative of performance. High current anxiety means test scores below average while low current anxiety means high scores.

Table 3. Correlations of types of anxiety and emotion regulation

	Core Anxiety	Application Specific Anxiety	Current Anxiety	Emotion Regulation
Core Anxiety	1	.613(**)	.288(**)	-.569(**)
Application Specific Anxiety	.613(**)	1	.501(**)	-.471(**)
Current Anxiety	.288(**)	.501(**)	1	-.094
Emotion Regulation	-.569(**)	-.471(**)	-.094	1

** Correlation is significant at the 0.01 level (2-tailed).

Table 4. Analysis of variance between emotion regulation groups and core anxiety means

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.316	2	2.158	18.554	.000
Within Groups	10.700	92	.116		
Total	15.015	94			

Table 5. Analysis of variance between emotion regulation groups and specific anxiety means

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.345	2	4.173	15.226	.000
Within Groups	25.213	92	.274		
Total	33.558	94			

Table 6. Multifactorial ANOVA (Factors - Core Anxiety, Application Specific Anxiety and Aesthetics)

Dependent Variable: Score %

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
	(a)				
Matched Aesthetics	1097.361	1	1097.361	4.238	.043
core_groups * specific_groups* Matched Aesthetics	983.259	1	983.259	3.797	.055

(a) R Squared = .102 (Adjusted R Squared = .017)

4 Extending the proposed user model in generic web environments

The second phase of our research was to apply our evaluated information processing model in a setting other than educational. For the purposes of such an empirical validation, we created an adaptive version of a commercial site[2], in order to investigate users' possible responses to a personalization process as the aforementioned.

At this point we should mention that our methodology in this preliminary study is not yet concrete, since we have no objective dependent variables to indicate users' performance, but only their self-reported levels of satisfaction and a measurement of the amount of time spent for the completion of a set of simple tasks.

4.1 Sampling and procedure

A between participants experimental design was adopted; almost half of the participants were provided with the original website, whereas the other half navigated through a personalized version. In order to motivate them to explore the site at a satisfactory level they were asked to perform a set of simple tasks. Specifically, the web pages they visited in each condition presented a number of laptops, and their tasks were to find information in order to answer a 7 item questionnaire concerning which laptop model is most suitable for a specific use.

The experiment was conducted with a total sample of 144 users; 19 users were excluded from the analysis process since they were considered to have spent insufficient time navigating in the environment they were allocated in. All participants were students from the University of Cyprus; their age varied from 19 to 23, with a mean of 20 years. Approximately 40% were male and 60% female. All of them were quite proficient in the use of the English language, and due to their academic status were familiar with technological issues such as those involved in our study- though since this was a comparative study between two environments, this factor was not expected to have a main effect.

After completing the task questionnaire, users were asked to fill in a satisfaction questionnaire [24]. The amount of time that was required for each user to complete the tasks was also measured.

4.2 Personalization rules

For this preliminary study, the parameters that constituted each user's profile were cognitive style and visual working memory span (VWMS). According to these factors, the implications were similar to those described above for the case of the educational setting. The imager/verbalizer dimension of cognitive style affected the representation of the web content (pure text or diagrammatical presentation), whilst the holist/analyst dimension had an effect on the structure of the environment and the number of links. Holists also had an extra navigational and tabbing tool.

For the case of users with low VWMS, instead of segmenting the content (which was already rather clear cut and susceptible to cognitive style differences in terms of structuring the navigational patterns), we provided users with an additional tool that served as an extra buffer for storing information that was considered to be relevant to the tasks involved.

4.3 Preliminary results

The levels of satisfaction that users reported were identical in both conditions. There was absolutely no difference between the two conditions, as perceived by the users, since their overall mean in a scale from 1 to 5 was 3.2, with very little dispersion.

Even if the personalized environment was rather burdened with personalization tools and was more complicated, users didn't seem to be discouraged; this could be interpreted as positive, presuming of course that in the intrinsic level of information processing there could be some improvement. Still, since there is no objective dependent variable indicating performance in this study, we can only conclude that the extra web-site features did not have a negative effect on perceived ergonomics and usability.

[2]http://www.sonystyle.com/webapp/wcs/stores/servlet/CategoryDisplay?catalogId=10551&storeId=10151&langId=-1&categoryId=8198552921644507782&parentCategoryId=16154

There were however differences in the amount of time that users spent navigating in the environments before they decided to fill in the task questionnaire. By dividing users in four categories, according to the level of personalization provided or not, statistically significant differences were found. The division was as follows: non-personalized environment for users with low visual working memory span (VWMS), non-personalized environment for users with normal or high VWMS, personalized environment for users with normal or high VWMS and personalized environment for users with low VWMS. Post hoc analysis of variance has shown that there was a difference between users in the first and the fourth group (see table 7); this may be explained by the fact that these types of learners are assumed (in our approach) to be in further need of personalization.

Table 7: Post hoc analysis of differences between user groups with regards to navigating time

Dependent Variable: time
Tukey HSD

(I) matched	(J) matched	Mean Difference (I-J)	Std. Error	Sig.
pers_low	pers	1.29899	.84696	.421
	raw	1.43759	.88778	.372
	raw_low	**3.01974(*)**	.95669	**.011**
pers	pers_low	-1.29899	.84696	.421
	raw	.13860	.69557	.997
	raw_low	1.72074	.78162	.129
raw	pers_low	-1.43759	.88778	.372
	pers	-.13860	.69557	.997
	raw_low	1.58214	.82567	.227
raw_low	pers_low	**-3.01974(*)**	.95669	**.011**
	pers	-1.72074	.78162	.129
	raw	-1.58214	.82567	.227

* The mean difference is significant at the .05 level.

5. Discussion

Applying an individual differences approach as a personalization procedure in web environments has shown a positive effect in the case of educational settings. Users perform better when their intrinsic characteristics are taken into account, and the mapping and implication rules that were implemented seem to be in the right direction. Thus, when designing environments that involve information processing, emphasis should also be placed upon users' characteristics and abilities. Extending this approach in fields other than the web, such as virtual settings, individual differences could also be important in terms of comprehension, navigation and orientation.

However, the case of a generic web site has shown that the perceived by the users value of a personalization procedure is not easy to be elucidated. The benefit has to be objectively measured and validated in order to support the argument for incorporating human factors in generic adaptive applications. The differences in time spent within the environment could be indicative of different users' behaviours, and that encourages us to design personalization environments with our model (for the first time, to our knowledge, to that extent and analysis) since perceived usability and satisfaction do not seem negatively affected.

As it concerns the limitations of the second study, most of them were clearly stated in the methodology section. We should add that a further step of research would include the emotional aspect of our model, seeking out the elusive for the moment effects on perceived levels of satisfaction and objective efficacy.

In any case, in search for a significant difference, there are indications of differentiation in the ways individuals approach web environments that involve information processing, and there is a ground for a viable psychological theory that could serve as a set of personalization guidelines in corresponding settings.

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