User-Centric Profiling On The Basis Of Cognitive and Emotional Characteristics: An Empirical Study

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Abstract. In order to clarify whether extending learners' profiles in an adaptive educational system to cognitive and emotional characteristics may have a positive effect on performance, we conducted an empirical study that consists of two subsequent experiments. The human factors that were taken into consideration in the personalization process were cognitive style, visual working memory span, control/speed of processing and anxiety. With the exception of control/speed of processing, matching the instructional style to users' characteristics was revealed to be statistically significant in optimizing their performance (n=219). On the basis of this empirical assessment, this paper argues that individual differences at this intrinsic level are important, and their main effect can be manipulated by taking advantage of adaptive technologies.

Keywords: Cognitive style, working memory, anxiety, e-learning, personalization, user profiling

1 Introduction

The notion of personalization and the development of adaptive hypermedia [1, 2] has indeed generated research in the area of e-learning, and corresponding educational applications have been developed [3, 4, 5, 6]. Learning style theories have been quite popular as a personalization parameter, even though researchers from the educational field express reservations regarding the use of such constructs [7, 8].

However, the popularity of learning and cognitive style theories in user/learner profiling could perhaps be attributed to the fact that the typologies that are derived from these approaches are viable for implementation in hypermedia environments. On

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the contrary, educational and psychological theories that introduce terms such as attention, perception, memory, reading processes, language comprehension, thinking and reasoning [9], are far more complex and profound in order to be mapped in a hypermedia setting.

Even though the entire spectrum of individual differences undoubtedly concludes the aforementioned constructs, learning and cognitive style theories seem to have a predominant role in the area adaptive hypermedia research. The function of these typologies as "…an important interface at the border of personality and cognition" [10] is certainly of importance, but an approach that disregards the rest of the human factors involved in information processing would be inadequate, at least in search of a significant difference.

In search of a model that combines the construct of cognitive style with other human information processing parameters, the authors have introduced a three dimensional model [11]: Cognitive Style, Cognitive Processing Efficiency and Emotional Processing. The first dimension is unitary, whereas Cognitive Processing Efficiency is comprised of (a) Visual Working Memory Span (VWMS) [12] and (b) speed and control of information processing and visual attention [13]. The emotional aspect of the model focuses on different aspects of anxiety [14, 15, 16] and self-regulation.

A corresponding adaptive hypermedia system has been built around this model [17] and there is a continuing process of evaluating our approach and reforming both the theoretical model and the system. This paper presents new results that are gathered from experiments conducted throughout the assessment procedure, in order to clarify at some extent whether such a combination of human factors is of importance in the area of educational adaptive hypermedia.

2 Theoretical background

The rationale behind opting for the parameters that comprise our proposed user profiling model has been thoroughly presented in previous publications [18]. In short, the theories that are involved satisfy the criteria of scientific value and of the possibility to be integrated into a hypermedia system.

Firstly, the use of cognitive rather than learning style is due to the fact that the latter is "a construct that by definition is not stable- it was grounded in process and therefore susceptible to rapid change" [19] Moreover, we are research-wise interested in individual information processing parameters, whereas the social implications of other learning typologies are not examined.

More specifically, Riding and Cheema's Cognitive Style Analysis (CSA) has been opted for. The CSA is derived from a factor analytic approach on previous cognitive style theories, summarizing a number of different yet highly correlated constructs into two distinct independent dimensions [20]. This covers a wide array of the former cognition based style typologies, without going into unnecessary depth- for the needs of hypermedia education that is. The dimensions are the holist/analyst and the imager/verbalizer; the former alters the structure and amount of learner control, while the latter affects the type of resources that are presented to provide the necessary educational information.

As mentioned above, in search of a more coherent approach, the term of working memory [21] has also been introduced as a personalization factor. A brief description of the working memory system is that is consisted of the central executive that controls the two slave systems (visuo-spatial sketchpad and phonological loop), plus the episodic buffer that provides a temporary interface between the slave systems and the Long Term Memory [22]. Due to the visual form of presentation in the web, we have focused especially on the visual working memory [23]. In any case, each individual has a specific and restricted memory span. As to decrease the possibility of cognitive load in hypermedia environments [24], our system takes into account each users' visual working memory span (VWMS), by altering the amount of simultaneously presented information.

In parallel to VWMS, a number of other individuals' "cognitive processing efficiency" parameters are also measured. This term refers to "hardware" functions of the brain, based on Demetriou's architecture of the mind [25]. It is not a unitary concept, but an aggregation of learners' abilities: (a) control of processing (refers to the processes that identify and register goal-relevant information and block out dominant or appealing but actually irrelevant information), (b) speed of processing (refers to the maximum speed at which a given mental act may be efficiently executed) and (c) 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).

Lastly, an endeavor to take into account learners' emotional state has been carried out. Our approach is entirely differentiated from affective computing [26], since we have focused exclusively on learners' levels of anxiety and their ability to control their emotions. At this levet, we make use of the term "Emotional Processing", which includes (a) Emotional Arousal, which is the capacity of a human being to sense and experience specific emotional situations- with anxiety [14, 15, 16] as the main indication of emotional arousal, and (b) Emotion Regulation, which is the way that an individual perceives and controls his emotions [27, 28, 29, 30].

The greatest challenge is of course to extract from the abovementioned theories the corresponding implications for an educational hypermedia environment. As it concerns cognitive style and VWMS, such an elaboration is rather explicit. On the other hand, in order to experimentally assess the effect of individuals' cognitive processing efficiency, we necessarily imposed time limitations within the learning process. By manipulating time limits, we examine how learners perform (level of comprehension). Finally, in the ambiguous field of emotions, the aesthetic enhancement of the system was expected to have a positive effect on highly anxious learners.

Therefore, our research questions may be set forth as follows:

i) Does matching online instructional style to users' cognitive style have a significant effect on their performance?
ii) Does providing the right amount of information according to users' VWMS alleviate cognitive overload?
iii) Is users' cognitive processing efficiency related to the available amount of time, with an effect on comprehension and performance?
iv) Is there a correlation between learners' performance and their levels of anxiety and emotional regulation? In that case, is the aesthetic enhancement of the environment any useful?

In order to elucidate the abovementioned issues, we conducted two subsequent experiments in parallel with the development of the system, whilst the assessment methods where derived from the field of experimental psychology. Our efforts were also focused on "translating" our theoretical framework into personalization rules; it should be mentioned that the mapping of such a user profile into a hypermedia system is a complex procedure, due to the non-linearity and the unforeseen interactions of human traits. However, this is the main challenge of our research work- the successful integration of theory into practice in a coherent way.

3 Method

The experimental design in both experiments was a between participants memory posttest. Users created their profiles through a series of psychometric tests, logged into the system, took the online course, and afterwards participated in an on-line exam in order to assess their level of comprehension. Therefore, in all cases the dependent variable was users' score at the memory posttest.

The total number of participants was 219; all of them were students in the Universities of Athens and Cyprus, and their age varied from 17 to 22 with a mean age of 19. About 70% of the participants were female and 30% were male. The academic subject was a computer science course on algorithms, which was chosen because at the departments where the experiments took place students have absolutely no experience or previous knowledge on programming, due to the theoretical orientation of their curriculum. Participation in the experiments was voluntary, but most students were willing to take the course, as an additional help on a very difficult academic subject.

Almost half of the participants received an online course that was personalized to their preferences, whilst the other half received courses that didn't coincide with their profiles. This allocation was quasi-random; each user that logged in was placed in the opposite, from the previous user, group (matched or mismatched).

The first experiment took place at the University of Cyprus, while the second was conducted at the University of Athens. The number of participants in each experiment was 138 and 81 respectively.

3.1 Materials

Cognitive style: Riding's Cognitive Style Analysis, standardized in Greek and implemented in the .NET platform.
Visual Working Memory Span: Visuospatial working memory test [31], firstly developed on the E-prime platform (a software tool for developing psychometrical applications), afterwards implemented in the .NET platform.
Cognitive Processing Efficiency: Speed and accuracy task-based tests that assess control of processing, speed of processing and visual attention. 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) [16].
Application Specific Anxiety: Cassady's Cognitive Test Anxiety scale – 27 items [15].
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

3.2 Personalization rules

A short description of the way that our system adapts to users' preferences is needed in order to provide the reader an insight to our research framework.
(a) Cognitive style: There are two dimensions of users' cognitive style that are mapped in the educational environment: the holist/analyst scale affects the structure, the navigational patterns and the amount of learner control, whereas the imager/verbalizer is related to the textual or graphical representation of information (where possible of course).
(b) VWMS: Each users' visual working memory span is measured and classified. Users that have low levels of VWMS receive segmented content that is unfolded gradually. The main idea is to alleviate the possibility of cognitive overload, and is based on the notion that information processing is not sequential but parallel- therefore, the segmentation in clear-cut chunks may assist users' with low VWMS.
(c) Cognitive Processing Efficiency: Since the term efficiency refers mainly to speed, in order to distinguish whether there is a relationship between users' ability and the time required to complete an online course, we set different time limits for each category.
(d) Anxiety: In these first experiments, we were based on the results of the "core" and "application specific" anxiety questionnaires. The measurement of "current" anxiety and "Emotion Regulation" was used for exploratory reasons and for investigating the validity of such constructs- which is beyond the scope of this paper. In any case, if there were high levels of anxiety (on behalf of the user), we provided aesthetical enhancement of the environment and further annotations; in a sense, the aesthetical aspect predominates over functionality (in terms of font size, colours, annotations).

As mentioned above, the matched/mismatched methodology was followed, with the addition of control groups in the case of cognitive style and levels of anxiety (see results). We are still conducting experiments at the same departments with quite the same methodology, in order to improve the effectiveness of the system; these are the first of a series of experiments that provide statistically significant results.

The actual system, the psychometric tests and the course can be reached at http://www3.cs.ucy.ac.cy/adaptiveweb/ .

4 Results

Experiment I

The first experiment focused only on the construct of cognitive style as a personalization factor. Besides users' cognitive style, their VWMS was also included in their profile as a control variable. Participants had either a cognitive style preference or were classified as intermediates (no cognitive style preference). The latter were treated as a control group that has no need for a personalized environment, and received a "baseline" balanced course. The remaining users were randomly allocated to a "matched" or "mismatched" group of learners. If cognitive style is of any importance, these two groups should have statistically significant different scores.

A 3X3 analysis of variance was performed (three groups of cognitive style and three groups of VWMS), since the variance of the dependent variable was homogeneous, in order not only to assess the effect of matching the environment to users' style, but also to control for the effect of VWMS. Indeed, learners that received matched environment (n=53) outperformed mismatched learners (n=61): $F_{(2,137)}$=4.395, p=0.014. There was no main effect of VWMS, or interaction with cognitive style.

Post hoc analysis (see table 1) has demonstrated that the differences actually exist between matched and mismatched learners; intermediates (n=24) do not seem to vary from the former groups, and they are more dispersed. Perhaps in the absence of a cognitive style preference, some other factors mediate their performance in a hypermedia environment. In any case, our next experiment was to shed light on what happens with the rest of our theoretical model.

Dependent Variable: Score %
Tukey HSD

(I) Matched Environment	(J) Matched Environment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Matched	Mismatched	8.74(*)	3.455	.034	.55	16.93
	Intermediate	7.94	4.527	.189	-2.79	18.68
Mismatched	Matched	-8.74(*)	3.455	.034	-16.93	-.55
	Intermediate	-.80	4.433	.982	-11.31	9.72
Intermediate	Matched	-7.94	4.527	.189	-18.68	2.79
	Mismatched	.80	4.433	.982	-9.72	11.31

Based on observed means.
* The mean difference is significant at the .05 level.

Table 1. Post hoc analysis of learners' scores in all three conditions of experiment I

In sum, the argument that personalization on the basis of cognitive style may improve learners' information processing in a hypermedia environment can be supported; those who demonstrate cognitive style preference are indeed benefited. The mean difference of app. 9 points should also be evaluated in relation to the small variation of participants score.

Experiment II

By controlling the cognitive style parameter (environment matched to this preference), users received either matched or mismatched environment in regards to each separate factor of our model (VWMS, cognitive processing efficiency and level of anxiety). In order to distinguish the effects of matching/mismatching each factor, since the distribution of the sample was homogenous, a 2X2X3 analysis of variance was performed; there were three groups of learners in the emotional categorization, since users with low levels of anxiety were treated as a control group. The composition of groups was the following: a) 19 mismatched low VWMS learners, b) 62 matched VWMS learners, c) 42 mismatched CPSE learners, d) 39 matched CPSE learners, e) 29 mismatched anxious learners, f) 22 matched anxious learners and g) 30 participants in the emotional control group.

There was a significant main effect of matching the instructional style to users' VWMS ($F=_{(1,80)}=4.501$, $p=0.037$), and to their levels of anxiety ($F=_{(2,80)}=3.128$, $p=0.05$). Cognitive processing efficiency was not found to have a main effect on score or interaction with the other parameters. The differences in mean scores are demonstrated in Tables 2 and 3.

Dependent Variable: Score %

			95% Confidence Interval	
Match_Emotion	Mean	Std. Error	Lower Bound	Upper Bound
matched	56.250	3.905	48.461	64.039
mismatched	43.107	3.667	35.792	50.421
control	51.826	4.567	42.716	60.936

Table 2. Differences of mean scores in the matched and mismatched condition with regards to users' levels of anxiety

Post hoc analysis of the differences between the three anxiety groups has demonstrated that the difference is statistically significant between matched and mismatched anxious users, with the control group scoring in between.

Dependent Variable: Score %

			95% Confidence Interval	
Match_VWMS	Mean	Std. Error	Lower Bound	Upper Bound
matched	55.372	2.016	51.351	59.393

mismatched	45.417	4.237	36.963	53.780

Table 3. Differences of mean scores in the matched and mismatched condition with regards to users' VWMS

The relatively small sample of the second experiment necessary limits the level of analysis that can be applied. However, it is certainly encouraging the fact that there were found significant differences in learners' scores that can be attributed to the importance of taking into account factors such as those included in our approach; it seems that designing educational hypermedia with such factors left at chance level may hamper the performance of users.

The finding that cognitive processing efficiency didn't affect users' performance may be explained by the fact that there were no real-time tasks involved in our online course; therefore, it would be difficult for this kind of individual differences to be revealed. It is also possible that a different approach to the personalization process or the experimental design could have provided different results.

Our methodology in this first endeavor to investigate the role of these human factors is of course not exhaustive. VWMS has been proven to be of importance as a parameter, and a certain effect of aesthetics has been demonstrated, but further empirical research is undoubtedly required.

5 Discussion and Conclusions

The results that are presented above may provide a good argument for incorporating human factors in educational adaptive hypermedia. More specifically, our research questions were answered as follows: (i) Matching the instructional style to users' cognitive style promotes performance, in the sense of more efficient information processing (ii) segmenting the simultaneously presented information according to learners' VWMS benefits their comprehension (iii) cognitive processing efficiency does not have an effect, nor is related to the amount of available time, and (iv) the aesthetical enhancement of the environment is correlated to the increase of performance of anxious learners.

These findings are quite consistent with the psychological theories that are refereed to in our framework, and it seems that the difficult task of translating these theories into adaptation rules was at some extent successful. The differences in scores are not extreme, but an aggregation of the added values that each human factor has for an educational environment may as well lead to a far more efficient learning procedure. Our next step is the provision of educational environments that are fully adapted or non-personalized (baseline), and the comparison of these two conditions. Our expectations, as demonstrated by the abovementioned findings, is that the differences will be far greater than marginal, also taking under consideration the results of the control groups that were used in some of the conditions of our experiments (see results section).

At this point we should mention that there are several limitations in our study. First of all, the second experiment was conducted with a limited sample. Though it is impressive that it yielded statistically significant results, we are aware that these findings must be repeatedly confirmed. We have already designed and conducted a replication study with a larger sample and we are in the process of analyzing our data-we may for the time being report that the role of VWMS seems to be prominent and highly important.

Secondly, our experiments were conducted within a specific adaptive system, which may as well not be considered as representative of all possible hypermedia applications. The integration of our theories seems to be viable in this specific educational hypermedia system, but it should be nevertheless tested in other e-learning procedures. We have clarified that our interest is on individual information processing differences, and the interaction of these human factors with other parameters (predominantly socially oriented) should be examined.

However, the feedback that this study has provided us is encouraging, and in our opinion there is quite some depth in personalization on individual differences. We certainly not consider our model as a rigorous construct, but as a framework that is driven by experimental research and methodology. The value of this approach for educational hypermedia designers is that the emphasis is placed upon the learner, exclusively on the level of a better understanding of the educational content. Since adaptive technologies offer the possibility of a highly personalized e-learning course, it would be rather obscure to not place users' intrinsic characteristics in the center of such an endeavor.

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