EVALUATING THE SIGNIFICANCE OF COGNITIVE AND EMOTIONAL PARAMETERS IN E-LEARNING ADAPTIVE ENVIRONMENTS

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ABSTRACT

This paper presents experimental evidence supporting the notion that users' individual information processing characteristics are significant in the context of e-learning environments. In the wider field of Adaptive Hypermedia research, we have implemented into our system a three dimension user model (consisted of cognitive and emotional parameters) as the main filter for personalization. Consequently, we conducted an experiment, consisted of two sequential phases, in order to measure the effect of adaptation on the basis of our model (User Perceptual Preferences), in contrast to web learning content that does not suit users' needs and preferences. The dependent variable was performance in an exam procedure, as the main indicator of effective information perception and processing.

KEYWORDS:

E-learning, Adaptive Hypermedia, Cognitive, Affective

1. INTRODUCTION

One of the most important aspects of designing e-learning applications is the integration of educational theories in order to optimize the effectiveness of distant education, as opposed to traditional classroom environments. Designing e-learning applications is not a mere matter of web design, often driven by convenience factors, but requires a holistic pedagogical approach, in correspondence to the needs of different groups of participants.

A well-established framework for classifying the objectives of learning theories is Bloom's taxonomy, which distinguishes three major domains that comprise a comprehensive approach to learning: cognitive, affective and psychomotor [Bloom, 1969]. The notion of cognitive and affective parameters in learning is a key issue in our approach; psychomotor parameters are not easily integrated into e-learning procedures and our beyond the scope of our research.

Therefore, on the basis of a cognitive information processing approach to educational psychology [Santrock, 2006], we propose an information processing model, in the context of the Web, that takes into account cognitive and emotional parameters. Our model [Germanakos et al., 2007a], respectively named User Perceptual Preferences, consists of three dimensions (see fig.1):

- Cognitive Style
- Cognitive Processing Efficiency
- Emotional Processing

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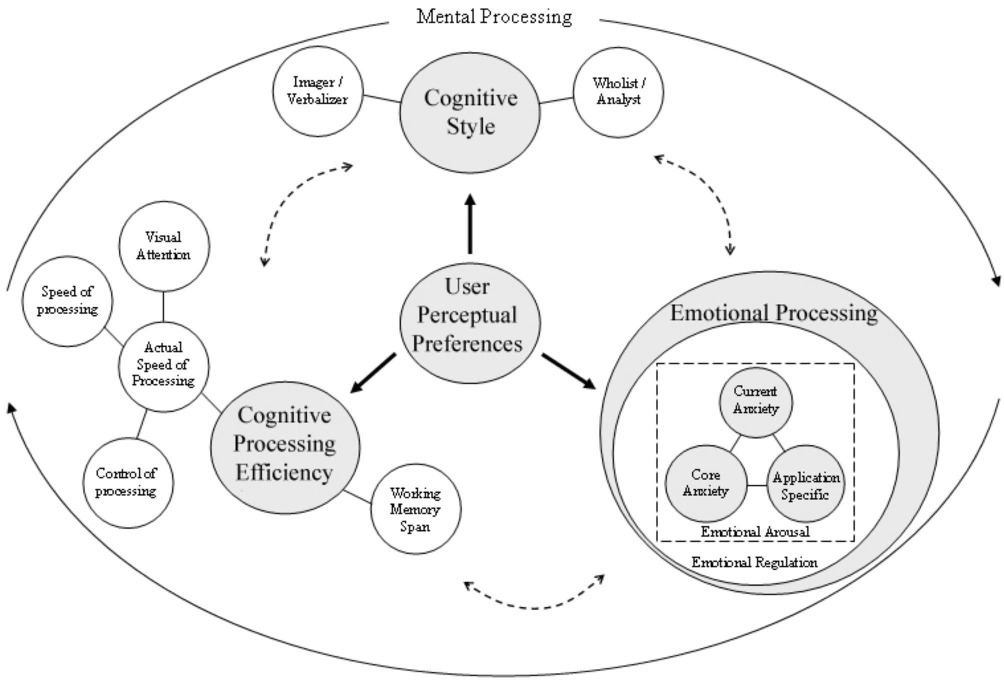

Figure 1. User Perceptual Preferences

The theoretical assumptions and the experimental evaluation that support this model will be discussed later. It should be clarified however that this approach is focused on web-learning, and more precisely on Adaptive Hypermedia.

Naturally, the term of adaptivity is of equal importance in our approach. Adaptivity is a particular system functionality that distinguishes between interactions of different users within the information space [Eklund, & Sinclair, 2000; Brusilovsky & Nejdl,, 2004]. Adaptive Hypermedia Systems employ adaptivity by manipulating the link structure or by altering the presentation of information, on the basis of a dynamic understanding of the individual user, represented in an explicit user model [Brusilovsky, 2001; 1996].

We suggest a user model that benefits from the aforementioned concept of adaptivity, since when referring to information retrieval and processing one cannot disregard the unique top-down individual cognitive processes [Eysenck & Keane, 2005] that significantly affect individuals' interactions within the hyperspace, especially when such processes involve educational or learning, in general, goals. Our aim is to adapt as many as possible aspects of web-learning environments on the basis of these individual User Perceptual Preferences.

Subsequently, we have built an adaptive e-learning system, the Adaptive Web System [Germanakos et al., 2007b] that takes into account users' cognitive and emotional parameters and provides them with information matched to their preferences. We have incorporated an educational platform in the system, seeking to investigate our main research hypotheses:

- Are the cognitive and emotional parameters of our model significantly important in the context of an educational hypermedia application, and
- Does matching the presentation and structure of the information to Users' Perceptual Preferences increase academic performance?

This paper presents aggregated results from the experimental evaluation of our system that are supportive of our approach, in the sense of increasing the level of information comprehension and academic performance by adapting the learning environment to Users' Perceptual Preferences.

2. THEORETICAL BACKGROUND

As illustrated above, our model's primary parameters formulate a three-dimensional approach to the problem of building a user model that takes into account cognitive and affective parameters. The first dimension investigates users' cognitive style, the second their visual and cognitive processing efficiency, while the third captures their emotional processing during the interaction process with the information space.

2.1 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…" [McKay, Fischler & Dunn, 2003]. Amongst the numerous proposed cognitive style typologies [Cassidy 2004] we favor Riding's Cognitive Style Analysis [Riding, 2001], because we consider that its implications can be mapped on the information space more precisely, since it is consisted of two distinct scales that respond to different aspects of the Web. The imager/verbalizer axis affects the way information is presented, whilst the wholist/analyst dimension is relevant to the structure of the information and the navigational path of the user. Moreover, it is a very inclusive theory that is derived from a number of pre-existing theories that were recapitulated into these two axises.

We prefer the construct of cognitive rather than learning style because it is more stable [Sadler & Riding, 1999], and to the extent that there is a correlation with hemispherical preference and EEG measurements [Glass & Riding, 1997; McKay, Fischler & Dunn, 2003], the relationship between cognitive style and actual mode of information processing is strengthened.

2.2 Cognitive Processing Efficiency

The cognitive processing parameters [Demetriou et al., 1993; Demetriou & Kazi, 2001] 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. *working memory span* (refers to the processes that enable a person to hold information in an active state while integrating it with other information until the current problem is solved)
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 [Baddeley, 1992], since all information in the web is mainly visual.

2.3 Emotional Processing

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 that an individual perceives and controls his emotions.

We have deliberately focused on anxiety, as the main indicator of emotional arousal, because it is correlated with academic performance [Cassady, 2004], as well as with performance in computer mediated learning procedures [Smith & Caputi, 2007; Chang, 2005]. We measure users' trait anxiety [Spielberger, 1983], their "application specific" anxiety, which in the case of e-learning is Cognitive Test Anxiety [Cassady & Johnson, 2002] and their self-reported state-anxiety levels. Including these different measurements in user profiling provides us with more precise information about users' levels of anxiety, which in general is not easily expressed explicitly.

The construct of emotional regulation that we have used includes the concepts of Emotional Control (self-awareness, emotional management, self-motivation) [Salovey & Mayer 1990; Goleman, 1995], Self – Efficacy [Bandura, 1994], Emotional experience and Emotional Expression [Halberstadt, 2005]. By combining the levels of Anxiety with the moderating role of Emotion regulation, it is possible to examine how affectional responses hamper or promote learning procedures [Lekkas et al, 07].

From a systemic point of view, these cognitive and emotional parameters have been integrated into our AdaptiveWeb system, making adaptation on each individual's preferences possible. The implications of theory on the information space (on the web content and structure) and the adaptive mechanisms have been discussed on our previous publications, and are beyond the scope of this paper.

3. EVALUATION

3.1 Method

The experiment consisted of two distinct phases: phase I was conducted at the University of Cyprus, while phase II was conducted at the University of Athens. The aim of the first experiment was to clarify whether matching (or mismatching) instructional style to users' cognitive style improves performance. The second experiment focused on the importance of matching instructional style to the remaining parameters of our model (working memory, cognitive processing efficiency, emotional processing).

3.2 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 on computer science, and traditionally perform poorly. By controlling the factor of experience in that way, we divided our sample in two groups: almost half of the participants were provided with information matched to their Perceptual Preferences, while the other half were taught in a mismatched way. 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 (see table 1).

Table 1. Implications for matched/mismatched conditions

	Cognitive Style	**Working Memory**	**Cognitive Processing Speed Efficiency**	**Emotional Processing**
Matched Condition	Presentation and structure of information matches user's preference	Low Working Memory users are provided with segmented information	Each user has in his disposal the amount of time that fits his ability	Users with moderate and high levels of anxiety receive aesthetic enhancement of the content and navigational help
Mismatched Condition	Presentation and structure of information does not coincide with user's preference	Low Working Memory users are provided with the whole information	Users' available amount of time does not coincide with their ability	Users with moderate and high levels of anxiety receive no additional help or aesthetics

3.3 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 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) [Spielberger, 1983].
- ***Application Specific Anxiety***: Cassady's Cognitive Test Anxiety scale – 27 items [Cassady & Johnson, 2002].
- ***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.

4. RESULTS

As expected, in both experiments the matched condition group outperformed those of the mismatched group. Figure 2 displays the aggregated differences in performance (the dependent variable of exam score), in matched and mismatched conditions.

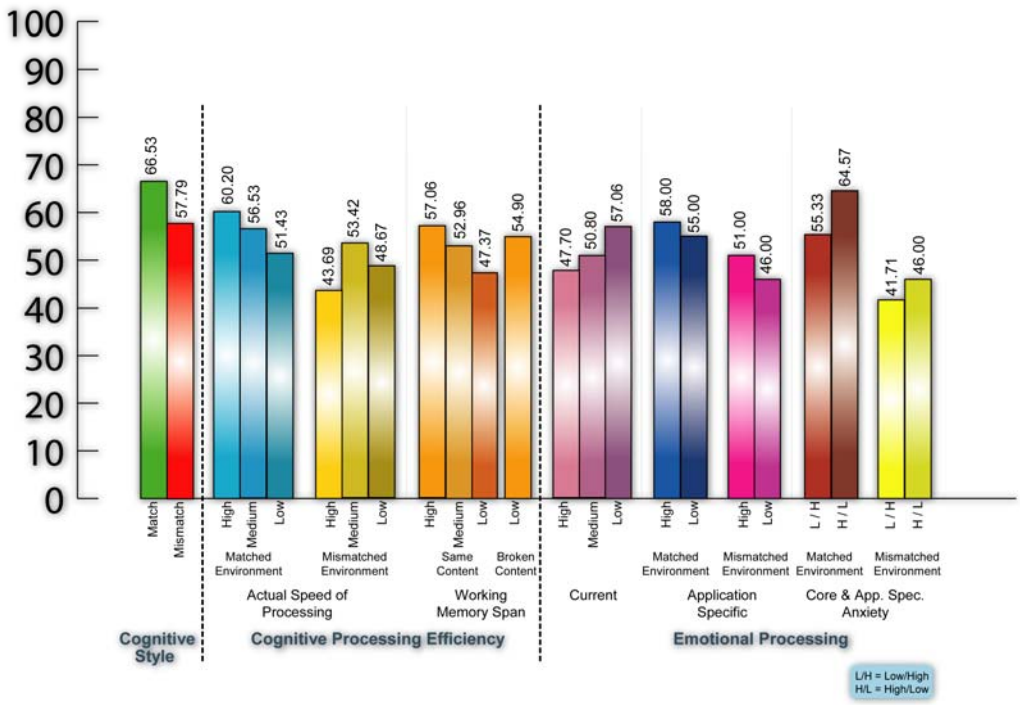

Figure 2. Aggregated differences in matched/mismatch condition

Table 2 shows the differences of means (one way ANOVA) and their statistical significance for the parameters of Cognitive Style, Cognitive Efficiency Speed, and Emotional Processing.

Table 2. Differences of means in the matched/mismatched condition for Cognitive Style and Cognitive Efficiency Speed

	Match Score	Match n	Mismatch Score	Mismatch n	F	Sig.
Cognitive Style	66.53%	53	57.79%	61	6.330	0.013
Cognitive Efficiency Speed	57.00%	41	48.93%	41	5.345	0.023
Emotional Processing	57.91%	23	48.45%	29	4.357	0.042

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. Though we have referred above to the construct of Emotional Regulation and the Self-Report tool, which have both shown statistically significant correlation (negative and positive respectively) to anxiety, such an analysis is beyond the scope of this paper.

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).

5. DISCUSSION

Our results show that it is possible to increase academic performance by taking into account cognitive and emotional parameters within the context of web-learning. Research in Adaptive Hypermedia often focuses on a single aspect of individual differences (such as learning style), resulting in limited effects on academic performance. However, the combination of multiple individual differences and emotional parameters in a comprehensive user model may promote effective learning, regardless of specific users' preferences and abilities, ensuring the success of e-learning environments.

Also, our proposed model seems to cover a wide area of human factors that are proven significant in computer mediated learning procedures, and may provide a basis for meaningful personalization. Cognitive style is certainly of high importance, cognitive processing efficiency and Working Memory have an impact on the web environment, and anxiety (as the main component of Emotional Processing) can be manipulated for optimization of performance.

There are of course limitations in our approach, mainly due to the nature of the web content that often limits radically differentiated adaptation, and the psychometric challenges of measuring a wide spectrum of human cognition and emotionality. The relationship between different dimensions of the model must be further investigated, and an experiment focused on the effect of working memory must be conducted.

Our future work includes the incorporation of physiological measurements of emotions and anxiety in our model, with the use of biometrical sensors. Moreover, an eyetracker will be used to clarify the role of Visual Attention in web learning environments.

Finally, we are in the process of applying our model on web information other than learning, in order to examine whether these parameters can be proven equally important in web content such as news portals, e-commerce, e-services and mobile services.

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