Integrating Cognitive and Emotional Parameters into Designing Adaptive Hypermedia Environments

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Abstract
This paper introduces a “new” user profiling model in the field of adaptive hypermedia, which integrates cognitive and emotional parameters, in particular (but not exclusively) when information perception and processing are involved in a Web-based learning environment. The proposed model combines theories from the field of cognitive psychology, applying them on Web-based interactions, in order to improve learning performance and, most importantly, to personalize Web-content to users’ needs and preferences, eradicating known difficulties that occur in a “one size fits all” approach. The specific article emphasizes on the emotional aspect of our model, since it presents results of our efforts to measure and include Emotional Control parameters, by re-constructing a theory that addresses emotion and is feasible in Web- learning environments.

Introduction
One of the main challenges in Adaptive Hypermedia research is alleviating users’ orientation difficulties, as well as making appropriate selection of knowledge resources, since the vastness of the hyperspace has made information retrieval a rather complicated task (De Bra, Aroyo, Chepigin, 2004).

Adaptivity is a particular 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).

A system can be classified as an Adaptive Hypermedia System if it is based on hypermedia, has an explicit user model representing certain characteristics of the user, has a domain model which is a set of relationships between knowledge elements in the information space, and is capable of modifying some visible or functional parts of the system, based on the information maintained in the user model (Brusilovsky, 2001; 1996; Brusilovsky & Nejdl, 2004).

In further support of the aforementioned concept of adaptivity, when referring to information retrieval and processing, one cannot disregard the top-down individual cognitive processes (Eysenck & Keane, 2005), that significantly affect users’ interactions within the hyperspace, especially when such interactions involve educational or learning, in general, goals.

Consequently, besides “traditional” demographic characteristics that commonly comprise the user model in hypermedia environments, we believe that a user model that incorporates individual cognitive characteristics and triggers corresponding mechanisms of adaptivity, increases the effectiveness of Web- applications that involve learning processes.

The goal of our research in general is to integrate individual cognitive and emotional characteristics as main parameters in an adaptive system we have already developed. Our system focuses on educational purposes, and its personalization mechanism relies on mapping the provided content on each user’s preferences and inclinations.

This paper focuses on emotional factors that we hypothesize to be proven significant in defining usability and aesthetics aspects, taking into consideration psychometric challenges, as well as the complicated matter of quantifying and subsequently mapping emotions on a hypermedia environment.

At a first level, we have experimented with two variables that we expect to correlate with each other, anxiety and Emotional Control. Our main hypothesis is that the moderating role of Emotional Control reduces the negative effect of high levels of anxiety, and should be taken into account in an adaptive e-learning process.

User Perceptual Preference Characteristics
This is the new component / dimension of the user profiling defined above. It contains visual attention and cognitive processes (including emotional parameters) 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.

This model’s primary parameters formulate a three-dimensional approach to the problem. The first dimension investigates the visual and cognitive processing of the user,
the second his / her learning style, while the third captures his / her emotionality during the interaction process with the information space.

Visual & Cognitive Processing

Special emphasis is given to visual attention, in the sense of tracking user’s eye movements, and in particular scanning his / her eye gaze on the information environment (Gulliver & Ghinea, 2004). It is composed of two serial phases: the pre-attentive and the limited-capacity stage. The pre-attentive stage of vision subconsciously defines objects from visual primitives, such as lines, curvature, orientation, color and motion and allows definition of objects in the visual field. When items pass from the pre-attentive stage to the limited-capacity stage, these items are considered as selected. Interpretation of eye movement data is 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.

Cognitive Processing parameters could be primarily summarised in (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 (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). Many researchers (Demetriou et al., 1993; Demetriou & Kazi, 2001) have identified that the speed of cognitive processing and control of its processing is directly related to human age, as well as to continuous exercise and experience, with the former to be the primary indicator. Therefore, the processing development speed decreases non-linearly at the ages between 0 – 15 (1500 msec), it is further stabilized at the ages between 15 - 55-60 (500 msec) and increases from that age on (1500 msec). However, it should be stated that the actual cognitive processing speed efficiency is yielded from the difference (maximum value 0.8 msec) between the peak value of the speed of processing and the peak value of control of processing.

Learning Styles

Learning styles represent a particular set of strengths and preferences that an individual or group of people exhibit when they perceive and process information. By taking into account these preferences and defining specific learning strategies (in our case by mechanisms of adaptation), empirical research has shown that more effective learning can be achieved (Boyle et al., 2003), and that learning styles correlate with academic achievement in an e-learning web-based environment [Wang et al., 2006].

A selection of the most appropriate and technologically feasible 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 in order to identify how users transforms information into knowledge (constructing new cognitive frames):

- Felder / Silverman Index of Learning Styles [4 scales: Active vs Reflective, Sensing vs Intuitive, visual vs Verbal and Global vs Sequential] (Felder & Silverman, 1988).
- Witkin’s Field Dependency [Field-Dependent vs Field-Independent] (Witkin et al., 1977).
- Kolb’s Learning Styles [Converger, Diverger, Accommodator and Assimilator] (Kolb & Kolb, 2005).

We consider that Riding’s CSA and Felder / Silverman’s ILS implications can be mapped on the information space more precisely, since they are consisted of distinct scales that respond to different aspects of the Web.

Learning style theories that define specific types of learners, as Kolb’s Experiential Learning Theory, have far more complex implications, since they relate strongly with personality theories, and therefore cannot be adequately quantified and correlated easily with Web objects and structures.

As part of our research, we did find significant correlation between academic performance and adaptation on specific learning style (Tsianos et al, 2005), though we now work on implementing Riding’s typology implications in hypermedia applications, rather than Felder’s that we first used.

Emotionality

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 (Kort & Reilly, 2002). Emotional Intelligence seems to be a possible predictor of the aforementioned concepts, and is a grounded enough construct, already supported by academic literature.

On the basis of the research conducted by Goleman (1995), as well as Salovey & Mayer (1990), who have introduced the term, we are in the process of developing an EQ questionnaire that examines the 3 out of 5 scales that comprise the Emotional Intelligence construct (according to Goleman), since factors that deal with human to human interaction (like empathy) are not present in our Web-applications - at least for the time being.

As a result, our variation of the EQ construct, which we refer to as Emotional Control, consists of:

- The Self- Awareness scale
- The Emotional Management scale
- The Self-Motivation scale

While our sample is still growing, Cronbach’s alpha, which indicates scale reliability, is currently 0.756. Revisions on the questionnaire are expected to increase reliability.

Still, there is a question about the role of primary / secondary emotions, and their cognitive and / or neurophysiologic intrinsic origins (Damasio, 1994). Emotions influence the cognitive processes of the individual, and therefore have certain effect in any educational setting. Again, bibliographic research has shown that anxiety is often correlated with academic performance (Cassady, 2004), as well with performance in computer mediated learning procedures (Smith & Caputi, 2005; Chang, 2005). Subsequently, different levels of anxiety should have also a significant effect in cognitive functions.

We believe that combining the level of anxiety of an individual with the moderating role of Emotional Control, it is possible to clarify, at some extent, how affectional responses of the individual hamper or promote learning procedures. Thus, by personalizing on this concept of emotionality the educational content that our already developed adaptive system provides, we can avoid stressful instances and take full advantage of his / hers cognitive capacity at any time.

At a practical level, we assume that users with high anxiety levels lacking the moderating role of Emotional Control are in a greater need of enhancing the aesthetic aspects of our system, while users with low anxiety levels focus more on usability issues.

This is why we are interested in clarifying the relationship between the construct of Emotional Control and anxiety, and if a typology could be extracted.

There are two ways to measure anxiety. Firstly, with anxiety questionnaires, many of them dealing with anxiety at educational settings, providing information about how an individual reacts when is obliged to learn or to go through exams (cognitive test anxiety).

Still, since we are interested also in his emotional state during the Web-based learning procedures, real-time monitoring of anxiety levels would also provide us useful indications. That can be done by a self-reporting instrument (e.g. by giving the user the possibility to define his anxiety level on a bar shown on the computer screen), and / or by specially designed gadgets that measure heart rate, sweat and other physical evidence.

We intend to use all these methods of measurement, as the main direction of our future work, controlling at the same time confounding or correlated variables like verbal ability (or IQ), in an effort to ground our hypothesis that personalizing web content according to the participants emotional characteristics (an individual’s capability or incapability to control his / hers emotions and use anxiety in a constructing way), is of high significance in optimizing computer mediated learning processes.

Incorporating Emotional Intelligence and Anxiety in User Modeling

At the time being, we used a battery of questionnaires to clarify and shape the aforementioned typologies, intending to enhance our adaptive educational hypermedia environment by incorporating all aspects of the proposed user model. In terms of emotionality, the instruments we have used are a standardized (in greek) version of Cassady & Johnson’s Cognitive Test Anxiety Scale (2002), and the Emotional Control questionnaire which consists of the three sub-scales we mentioned above.

These questionnaires, as all tests involved in our proposed method of user profiling, are taken on-line within the context of our adaptive web system. The reason that we use questionnaires relates strongly to the very nature of Web environments, where psychometric instruments are bound to be presented verbally or graphically and have to be answered in the form of multiple choices, allowing the system to quantify the collected data.

In order to manipulate the parameters of our adaptive system according to user characteristics, our research has to go through the stage of extracting quantified elements that represent deeper psychological and emotional abilities. The latter cannot be directly used in a Web environment, but a numerical equivalent can define a personalization parameter.

After the construction and standardization of our instruments we are currently trying to find the weighting, the importance and the implications of Emotional Control and anxiety, the two basic terms that comprise our emotionality factor. Our main hypothesis is that Emotional Control and anxiety are negatively correlated. It is proposed that an individual with high emotional control will have low anxiety levels because of his ability to control and organize his emotions. The procedure that we followed as a part of the standardization process and our first statistical analyses is the following:

Method
Sampling and data collection: The study was carried out within the University of Athens. All participants are students. They were given a battery of questionnaires and tests covering our three dimensional proposed model. A total of 108 questionnaires were filled and 88 could be used. Twenty of them were half completed or had inadequate answers and were omitted from the sample. Participants varied from the age of 18 to the age of 25, with a mean age of 20. 30% of the respondents were male and 70% were female.

Procedure
The participants were asked to fill in the questionnaires that could be found in the adaptive hypermedia webpage. The
results were kept in a database for easier access and retrieval.

**Questionnaires**
The study used two questionnaires to collect quantitative data. The Emotional Control Questionnaire included three measures, emotional Self-Awareness, Emotional Management and Self-Motivation, and a total of 28 items. The Cognitive Test Anxiety Scale included 26 items. Participants received two questionnaires with 54 questions total and scales from 1 to 5 for all items.

**Design**
Internal consistency was assessed by computing Cronbach alphas for the two questionnaires. Although there are no standard guidelines available on appropriate magnitude for the coefficient, in practice, an alpha greater than 0.60 is considered reasonable in non-clinical research. After the inspection of the alpha's coefficients it was decided that item 13 from the Emotional Control Questionnaire and items 8, 17, 20 from the Cognitive Test Anxiety Questionnaire if removed from the scale could lead to an improved alpha coefficient. Consequently the above items were removed from each scale (see Table 1).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient α</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional Control</td>
<td>0.756</td>
</tr>
<tr>
<td>Cognitive Test Anxiety Scale</td>
<td>0.684</td>
</tr>
</tbody>
</table>

**Table 1: Scale reliabilities for psychometric scales**

Descriptive statistics for the study sample as a whole are provided in Table 2.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>Range Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional Control</td>
<td>3.39</td>
<td>0.38</td>
<td>1-5</td>
</tr>
<tr>
<td>Cognitive Test Anxiety</td>
<td>2.88</td>
<td>0.37</td>
<td>1-5</td>
</tr>
</tbody>
</table>

**Table 2: Means, standard deviation and scale range for Emotional Control and Cognitive Test Anxiety variables**

**Results**
Correlation Analyses (Pearson’s r): For the purposes of the study, correlation analyses were performed in order to indicate the relationships between the variables of the study. For the comparisons between scores Pearson’s r coefficient analyses were used. Table 3 presents the main correlations between the scale emotional control and cognitive test anxiety. The analyses indicated that Emotional Control negatively correlated with Cognitive Test Anxiety (r=-0.261, p<0.05). This finding indicates that as scores in Emotional Control rise, scores in anxiety decrease. High emotional control means lower anxiety levels. This seems to support our hypothesis, although at moderate levels.

**Table 3: Correlation analysis for the variables (Pearson’s r)**

<table>
<thead>
<tr>
<th>Variables</th>
<th>Emotional Control</th>
<th>Cognitive Test Anxiety</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emotional Control</td>
<td>-</td>
<td>-0.261*</td>
</tr>
<tr>
<td>Cognitive Test Anxiety</td>
<td>-0.261*</td>
<td>-</td>
</tr>
</tbody>
</table>

*p<0.05 - Correlation is significant at the 0.05 level (one-tailed).

**Discussion**
More than a technologically driven determinism, adaptive hypermedia provide a very flexible platform for individual differences to be taken into account, and to assess their importance and role in cognitive processes. Still, there is the issue of which users’ characteristics are to comprise the basis of personalization, since it is not yet clarified which cognitive science theories apply to human-computer interaction. Knowing that, we intend to continue conducting experiments involving the aforementioned three-dimensional model, in order to optimize and refine it. We have already built a Web-platform that supports personalizing techniques, and have designed corresponding educational material. The content itself presents a number of challenges, since it must be written as fine-grained as possible, and it must address all possible learning (or cognitive) styles. Our experience has shown that the match/mismatch factor of teaching and learning style is of importance. The issue of Emotionality is under research, since its role and effect on academic performance is yet to be proven. We have some indications that Emotional Control and Anxiety correlate as we hypothesized- still, safe conclusions can be drawn only after we have conducted further experiments within the actual learning environment. The same applies for the Visual Attention and Cognitive Parameters. Nevertheless, our intention is to fine-tune our proposed model, and its equivalent Web-architecture, in order to cover numerous approaches in the field of cognitive studies, always in terms of applicable in hyperspace theories.

**References**