Incorporating Cognitive Styles into Adaptive Multimodal Interfaces

Halima Habieb Mammar (habieb@ictthp.insa-lyon.fr)
Laboratoire d'Interaction Collaborative Télé-enseignement Téléactivités,
Edifice Léonard de VINCI 21 Avenue Jean Capelle INSA de Lyon 69211 Villeurbanne Cedex - FRANCE

Franck Tarpin Bernard (tarpin@gprhp.insa-lyon.fr)
Laboratoire d'Interaction Collaborative Télé-enseignement Téléactivités,
Edifice Léonard de VINCI 21 Avenue Jean Capelle INSA de Lyon 69211 Villeurbanne Cedex - FRANCE

Abstract

Many applications accessible through the web suffer from a noticeable lack of support in adapting the information presentation to users. The way users learn differs from an individual to an other, if not for the same individual from an application to an other one. These individual differences affect the learning style of users. They are classified into 3 categories which are: *affective*, *cognitive* and *physiologic styles*. There is little research to examine how to design adaptive systems based on user's cognitive styles. In this paper, we are focusing on user cognitive styles definition and suggest a technique in the design of an adaptive hypermedia system. We investigate the selection of the output modality that best tailor the user profile.

In section 1 we introduce the problematic of learning from net-structured knowledge then we define the cognitive styles. In section 2, we present the main cognitive styles which are the most mentioned in literature. The taxonomy of these cognitive styles and techniques to assess them are detailed in section3. In the last section, we present the structure of our site and model. We investigate the relationship between the cognitive style and the filtering process of the outcome modalities. For the development of the system, we have chosen the two technologies : XML and ASP.

Introduction

In e-learning systems, the user is confronted to lessons, exercises, games... which, on the one hand are relevant to his/her needs and preferences i.e. educational level, domain knowledge (expert or novice) but which, on the other hand, do not take into account his/her abilities for assimilation, memorization, etc. which are parts of the cognitive abilities (Lemaire, 1999). In some cases, the learner gives up the game or the exercise because of the frequent situations of defeats. In other cases, he/she tries hard to make his/her best in order to avoid these situations which overload his/her abilities. The aim of our project consists in developing an adaptive multimodal interfaces where individual cognitive styles are considered. Indeed, the adaptation process deals with the estimation of the document combination (in other word, the multimodal interface) which is the most compatible with the cognitive profile.

In the following sections, we present our site then we define the term "cognitive styles", assess the main styles encountered in literature then discuss the taxonomy of ways employed to measure the cognitive style. Later in section 4, we describe the functionalities of our site and the model we adopted to establish the relationship between the cognitive style and the filtering process of the outcome modalities.

Our Site

In collaboration with the society SBT, we work on an interactive web site for a supervised cognitive training (www.happyneuron.com). During each training session (i.e. each connection), the user executes a set of exercises that the system suggests. Presented into a playful and cultural dimension, the exercises vary in difficulty's level, speed… in order to entertain the user (Habieb-Mammar et al, 2001).

A database stores normalized data (means and standard deviations) for each variant of exercise and family of population distinguishing gender, level of education and age (Tarpin-Bernard et al, 2001). The current statistics show that since the web site has been opened to the public, the number of performed exercises exceeds 400.000. Comparing the trainee's results and the normalized data we progressively build his/her cognitive profile. Thanks to it, the system advises the elderly user in the choice of exercises.

In this context, we built an evaluation module composed of ten precise exercises that allows to quickly build a cognitive profile. Then, this profile, which is quite stable, can be used in very different context. Our first purpose is to elaborate an adaptive multimedia course on the brain. Depending on one's profile, the lesson will be presented using the most adapted medias.

Before describing the relationship between cognitive styles and interactive styles let start with the definition of these cognitive styles and the methods of their assessment.

What are Cognitive Styles?

Cognitive styles refer to a person's habitual, prevalent, or preferred mode of perceiving, memorizing, learning, judging, decision-making, problem-solving (Dufresne, 1997).

Individual differences about how people carry out tasks involving these functions may constitute a style if they appear to be: pervasive, which means that they emerge consistently in different contexts, independently of the particular features of situation; or stable, that is, they are always the same at different times.

They are one of the most stable user characteristics overtime (Dufresne, 1997). they are consistent across a variety of situations, as opposed to user knowledge or experience that are more specific and evolving . Many research have shown the importance of cognitive styles in the area of HCI and their implication in the interface design (Muylwijk et al, 1983).

Cognitive styles induce persons to adopt similar attitudes and behaviors in a variety of domains they concern (Daniels, 1996). Cognitive styles are important in determining the most effective interface for a particular category of user, especially in the formative stages of an interaction (Fowler et al, 1985).

They can be conceptualized as a cross-road of thinking, personality, and motivation. In fact they concern the kind of strategies which an individual tends to apply when he/she faces a situation or the preferred way of processing information.

The Main Cognitive Styles

Field Dependence

The first style we introduce is: field-independent style. People tend to have good analytical and cognitive restructuring skills. They will actively reorganize information according to contextual demands and impose structure when necessary according to their experience. They are likely to form a mental model of the situation before proceeding with their task. Field-independent people seem to follow more easily a restructuring approach and use internal referents in other situations (Antonietti et al, 2000).

Field-dependent people tend to adopt a passive approach in learning and problem solving. They prefer to be guided and to rely on external referents. Perception is dominated by the prevailing field.

When internal referents are less available, field dependent people are more likely to respond to the dominant properties of the field as given.

Lesser use of restructuring may handicap field dependent people in unstructured situations. field dependent people may need more explicit instructions in problem solving strategies or more exact definitions of performance outcome than field independent, who may even perform better when allowed to develop their own strategies (Witkin et al, 1981).

However, the restructuring process occurs only when the field lacks organization. When the material to be learned is presented in an already organized form, so that structuring is not particularly called for, field dependent and field independent people are not likely to differ in their behavior and learning (Antonietti et al, 2000).

In general field independent subjects :

- Perceive objects as separate from the field;
- Can disembed relevant items from non-relevant items within the field;
- Provide structure when it is not inherent in the presented information;
- Reorganize information to provide a context for prior knowledge;
- Tend to be more efficient at retrieving items from memory.

Conversely, field dependent subjects:

- Rely on the surrounding perceptual field;
- Have difficulty attending to, extracting, and using non salient cues;
- Have difficulty providing structure to ambiguous information;
- Have difficulty restructuring new information and forging links with prior knowledge;
- Have difficulty retrieving information from long-term memory.

The test of field dependent-independent subjects is done through several exercises where individual are asked to remember shapes or other types of information whether they where presented in significant context (Fig. 1) or not (Fig. 2) (Tarpin-Bernard et al, 2001).

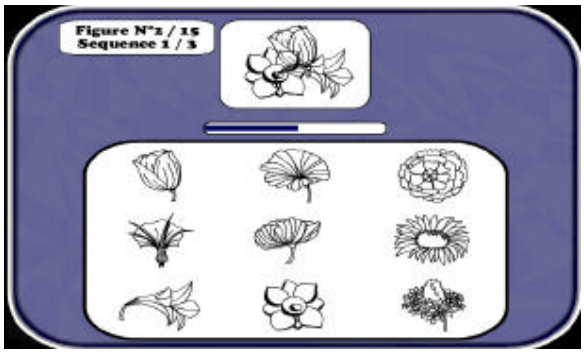

Figure 1: Significant context.

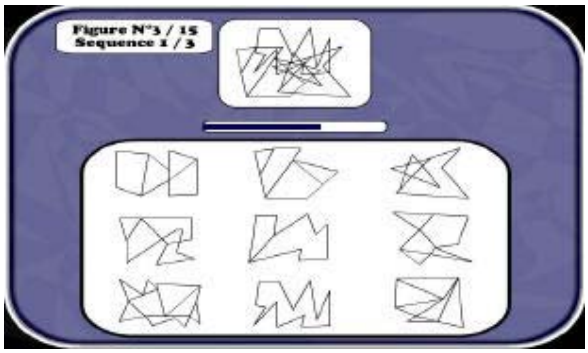

Figure 2: Non-significant context.

Impulsive reflective style

The impulsive subject tends to put forward the first idea that comes to him/her, whereas the reflective subject considers alternatives. This style is generally assessed by measuring differences in decision-making under conditions of uncertainty. Tasks used present several plausible choices, only one of which is correct:

- who responds quickly often errs;
- who pauses to reflect is more often correct.

Fig. 3 is an example of exercise where it is possible to identify one of the following categories:

- *fast-responding/high-error* (FH),
- *fast responding/low-error* (FL);
- *slow-responding/high-error* (SH);
- *slow-responding/low-error* (SL).

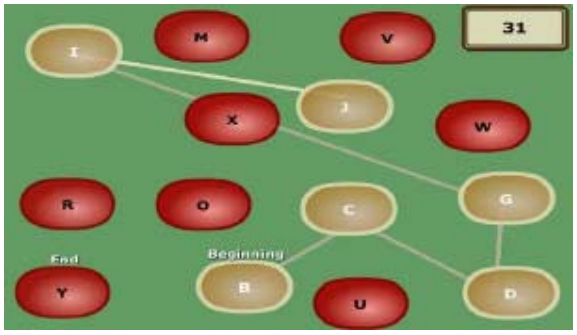

Figure 3 Exercise type for impulsive reflective identification.

Categorization style

Other individual differences consist in giving a number of objects and asking subjects to sort them into categories. Some individuals place objects into a wide number of small categories, so that each category contains only objects sharing a high number of similar features; other individuals place objects into a small number of wide categories which include items with few common features. Other individuals may group objects into different categorization where the criteria are not only the width:

- *analytic-descriptive style* induces to include in the same category items showing surface physical-perceptual similarities;
- *conceptual-inferential style* induces to define categories on the basis of similarities in objects' functions;
- *thematic-relational style* induces to include in the same category disparate objects which have in common only the fact that they occur in the same action or situation.

Figure (Fig.4) shows an exercise where subjects are invited to sort objects into categories suggested by the supervisor. Firstly, the users select the category then they sort object into this category.

Figure 4 Exercise type for the category identification

Analytic-global style

The last style we consider is the analytic-global style which refer to either considering the details of a situation or the whole picture (Euzeby, 1999). Analytic individuals have a focused attention, an interest in operations and procedures or the 'proper' ways of doing things and prefer step-by-step schemes; their thinking is controlled and consciously directed. Global persons tend toward scanning, leading to form overall impressions, including entry of feelings into decisions; their organizational schemes involve random or multiple accessibility of components and varied associations between them.

Some tests in cognitive styles analysis (Riding and Rayner, 1998) allow to measure the analytic dimension by presenting items each comprising a simple geometrical shape and a complex figure and by asking to indicate whether or not the simple shape is contained in the complex figure.

How do we Assess Cognitive styles?

Three main kinds of data can be employed to measure cognitive styles: behavioral, self-report, and physiological (Antonietti & Giorgetti, 1998)

Behavioral data can be obtained by recording the final result of a given task or the procedure followed in performing the task. The task may consist in filling out a paper-and-pencil test or a sorting test, in carrying out trials by means of an experimental apparatus, or in interacting with the computer like during exercise running (Tarpin-Bernard et al., 2001). For an example, to assess whether a person is a visualizer or a verbalizer, it is possible to present him/her with tasks which can be performed through both visual and verbal strategies and to record the extent to which each of the two kinds of procedures has been followed.

Self-reports require that people evaluate themselves by describing by introspective manner the way in which they performed tasks, by checking personal habits or preferences, or by endorsing statements about what they think of themselves. This may be done, for example, by asking subjects to keep a diary of what occurred to them during a period of their life, by interviewing them, or by adopting questionnaires.

The following example is given by Antonietti (Antonietti & Giorgetti, 1998):

In order to understand how much an individual tends to visualize, he/she can be requested to keep a record of the times in which he/she has experienced imagery during the day. Information of this kind may be derived also through questionnaires in which people are asked to rate how frequently they create and process various kinds of mental images. These instruments incite subjects to consider their habitual modes of thinking as they emerge in the complete range of mental activities and to assess the occurrence of visual images in different tasks, domains, contexts, and so on.

Finally, some physiological measures can be interpreted as indices of particular cognitive preferences in processing stimuli. Indeed, Physiological measures observations have indicated that when someone is asked a question requiring a little thought the eyes make an initial movement to the left or right. Since it was argued that the right cerebral hemisphere is associated with the processing of visual information and that the spontaneous lateral eye movements are under the control of the counter-lateral hemisphere, it was claimed that the presentation of a visual-spatial question produces the activation of the right hemisphere and, consequently, left lateral eye movements. However, verbalizers should turn their eyes consistently to the right and visualizers to the left, whatever the kind of question. Thus, it has been suggested to use lateral eye movements as a criterion to assess the preference for either a visual or a verbal processing.

Relationship Between Cognitive Styles and Interaction Styles

The most important components of HappyNeuron's technology are structured as follows (Fig.)5 :

First stage: User's profile generation process (Tarpin-Bernard et al, 2001)

- Questionnaire;
- Exercises;
- Supervision process;
- Cognitive styles
- User profile;

Second stage: Adaptation process

- Compatibility matrix;
- User profile;
- XML (eXtensible Markup Language) documents (multimodal documents);
  - Text;
  - Image or graphics;
  - Sound;
  - Video.
- Stylesheet;

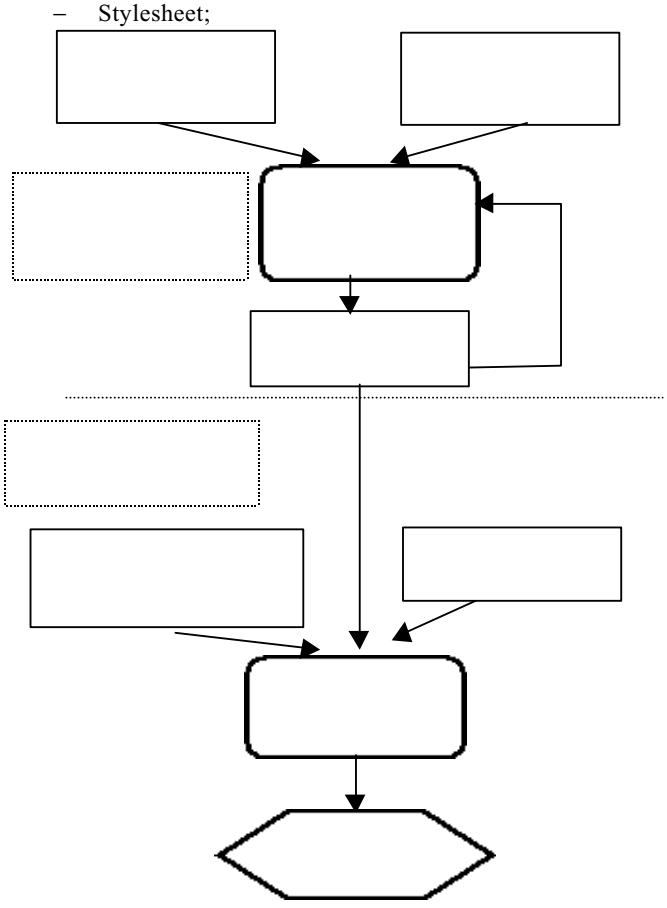

Figure 5: User profile generation and adaptation process

User's profile generation process

The user's profile generation process consists on the one hand in executing interactive exercises then constructing the user cognitive profile. On the other hand, it deals with other user's behavior such as the time to run an exercise, performance variations for the same exercise type, etc. This indicators are adjusted with each other and constitute the final user profile (Fig. 6).

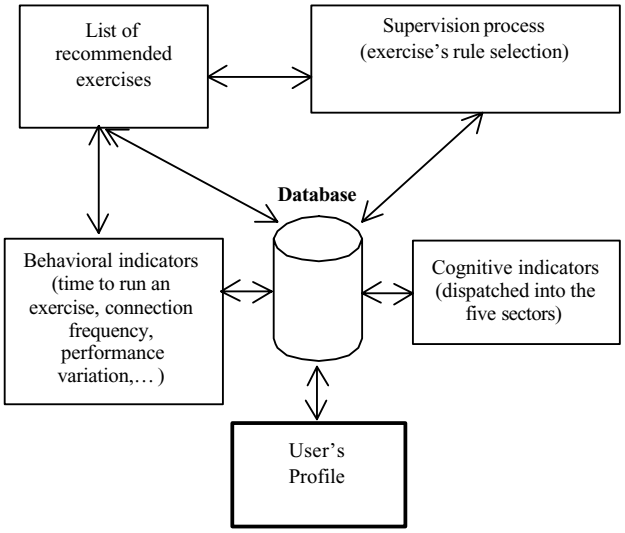

Figure 6:The user's profile generation process

During each training session, the supervisor suggests a set of three or four exercises. The user can also select other exercises in the complete list. At any moment, the system gives users feedback about their progression and enables them to:

- check their performance by consulting *the profile performance* page,
- have a summary of the exercises they have already done,
- browse some documents (news, forums,…).

Thus, the main components of the output profile are:

1- Cognitive indicators dispatched into 5 sectors: *memory, attention, executive functions, language and visual and spatial capacities* [Tarpin-Bernard et al, 2001]. In total, 25 indicators have been determined, we can mention several of them as an illustration: cultural memory, old personal memory, recent memory (verbal, visual or musical), working memory and short term memory with the tree modalities, lexical spelling, categorization, comprehension, arithmetic, planning, reasoning, mental imagery, form recognition, etc ;

2- Behavioral indicators (time during exercise running, connection frequency, etc.);

3- Indicators revealing some characteristics of styles such as field dependent or independent.

These indicators are affected with some weightings and contribute in the adaptation process. For example to determine whether the subject is field dependent or independent, we use the indicator which measures the difference in performance after running the same exercise with two different images (the first with significant context and the second with non-significant context) then we adjust it with other cognitive indicators such as recent memory (verbal, visual or musical) and comprehension.

Adaptive Process

As described in figure 5, the training process yields a user profile which constitutes the input data for the adaptation process. Indeed, this profile enables the selection of the outcomes style sheets. The multimodal document is defined into an XML document.

Prior to any process, each style sheet contains the layout of a complete page to be presented. For a specific subject, the final layout of this page is brought through the adaptive process. This page is the most compatible one to the user profile.

To illustrate the adaptive process, we give hereafter an example of a page to be presented dealing with the following subject : "The main parts of a language : the vocabulary and the syntax". In the XML document, the page falls under 2 elements. Each one could be presented according to different modalities. (Fig.7).

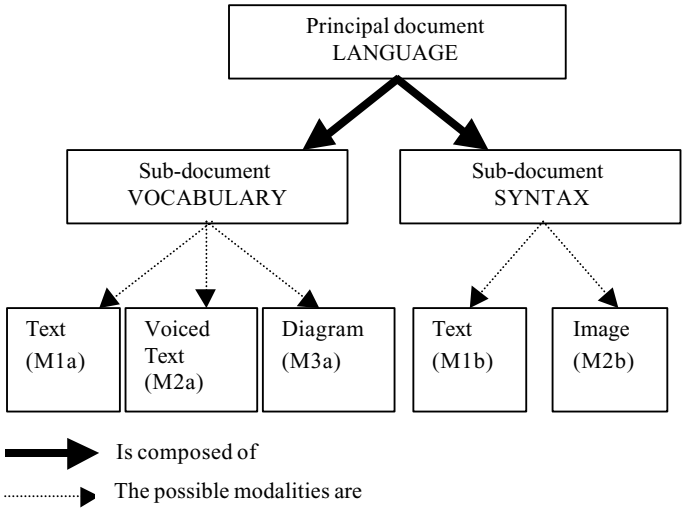

Figure 7: XML document structure

The problem is to find the "best" combination of modalities according to the willing of the designer and the abilities of the reader. According to the XML structure, the possible combinations are: (M1a, M1b), (M1a, M2b), (M2a, M3a, M1b), etc. Then, we can build