Personality-Aware Interfaces for Learning Applications

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ABSTRACT

Although several personalization features are included in the design of e-learning applications, both the personality and the cognitive requirements of the users are among the last characteristics that are considered. As a result, almost all software usually present contents in exactly the same fashion to all users, without taking into account their different attitudes. Conversely, cognitive theories declare that the learning process can be improved by tailoring the way in which information is conveyed. Unfortunately, many parameters have to be considered to obtain reliable results, and processing personality is computationally expensive. In this study, we introduce a light-weight framework for eliciting personality traits and translating them into user interface characteristics which adapt on-line to the diverse learning styles. Our system recognizes the heterogeneity of cognitive requirements, and simultaneously segments user populations accordingly. Also, a personality-aware interface automatically reconfigures its information presentation layer in real-time, accommodating the character traits acquired from the users, to improve the learning performance. We evaluated the bi-directional relationship between personality and interface in the context of web-based e-learning software for customer management services. Our experimental study focused on the mutual influence between the organization of the information presentation layer and the cognitive attitude of the users. Results show that, by choosing the appropriate parameters and by tuning the interface accordingly, the learning curve can be reshaped so that the time required to learn both the application features and the content can be shortened by approximately 30%.

Categories and Subject Descriptors

H.5.4 [**Information Interfaces and Presentation**]: Hypertext/Hypermedia – a*rchitectures, navigation, theory, user issues.*

General Terms

Design, Experimentation, Human Factors, Performance.

Keywords

Experiential Learning Theory, Learning style, Visual Auditory Kinesthetic, Web-Based Educational System, Learning Object.

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1. INTRODUCTION

The prerequisite for designing usable user interfaces is the deep knowledge of the different characteristics of final users. However, traditionally, both software engineers and application programmers aimed at standardizing the development process, including the design of the Graphical User Interface (GUI).

Recently, thanks to the contribution of Human-Computer Interaction (HCI), the study of users' characteristics was introduced as one of the key aspects in software development. As a result, nowadays the attention to diversity among individuals is increasing, and Human-Centered Design has emerged as a crucial discipline. One step forward, the Participatory Design [1] methodology proactively includes potential users in project teams, from the beginning of the process, as if they were developers. Conversely, Software Shaping Workshops [2] have been conceived to provide final users with tools that allow them to customize the interface of the product according to their specific needs, once it has been released (reactively). Depending on the type of application, many personalization options are available; usually software also have tailoring tools which translate (either implicitly or explicitly) users' preferences into features that render interaction more spontaneous, increasing productivity. Moreover, the look and feel of almost all GUIs can be changed at run time, without any modification to the application code. As a result, current software has multiple user interfaces.

Nonetheless, of all the characteristics included in the design, users' personalities are among the last, or it is not addressed at all. Although it is incorporated in a few applications, this type of requirement is implemented by programmers through formal specification of individual features; user profiles are either configured manually or by explicitly setting options in the information presentation layer. Indeed, once released, the number of the degrees of freedom related to possible changes is fixed; the adaptivity of each parameter can vary in a very limited range. As a result, usually almost all software present contents in exactly the same fashion to all users, without taking into account their attitudes [3]. Despite the incredible amount of effort spent in customizing higher-level interaction dynamics, there is still a substantial lack of attention to the inherent cognitive heterogeneity within the different psychological profiles of users.

In this paper, we focus on the design of adaptive learning applications, and we introduce a novel approach to user modeling considering perceptual, cognitive, and attitudinal characteristics. We also discuss a strategy for eliciting individuals' preferences using ambiguity as a resource. One experiment is conducted to evaluate

the impact of personality type on the performance of users in the context of web-based e-learning software for customer management services.

2. RELATED WORK

Although in the last decades the scientific community of HCI experts enormously contributed to enhance dialogue with users, there have been few studies on the relationship between personality types and user interfaces. Moreover, most of the studies investigated this aspect in a one-directional fashion: usually, only the influence of users' attitudes on customization was taken into consideration. In contrast, empathic involvement with interfaces was not investigated.

Indeed, there is poor attention to the mutual influence between humans and machines, and to the synchronization dynamics that usually characterize interaction among individuals. A huge amount of work regarded the appearance of applications (e.g., skins and themes) rather than the style of content delivery [4]. In [5], perceived personality of typefaces in text presented onscreen is analyzed, with the aim of establishing the relationship between different font families (e.g., Sans-Serif, Script, Modern) and personality traits perceived by the user, in order to appropriately associate specific font faces to applications.

Adaptive and Intelligent Web-Based Educational System (AIWBES) have been introduced as tools that are able to manipulate information and to generate or assemble contents which accommodate the individual needs of each student [6]. Adaptive Presentation is the most explored technique in the context of Adaptive Hypertext and Hypermedia Systems. Its purpose is to adapt contents to the objectives of students according to the educational goals defined in each user profile. In [7], the authors present a study on the relationship between users' personality and the effectiveness of interfaces in the context of e-learning applications. They employ the Jungian model to distinguish the needs of different human types and they discuss the impact of the style of the information presentation layer on students' performances, showing a significant correlation. The results of studies about e-learning in the domain of Public Administration [8] outline the relationship between attitudinal characteristics extracted from personality tests and the performance obtained from students. They point out that e-learning may be especially suitable for employees, and that it is not necessary for users to be abstract thinkers. Nonetheless, as individuals may differ, it may not be applicable to customer services, and it may not be effective in providing clients with an alternative access to knowledge-bases. In [9], the authors conclude that, as users respond differently to contents and structure, it is convenient to prepare learning material according to students' personality. They also detail how this may improve the performance of learning tasks.

Although several adaptive e-learning systems already contain mechanisms to provide personalized training through differentiated educational materials, interaction profiles are determined prior to any actual interaction with the specific end user. Indeed, there have been too few studies on the relationship between personality and interfaces for e-learning, and further investigation is required. Moreover, the main drawback of the majority of adaptive applications [10] is the presence of a questionnaire for personality assessment. Nevertheless, such self-tests are under criticism because they are based on users' judgments, and consequently, they are prone to errors due to wrong perception of self.

3. PERSONALITY-AWARE E-LEARNING

In the context of conventional learning, the dialogue between teachers and students provides participants with the opportunity of a bidirectional modulation (either voluntary or involuntary) of the interaction style, in compliance with characteristics of the information being delivered. Usually, this approach ensures better performance of both teaching and learning. Contrarily, Learning Management Systems (LMS) rarely exploit the full potential offered by personalization, and they lack tools that achieve a complete user-tutor adaptation in terms of personality and co-development. With respect to this, in Advanced Distributed Learning (ADL) systems, adjustment is one-way only, from the user towards the application. Moreover, in this domain, the concepts of interactivity and adaptivity usually have a different connotation with respect to conventional training; they refer to the functional aspects of software, and to the structural organization of the course, rather than implementing the typical adaptive dynamics of person-to-person teaching. Furthermore, hypermedia published on the Internet (e.g., Wikipedia, HTML encyclopedias) offer a complete freedom of choice, and they give individuals full autonomy. As a result, in most cases, the teaching model is unstructured: it excludes the user, and it gradually leads to a chronic process of exclusion of the traditional preceptor-student approach to learning.

Our work aims at designing applications that are able to automatically adjust their behavior in relation to the mental state of users, changing their interactive attitude and adapting the syntactic structure of the information presentation layer to the semantic needs of the situation. This may allow ADL applications to achieve better performance more quickly. To this end, we designed a light-weight framework that incorporates psychological dimensions of users as a crucial requisite for the reconfiguration of the information presentation layer. As a result, implemented e-learning tools will be able to automatically adjust the teaching style in accordance to the characteristics of users. They will organize contents specifically addressed to learning styles, and they will deliver information through the most appropriate multimedia display.

4. SYSTEM DESIGN

Our personality-aware framework for ADL consists of three components: the Learning Content (i.e. Learning Objects such as texts, videos, animations, presentations, graphics), the Learning Container (i.e., the macroscopic structure of materials and the application itself), and the Learning Manager (i.e., the dynamic component of the system). The former refers to modular informative resources; it includes conventional learning material (either aggregated contents or basic individual elements) marked with metadata containing attributes that describe the specific psychological attributes of their target audience. This is addressed through the cognitive, the perceptual, and the attitudinal dimensions. The Learning Container comprises structures that define the organization of the information presentation layer. It specifies both the high-level requirements of the interaction style and the goals of the course for each psychological dimension being considered. Basically, both the Learning Content and the Learning

Container are static, in the sense that they are conceived as an archive of multimedia documents. On the contrary, the Learning Manager acts as a software agent for filtering contents upon the criteria specified by both the user model and the application designer. It handles the elicitation of individual's personality and manages the reconfiguration of the interface. Figure 1 describes the architecture of the system. In our design, e-learning tools are divided into a premise and a course. The former delivers an introductory overview of the learning resources; it has low informative content. It is a replacement for the conventional psychological assessment: its objective is to offer users a carefully designed ambiguous choice of mutually exclusive material, in order to force them to express their personal attitude. Then, the Learning Manager infers the user's model from the preferences extracted from the premise, and it selects the most appropriate delivery strategy for Learning Content. Finally, it reconfigures the Learning Container to provide each student with a course consisting of information specifically addressed to his learning requirements, and it implements the most suitable presentation style to interact with his personality type. The proposed model has a modular structure, and its logic extends Brusilovsky's structure for adaptive hypermedia [11].

In our framework, metadata play a crucial role as a language to express the semantics of resources, and in identifying both the Learning Content and the Learning Container. They have two main functions: they summarize the characteristics of the documents that are part of the application, and they represent the psychological dimensions of the potential target users for each informative resource. We employ an XML-based language to specify additional information on learning materials and to associate cognitive, perceptual and attitudinal attributes to them. Also, we define a simple syntax to include psychological dimensions into the modular organization of contents, and to represent the constituent atoms of learning units in a structure that can be processed by the Learning Manager. Annotations in the form of tags (see Figure 2) are used to associate a set of attributes to each Learning Content and to the Learning Container using the *Audience* tag. This element, which is also included in the IEEE LTSC Learning Object Metadata (LOM) [12], describes the category of users to which contents are addressed. We use the feature of this tag to specify the *dimensions* that represent the psychological aspects taken into consideration (i.e. cognitive, perceptual, and attitudinal). The tag *measure* identifies the assessment method being used, and the tag *attribute* indicates the specific category within each dimension. Each attribute is represented by a value normalized as a percentage. Also, we employ the Resource Description Framework (RDF) standard as the instrument to describe learning material and to associate it with personality traits. As a result, the design of our system is compatible with the Sharable Content Object Reference Model (SCORM) [13]. In our design, the Learning Container maps the definition of Sharable Content Objects (SCO), as it refers to collections that represent a set of resources addressed to a specific educational goal. Atomic objects that are represented by learning resources (i.e., assets), single or aggregate, constitute Learning Content. However, as the focus of this paper is personality-awareness, further description of both the architecture of the framework and the implementation of the tool for specifying the interface will be detailed in a follow-up paper.

4.1 User model

The challenge of connecting learning behavior to personality consists in finding relationships between learning styles, perceptual preferences and personality types, and to include them in a reference user model. This in turn may be exploited to establish a more effective style of communication to interact with the student. Figure 1 depicts the conceptualization of the psychological dimensions considered for the Learning Container and the Learning Content. As all of them contribute to represent the learner, the user model incorporates such aspects in our design. With respect to the perceptual and the cognitive profiles, several psychological theories were developed, offering many different perspectives on individuals. Although there are several scales based on psychological theories (e.g., multiple intelligences, sensor modality, and information processing dynamics) that specify the different dimensions to be considered, a matching between the various tools is not possible, and thus a standardized comprehensive reference of all theories is unpractical.

For the purpose of our study, we focus on Kolb's Experiential Learning theory [14], which is based on Jung's theory of types, to realize the mapping between personality traits and learning style. In Kolb's theory, learning is a four-stage cyclic process that can be started from any point (see Figure 4). Each stage requires different skills and involves specific features. Kolb's model can be represented on two perpendicular axes: the horizontal (which is the continuum of information processing, and it describes the

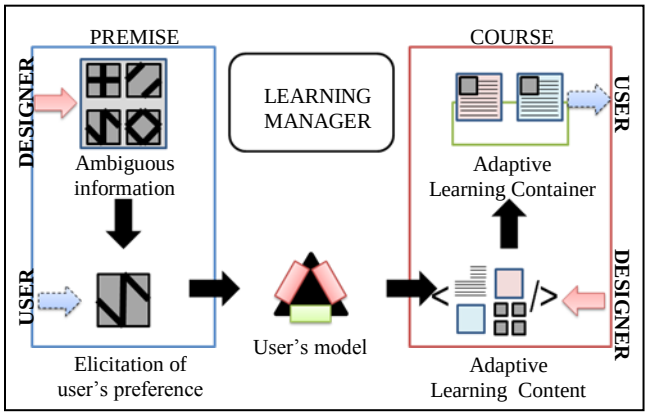

Figure 1. Diagram of personality-aware framework

```
<LO ID="LP_video_04" name="Loan procedure" type="video"
URL="/videos/LP_video_04.flv">
...
<audience ...>
  ...
  <measure dimension="cognitive" type="Kolb">
    <attribute type="Diverger">40</attribute>
    <attribute type="Assimilator">30</attribute>
  </measure>
  <measure dimension="attitudinal" type="MBTI">
    <attribute type="I">-70</attribute>
    <attribute type="N">20</attribute>
    <attribute type="F">-10</attribute>
  </measure>
  <measure dimension="perceptual" type="VAK">
    <attribute type="V">90</attribute>
  </measure>
  ...
</audience>
...
</LO>
```

Figure 2. Metadata representation of personality-aware LO

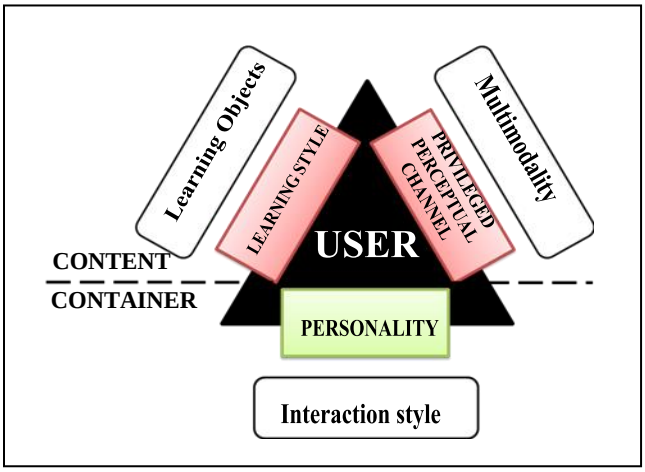

Figure 3. Psychological dimensions in the user model

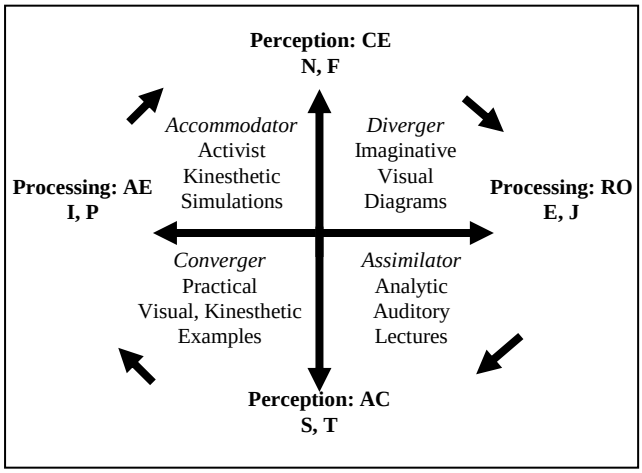

Figure 4. Mapping between psychological dimensions

approach to the experience), and the vertical (which is the continuum of perception, and identifies the acquisition of information). Jungian dimension of extraversion and introversion directly correlates with Kolb's east-west axis, which refers to active experimentation and reflective observation. Conversely, Jungian thought and feeling, identifying emotional involvement, are associated to the north-south axis of concrete experience and abstract conceptualization. Kolb's taxonomy of learning styles (i.e., diverger, assimilator, converger, and accommodator) is the result of the combination of the preferential ability of individuals in managing different learning skills, and they reflect semantic pathways exploited by the learners' mind. Moreover, the sensing-intuition dimension (which refers to the way learners prefer to take information) and the judging-perceiving axis (which represents individuals' attitude to the external world) coincide with the continuums of information processing and perception, respectively. Kolb's model plays a crucial role because it integrates Jungian dimensions in an iterative process, and it links the theoretical framework of personality types [15] into a pragmatic learning environment.

Moreover, with respect to perceptual style, that is the privileged sensory channel employed for the acquisition of information, many delivery strategies are available. Thus, the application should comprise different representations for contents, according to the diversity of echoic, iconic and haptic users, referring to the auditory, the visual, and the empathic perception [16] (respectively) characterizations of multimedia communication.

4.2 Assessing through ambiguity

Several methods are available to assess each specific dimension (i.e., Gardner's Multiple Intelligences, Benziger's Thinking Styles and Brain Dominance, Bloom's Taxonomy of Learning Domains) and a large number of tools can be implemented. Conversely, recognition of users' personality is more difficult if compared to other features, due to both the number of variables involved and for the inherent implicitness of such traits. In general, interaction with e-learning contents occurs in a Windows Icons Menu Pointing-device (WIMP) fashion, using only the mouse, and it requires very few keyboard operations. As a result, although lexical analysis is one of the most effective techniques for eliciting personality in chat applications, it is not suitable for e-learning because dialogue is limited and the available information is scarce. The trivial approach applied by many tools is to submit a personality test to students before the beginning of the course. However, this requires additional effort from the user and may introduce cognitive overhead.

As an alternative opportunity, we explored the use of ambiguity in order to force expression of users' preferences. Indeed, applications, especially in learning contexts, should present contents in a clear and unequivocal fashion, to avoid confusion and frustration. Therefore, the course should not contain any source of confusion. Conversely, when content is not essential, a certain amount of noise can be added to the style of information presentation, and it may be useful to rely on the individual's ability to disambiguate among multiple interpretations, to force the user's decision, so that they reveal their own preference. Specifically, ambiguity is a property of the interpretative relationship between people and artifacts [17], and it may be exploited as a resource (if carefully addressed) to increase involvement and to require users to explicit their attitude towards interaction. In our design, the premise is composed using Learning Objects that include various multimedia resources. They are displayed in a mutually exclusive fashion (e.g., by revealing only one object at a time, while blinding others with an overlay), and the user must choose to focus on one of them.

As each resource $r_1, r_2, ..., r_n$ is identified by a type t (associated with a learning style and with a perceptual channel), at the end of the premise, the Learning Manager will be able to classify the user according to the preference assigned to each object, and calculated using a number of indicators $f_1, f_2, ..., f_m$ (e.g. time spent on the resource). The preference

$$p_t = \sum_{i=1}^{n} \sum_{j=1}^{m} f_j(r_{i_t})$$

is calculated as the linear combination of all the indicators collected for each resource. Once normalized, they represent the user's learning style and his main sensory channel, and they can be further processed to extract his personality using the model shown in Figure 3.

4.3 Personality of Learning Content

Several guidelines and patterns [18] are available for associating contents with learning styles, and they can be implemented in the learning units of the course. However, in our design, the information presentation layer of the application is not defined a-priori. Conversely, when interacting with the user, the Learning Manager acquires student's personality both during the premise and throughout the course, in order to choose the most suitable material and to reconfigure the interface in real-time. Indeed, independently from the aspects being analyzed and the theories employed, the relationship between the user personality and the macro-structures of the personality-aware course can be also directly specified within the Learning Container, which is a Learning Object itself. Therefore, it can be identified with metadata, similarly to the Learning Content. Such modular structure allows the Learning Manager to reconfigure features such as Content selection, Presentation, Navigation, and Support in the whole application. Therefore, the Learning Manager analyzes metadata describing Learning Objects, and it applies Template Learning Objects (TLO) to link contents and to present them in a personality-aware interface. As they are Learning Objects, TLOs can also be described with metadata containing additional specifications regarding the relationship between the content and the various psychological dimensions, as shown in Figure 4.

The purpose of TLOs is to aggregate atomic Learning Objects in a structure that provides users with an interface specifically designed for both their personality and their learning needs. To this end, data about perceptual channels determines the proportion of multimedia contents (e.g., images, audio, video); also, information about cognitive styles prescribe the most appropriate resource (e.g., diagrams, verbal explanations, examples); moreover, personality types specify the style of presentation (e.g. inductive or deductive, analytical, or practical, student or teacher driven). For instance, the Learning Manager will provide introverted-visual convergers with a different template with respect to extraverted-auditory assimilators. Specifically, it will present the former type of students with a choice of materials in parallel, using a student-driven approach. Conversely, in the second case, it will propose a teacher-driven sequence of concrete examples starting from a theoretical model.

The Learning Manager applies a content reconfiguration strategy that provide users with different instructional materials that take into account indivduals' learning preferences. Nevertheless, at the same time, it diversifies the content presenting complementary information, in order to stimulate all the other skills. As a result, the reconfigured personality-aware interface accommodates several styles, and each TLO includes multiple Learning Objects: the main one and secondary others. Contrary to the premise, the objective of the reconfiguration strategy during the course is integrating multiple materials. Therefore, the application interacts through different non-exclusive channels to enhance the other modes.

5. EXPERIMENTAL STUDY

One experiment was realized to verify the performance of students using a personality-aware e-learning system. The experiment was organized in two phases: psychological self-assessment and learning experience. In the former, we submitted three questionnaires to users in order to identify their personality types, their learning styles, and their perceptual attitudes. In phase two, participants interacted with an implementation of our personality-adaptive framework that was divided in four parts: introduction (premise) and 3 chapters (course). The objective of our study was to investigate the difference between interfaces and contents which are personalized using information from the self-assessment and data extracted from the behavior of the user during the premise. Moreover, we aimed at evaluating the improvement with respect to interfaces without any personalization.

5.1 Materials and methods

5.1.1 Self-assessment

Phase one consisted of three tests (i.e., personality type, learning style, and perceptual attitude). Although there are different assessment tools which are available for classifying personality types, we employed the Myers-Briggs Type Indicator (MBTI) [15] because it is especially designed for learning purposes, and it has been widely applied to education and for designing teaching methods. The test consisted of 95 two-choice questions which allowed us to diversify participants with respect to the four dimensions defined by Jung's theory of types (introversion and extraversion, sensation and intuition, thought and feeling, judgment and perception). Moreover, we implemented a questionnaire based on Kolb's theory that allowed us to segment users' population into four groups (converging, accommodating, diverging and assimilating) using the 36 standard attributes. Subjects completed the Learning Style Inventory (LSI) test, consisting of 9 groups of 4 sentences each, by ordering the statements according to their preference. Furthermore, we asked participants to complete a VAK test based on NLP [16] to identify their learning attitude with respect to sensory modality (i.e., Visual, Auditory and Kinesthetic). The questionnaire consisted of 25 questions with three choices, each associated with a specific display modality (e.g., audio or images). The tests were delivered both on paper and on the web, and subjects could choose how to complete them according to their convenience. Also, this allowed us to understand their familiarity with computers.

5.1.2 Personality-aware course

An interactive e-learning base for customer management services was developed. It consisted of 10 XHTML web pages programmed using PHP. The course was intended to instruct the clients of a library about the book acquisition procedure. The premise consisted in a one-page introduction designed so that the Learning Objects were exclusive, in order to emphasize competition among them, and to exploit ambiguity to foster users' decision. To this end, we applied an overlay to contents so that only the Chapters (3 pages each) were customized with user preferences elicited either from data acquisition or from the results of the tests. As a result, contents were presented in different fashion according to the specific profile of the user. Also, we evaluate also the case of a chapter which did not include any personalization. After each chapter, subjects were asked 10 questions that aimed at assessing their comprehension of the learning unit.

5.1.3 Participants

We recruited 35 subjects (17 females and 19 males), aged from 24 to 55 years (with an average of ~43). They have homogeneous medium-high educational background (high school and above)

and similar knowledge of the use of the Internet. Participants belong to different nationalities and ethnicities. Subjects collaborated on a voluntary basis. We divided them in three homogeneous groups, so that test subjects were provided with different adaptive functionalities, while the control group received the course in the standard fashion.

5.2 Results and discussion

Table 1 shows the average learning performances of users measured using results from the questionnaires after each chapter. In Chapter I, Groups 1 and 2 received personalization based on their decision and on self-assessment, respectively. In Chapter II, we switched the reconfiguration mode. As Group 3 was the control, it received no personalization. Conversely, in Chapter III, Group 1 was the control, while Grousp 2 and 3 received personalization based on self-assessment and on their own disambiguation, respectively. With respect to reconfiguration of contents, personalization based on user's decision (UD) leads to a total of 90.5% of correct answers. Conversely, with the self-assessment test (SA) user achievement is 64%, worse than the performance (77.5%) of individuals using the interface without any personalization (NP). Moreover, within-group difference is not statistically significant, while two-way ANOVA revealed a difference between Chapters and Groups.

Table 1. Average learning performance (percentage)

	Group 1	**Group 2**	**Group 3**
Chapter I	89.9% (UD)	61,5% (NP)	68,2% (SA)
Chapter II	67,3% (SA)	90,3% (UD)	78,8% (NP)
Chapter III	85,6% (NP)	63,2% (SA)	91,2% (UD)

6. CONCLUSION AND FUTURE WORK

In this paper, we presented the architecture of a light-weight framework for personality-aware applications in the context of e-learning. We specifically focus on systems for the delivery of information, because they are recently becoming pervasive and ubiquitous. However, the same principles can be applied to other domains without any change to the design of our system. Our architecture is designed to be modular and to extend the concept of Learning Object using XML-based metadata in order to accommodate the psychological model of the user in the design. In compliance with current standards for e-learning applications, all the resources, including Template Learning Objects in the Learning Content and the Learning Container, are completely reusable as design patterns.

From the results of our findings, we can conclude that content organization should take into account users' personalities, because it can lead to a 30% improvement in learners' performances. However, our study has several limitations, mainly due to the number of experimental subjects. In our future work, we will develop new experiments to validate our design.

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