Open Access

Research Online Publishing
www.ronpub.com

Open Journal of Web Technologies (OJWT)
Volume 1, Issue 1, 2014

www.ronpub.com/journals/ojwt
ISSN 2199-188X

Integrating Human Factors and Semantic Mark-ups in Adaptive Interactive Systems

Marios Belk [A], Panagiotis Germanakos [A, B],
Efi Papatheocharous [C], Panayiotis Andreou [A], George Samaras [A]

[A] Department of Computer Science, University of Cyprus
P.O. Box 20537, 1678 Nicosia, Cyprus
{belk, pgerman, panic, cssamara}@cs.ucy.ac.cy
[B] SAP AG, Dietmar-Hopp-Allee 16, 69190 Walldorf, Germany
[C] SICS Swedish ICT AB
Isafjordsgatan 22/Kistagången 16, Box 1263
SE-164 29 Kista, Stockholm, Sweden
efi.papatheocharous@sics.se

ABSTRACT

This paper focuses on incorporating individual differences in cognitive processing and semantic mark-ups in the context of adaptive interactive systems. In particular, a semantic Web-based adaptation framework is proposed that enables Web content providers to enrich content and functionality of Web environments with semantic mark-ups. The Web content is created using a Web authoring tool and is further processed and reconstructed by an adaptation mechanism based on cognitive factors of users. Main aim of this work is to investigate the added value of personalising content and functionality of Web environments based on the unique cognitive characteristics of users. Accordingly, a user study has been conducted that entailed a psychometric-based survey for extracting the users' cognitive characteristics, combined with a real usage scenario of an existing commercial Web environment that was enriched with semantic mark-ups and personalised based on different adaptation effects. The paper provides interesting insights in the design and development of adaptive interactive systems based on cognitive factors and semantic mark-ups.

KEYWORDS

Adaptive Interactive Systems, Individual Differences, Cognitive Factors, Semantic Mark-ups, User Study

1 INTRODUCTION

Advances in Web technologies and services are taking place with a considerable speed all around the world. As communications and IT usage become an integral part in the life of many people and the variety of products and services is increasing and becoming more sophisticated, users expect to have personalised services that meet their individual needs and preferences. In addition, the plethora of information and services as well as the complicated nature of the World Wide Web often intensify orientation and navigation difficulties of users. They might for example lose sight of their original goal because they are overwhelmed by stimulating rather than informative material. Within this realm, the need to adapt and personalise Web environments that satisfy the heterogeneous needs of its users becomes nowadays a necessity [1].

Adaptive interactive systems move toward this direction with the aim to address such issues and provide solutions to user problems related to content presentation and navigation [2]. Bearing in mind that computer human interactions in Web environments are in principal cognitive tasks, several research works have suggested that these interactions should be adapted and personalised based on individual differences in cognitive processing [2, 3]. In this respect, user characteristics can be extended beyond the traditional ones such as age, gender, knowledge, goals, and interests, and might include intrinsic cognitive factors that could be considered as personalisation parameters for a more efficient adaptation process. To that direction, our efforts are focused on improving the efficiency and effectiveness of user tasks (such as browsing Web content of a product catalogue, comparing product characteristics, etc.) and providing a positive user experience within commercial Web environments by employing methods of personalisation based on cognitive characteristics of users.

Furthermore, in a technical point of view, an important challenge of designing an effective adaptive interactive system is to study and incorporate structures of meta-data (i.e., semantics) at the Web content provider's side, as well as propose the construction of a Web-based adaptation mechanism that will serve as an automatic filter, adapting the distributed Web content based on the user characteristics. Semantic mark-up can contribute to the whole adaptation process with machine-understandable representation of Web content. In this context, machine-understandable data can be incorporated in the design of Web-based systems to inform the adaptation mechanism of the intention of specific sections and accordingly adapt them based on the user characteristics and adaptation rules [4, 5].

To this end, the overarching aim of this work is to support the adaptation process for personalising content and functionality of interactive systems to specific cognitive characteristics of users through a complete adaptation framework embracing: i) user modeling techniques for eliciting the cognitive characteristics of users, ii) an authoring tool for supporting Web content providers throughout the creation of machine-understandable content, and iii) an intelligent adaptation mechanism for dynamically reconstructing the semantic-based content and functionality of the Web environment. Main objective is to investigate the added value, in terms of task efficiency and effectiveness, and user satisfaction, of adapting content and functionality of Web environments based on cognitive factors of users.

The remainder of the paper is structured as follows: Section 2 presents the theoretical background on adaptive interactive systems and semantic-based adaptation approaches. Section 3 presents the proposed semantic-based adaptation framework which is further assessed respectively with a user study, and a system performance evaluation in Section 4 and Section 5. Finally, in Section 6 and Section 7 we conclude the paper with discussions and future trends of our work.

2 Background Work

2.1 Adaptive Interactive Systems

Adaptive interactive systems aim to improve the usability and experience of users' interactions by providing personalised content and functionality based on their individual characteristics, needs and preferences. Effective personalisation of Web content and functionality in adaptive interactive systems involves two important challenges: i) appropriate user modelling dealing with what information is important to be incorporated in the system to decide on the adaptation effects, and ii) appropriate adaptation procedures dealing with what adaptation types and mechanisms are most effective to be performed and how they can be translated into adaptive user interface designs.

Various research works exist in the literature that propose different approaches for Web adaptation and personalization. Recent examples include [8] that proposed an approach for adapting user interfaces based on the cultural preferences of users, [6] and [7] that proposed an implicit user modelling approach for eliciting cognitive styles of users based on their navigation behaviour in the context of adaptive interactive systems, and [9] that proposed an adaptive spellchecker and predictor for people with dyslexia that adapts the user interface based on the users' behaviour.

Due to the multidimensional nature of adaptive interactive systems, existing research works primarily focus on specific aspects for improving the overall personalisation process, e.g., either focus on user modelling procedures for effectively eliciting the users' characteristics, or focus on adaptation procedures and adaptation effects for improving task usability and user experience of interactive systems. Apart from studying various user modelling and adaptation mechanisms, in order to build a comprehensive adaptive interactive system, it is also necessary to study and design the structure of semantics in the context of adaptive interactive systems [10]. In particular, the use of semantics and ontologies could support the adaptation process with machine-understandable representation of Web content. Therefore, we next investigate the incorporation of semantics, with the aim to feed the adaptation mechanism with semantically enriched, machine-understandable information in order to adapt the Web-page content based on the user models created.

2.2 Semantic Web Technologies

The Semantic Web initiative [11] is focusing on the creation of technologies and languages, and use of rich ontologies that can capture a wide variety of relationship types that facilitate machines to understand the meaning of information on the World Wide Web. These ontologies are modelled using ontology representation languages such as the Extensible Mark-up Language (XML), the Resource Description Framework (RDF), or the Web Ontology Language (OWL) [10].

Ontologies have been proven an effective means for enabling semantic-driven data processing [12]. Driven by many issues (i.e., interoperability problems, heterogeneity, lack of data structure, contextual dependency, etc.) in today's ICT systems, researchers and practitioners alike, seem to readily embrace the notion of ontologies in various contexts, such as i) mediating information access between heterogeneous enterprise applications [12, 13], ii) modelling user profiles [14], and iii) annotating Web-pages with semantic mark-ups [15] enabling machine-understandable Web filtering (e.g., search engines).

Various ontology-based annotation approaches for producing semantic mark-ups have been proposed in the literature. One such system is OntoSeek [16], which uses simple conceptual graphs to represent queries and resource descriptions for content-based information retrieval. Another popular system is SHOE [15] that uses a set of Simple HTML Ontology Extensions enabling Web content providers to annotate their Web-pages with semantics expressed in terms of ontologies. SemTag [17] is an application that performs automated semantic tagging of large corpora. Protégé [18] is a tool for ontology development and knowledge acquisition that can be adapted for editing models in different Semantic Web languages. Annotea [19] is a Web-based shared annotation system, based on a general-purpose open RDF infrastructure that provides a simple framework for associating annotations with Web documents. Google's search engine also supports enhanced searching in Web-pages, by using RDFa embedded in XHTML [20] with the aim to improve the way specific search results are presented to users.

In this context, ontology-based annotations could assist the adaptation process by enabling Web content providers to semantically annotate Web-page content that will be further fed to an adaptation mechanism in order to understand and effectively communicate the semantic content in an adaptive format to the user interface. Furthermore, it is important to assist the Web content provider, with novice level of knowledge regarding Web content creation, with an easy-to-use tool to create semantically enriched Web content that will be further transparently included in an adaptation mechanism.

Authoring tools in the context of adaptive interactive systems have been proposed in the past as part of adaptive educational systems. Chang et al. [21] proposed a learning content adaptation tool that assisted authors to adjust predefined Web templates for specific handheld devices of users. Another work of Grigoriadou and Papanikolaou [22] aimed to support educators throughout the authoring process of educationally meaningful content for personalised learning. A more recent example includes the Mobile E-learning Authoring Tool [23] that produces adaptive learning content and assessment material for mobile devices.

Taking into consideration previous works in this area, the authoring tool implemented and presented in the next section of this paper proposes a generic semantic-based adaptation framework. The framework is generic in the sense that it focuses on authoring content of any type of Web environment and is not limited on educational environments. In particular, the tool assists Web content providers to create semantic mark-ups in Web-pages for supporting the adaptation process based on cognitive characteristics of users.

Overarching aim of this work is to propose a complete semantic Web-based adaptation framework that assists both Web content providers with semantic content creation, as well as users by providing adapted content and functionality to their cognitive characteristics based on an effective adaptation mechanism. The proposed semantic-based adaptation framework is described next.

3 SEMANTIC-BASED ADAPTATION FRAMEWORK

The framework consists of the following interconnected layers: i) *User Modelling*, for extracting the demographic (i.e., age, gender, profession) and cognitive characteristics of users, ii) *Semantic Authoring Tool*, for the creation of semantically-enriched, machine-understandable content, iii) *Adaptation Mechanism*, that performs various adaptation rules obtained by experts and which are based on the user models and the semantically-enriched content, and iv) *Adaptive User Interface*, that presents the Web content in an adapted format and through adapted navigation controls based on the users' cognitive characteristics.

Accordingly, the personalisation process of the proposed framework consists of four main phases; a) the users' demographic and cognitive characteristics are elicited utilising specific psychometric tests, b) the Web content provider creates Web objects with semantic mark-ups utilising the semantic authoring tool, c) the adaptation mechanism parses the generated XHTML documents, extracts the semantic mark-ups and further applies specific adaptation rules based on the user models, and d) the adaptation effects are communicated to the users' interfaces.

Previous works of the authors support the user modelling and adaptation parts of the framework which are described in detail in [7, 24].

3.1 User Modelling

Among the popular theories of individual styles proposed in the literature [26], this work utilises Riding's Cognitive Style Analysis (CSA) [25] that classifies users based on how they process information (i.e., verbally or non-verbally), and how they organise information (i.e., holistically or analytically), and Baddeley's Working Memory model [27] that refers to a brain system that provides temporary storage and manipulation of information necessary during cognitive tasks. We next describe the theories selected to incorporate in our user model and how to elicit these characteristics.

3.1.1 Cognitive Styles

Riding's CSA consists of two dimensions; the Verbal/Imager dimension refers to how individuals process information, and the Wholist/Analyst dimension refers to how individuals organise information [25, 26]. The Verbal/Imager dimension consists of three classes, users that belong to the Verbal, Intermediate or Imager class. Users that belong to the Verbal class can proportionally process textual and/or auditory content more efficiently than images, whereas users that belong to the Imager class the opposite. Users that belong in between the two end points (i.e., Intermediate) do not differ significantly with regards to information processing. The Wholist/Analyst dimension consists of three classes, users that belong to the Wholist, Intermediate or Analyst class. Specifically, users that belong to the Wholist class view a situation and organise information as a whole. Users that belong to the Analyst class view a situation as a collection of parts, and stress one or two aspects at a time. Users that belong in between the two end points of the Wholist/Analyst scale (i.e., Intermediate) do not differ significantly with regards to information organisation.

In this context, Riding has proposed a psychometric test [25], which has been used in our user modelling component, for eliciting the users' cognitive styles that comprises of two sub-tests that respectively indicate the position of an individual on each of the Wholist/Analyst and Verbal/Imager dimensions by means of a ratio. In particular, users first complete a series of questions that measure the response time on two types of stimuli and the ratio between the response times for each stimuli type is computed in order to highlight differences in cognitive styles. The stimuli types are: a) statements (i.e., identify whether a statement is true or false), and b) pictures (i.e., compare whether two pictures are identical, and whether one picture is included in the other).

3.1.2 Working Memory Capacity

Working memory is a brain system that provides temporary storage and manipulation of information during processing of cognitive-based tasks (e.g., language comprehension, learning, and reasoning) [27]. Baddeley refers to individual differences in working memory and many other studies support that working memory capacity varies among people and predicts individual differences in intellectual ability. Each corresponding working memory instance (i.e., limited/intermediate/enhanced), indicates the working memory capacity of a person. Enhanced working memory increases the connections and associations that can be built either between the items of the newly encountered information or between this information and information already stored in the long-term memory.

Working memory capacity was elicited through a psychometric test that requires from the participants to memorise an abstract image and then compare that image with five other similar images. As the participant provides correct answers, the test presents more complex images for comparison, indicating an enhanced working memory capacity of the participant.

3.2 Semantic Web Authoring Tool

The semantic authoring tool supports the creation process of adaptive Web content with semantic mark-ups. The development has been based on Wordpress (wordpress.org), which is a widely used Content Management System on the World Wide Web. In particular, a customised version of Wordpress has been developed and extended to enable the creation process of Web content with specific RDFa tags. The RDFa standard has been used in this work since it easily integrates machine-understandable information into the current Web-page paradigm and workflow [28].

An RDFa schema[1] has been designed for that purpose to enable standard annotations in an XHTML Web-page, thus making structured data available for our framework's adaptation mechanism, but also for any service or tool that supports the same standard. Figure 1 shows an instance of the RDFa content model that illustrates the semantic annotation of text and image objects. Similarly, any other types of elements (e.g., video) could be annotated by the authoring tool, and depending on the adaptation effects of the system, the annotated tags would be processed and adapted by the adaptation mechanism.

The RDFa instance consists of a number of classes and properties which describe an adaptive Web object. The main class of the RDFa vocabulary is *SmartObject* representing an adaptive Web object. This class has the following properties: i) *name*, the concept's name, ii) *element*, the element of a concept, iii) *title*, the title of the concept's element, and iv) *content*, the content of the concept's element.

```
<div xmlns:v="personaweb.cs.ucy.ac.cy"
typeof="v:SmartObject">
  <span property="v:name">
    PC Specifications
  </span>
  <div property="v:element">
    <span property="v:title">
      Memory
    </span>
    <span property="v:content">
      <img src="mem.png" /> 250GB HD
    </span>
  </div>
  <div property="v:element">
    <span property="v:title">
      CPU
    </span>
    <span property="v:content">
      <img src="cpu.png" /> 2GHz CPU I5
    </span>
  </div>
</div>
```

Figure 1: RDFa Instance of a Web Object

Accordingly, the Web authoring tool has been extended to include actions that enable content annotations based on the RDFa schema. For example, in Figure 2, the Web content provider has created a section of information illustrating the specification of computer products and annotated the content based on the *SmartObject* class and its properties. In particular, the Web content provider has first annotated the whole information as a *SmartObject* and further annotated specific sections of the object according to the semantic meaning of the content, e.g., indicated that "Memory" is the *title* and "250GB HD" is the *content* of an *element* within the *SmartObject*.

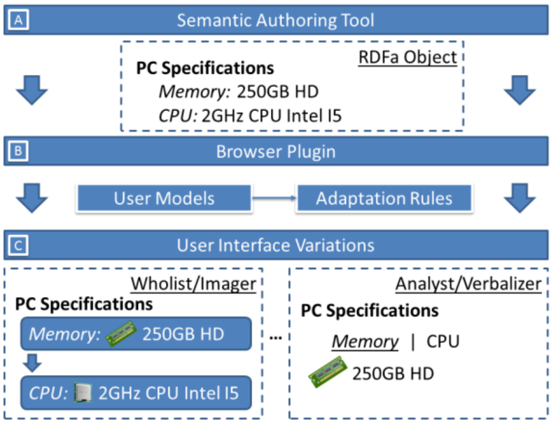

Figure 2: Personalisation and Adaptation Process

The annotated Web-page is then provided as input to the adaptation mechanism in order to adapt the content presentation of the RDFa-based *SmartObject* and users' navigation based on the proposed adaptation rules described in the next sections.

3.3 Adaptation Mechanism

The adaptation mechanism is responsible for adapting the RDFa objects that are generated by the semantic authoring tool. A Web browser extension has been developed in order for the Web browser to recognise and process the RDFa objects. Figure 3 describes the personalisation algorithm utilised on the RDFa objects to provide the adaptation effects based on the users' cognitive characteristics.

Accordingly, the user model characteristics are initially provided to the Web browser extension as input which will be used by the adaptation rules to decide on the adaptation effects to be performed. The Web browser extension will first parse the HTML content before presenting the content to the user and filter out all *SmartObject* elements. The *element* property is further utilised by the Web browser to distinguish the logical meaning of a section when performing specific adaptation effects (e.g., create a diagrammatical representation of the content). In other words, the *element* property is used to distinguish sub-elements of a *SmartObject*. As we will further see, the *element* property is interpreted differently by the browser when the user characteristics change. Next, the Web browser provides adaptive navigation support

[1] https://personaweb.cs.ucy.ac.cy/rdf.xml

tools based on the *SmartObject* sub-elements. In particular, the *title* property of each sub-element is used in this case to create an adaptive navigation menu with the *title* of each sub-element comprising an item of the menu that links to the containing information of the *content* element.

```
Algorithm : Adaptive Content and Navigation Support
Input : html_doc, vi = { verbal | intermediate | imager }, wa = { wholist | intermediate | analyst }, wmc = { limited | intermediate | enhanced }
Output : Personalise Content and Funcionality
procedure Personalisation(html_doc, vi, wa, wmc)
  var SmartObjects = Parse(html_doc);
  for each oSmartObject in SmartObjects
    var elements = GetElements(oSmartObject);
    var nav_menu;
    for each oElement in elements
      nav_menu.AddItem(oElements.Title);
      nav_menu.BindItem(oElements.Content);
      if (vi == imager) then
        oElements.CSS("diagram");
      end if
    end for
    if (wa == wholist || wa == intermediate) then
      nav_menu.Type("floating");
    else if (wa == analyst) then
      nav_menu.Type("tabbed");
    end if
  end for
  if (wmc == limited) then
    ContentStorageTool.Enabled = true;
  end if
end procedure
```

Figure 3: Personalisation Algorithm

Finally, the Web browser also provides users (with limited working memory capacity) a temporary memory buffer (i.e., content storage tool) for storing a section's summary (sub-element's *content*) of the *SmartObject* and keep active information that the user is interested in until the completion of a cognitive task.

3.4 Adaptive User Interface

This section describes the adaptation effects which are based on the following combination of cognitive characteristics of the user model; Imager, Intermediate or Verbal, Analyst, Intermediate or Wholist and Working Memory Capacity (i.e., limited, intermediate or enhanced). Figure 4 illustrates the original version of the *SmartObject* based on the RDFa instance of Figure 1 at the top, and two example adaptation effects at the bottom.

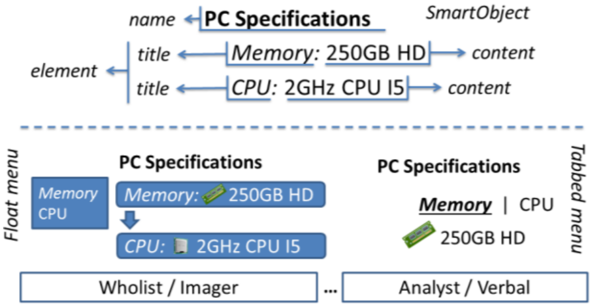

Figure 4: Adaptation Effects

Accordingly, in case a user belongs to the Imager class, a diagrammatical representation of the containing information of *SmartObject* is presented. The *element* property is used by the Web browser to distinguish the items (elements) of a *SmartObject* when creating a diagrammatical representation (e.g., Memory and CPU are two elements of the *SmartObject* instance). On the other hand, when a user belongs to the Verbal class (prefers verbal representations), the elements of the *SmartObject* are presented in its original format.

Furthermore, in case a user belongs to the Analyst class, the information will be enriched with a tabbed menu to arrange information in a manner that is closer to the analytic way of information organisation. In particular, each item of the tabbed menu will consist of the *title* property of each *SmartObject* element. This way, each item of the menu is linked to the *content* property of a particular *element*. The same logic of transformation is used when mapping the *SmartObject* with a Wholist user. In this case, a dynamic floating menu with anchors is created so to guide the users on specific parts of the Web content while interacting. Again, the *title* property of the *element* comprises the menu's item, linked to the *content* property of each *element*.

4 USER STUDY

4.1 Method of Study

A total of 70 undergraduate students participated voluntarily in the study (36 male, 34 female, age 17-27). All participants accessed a Web-site utilised for the study with personal computers located at the laboratories at the University of Cyprus. The procedure was divided in two phases: i) participants provided demographic information such as, name, age, education, etc.) and performed a number of interactive tests using specific psychometric tests [25, 27] in order to quantify their cognitive characteristics, and ii) the participants navigated in a commercial Web-site selling computer products that was developed for the purpose of the experiment.

The participants navigated in two different versions of the same environment (i.e., original and personalised) based on their cognitive characteristics and were asked to fulfill three tasks in each version. In particular, they had to find the necessary information to answer three sequential multiple choice questions that were given to them while navigating. All six questions were about determining which laptop excelled with respect to the prerequisites that were set by each question. The selection process of the sequence of version per individual was based on a random selection process. As soon users completed answering all questions in both versions, they were presented with a comparative satisfaction questionnaire based on WAMMI questionnaire [29]; users were asked to choose which environment was more usable (using a scale from 1-5, where 1 means strong preference for environment A -original- and 5 for environment B -personalised). Example questions were *"Which of the two Web Environments were more attractive?"* and *"Which of the two Web Environments do you prefer?"*.

4.2 Analysis of Results

For our analysis, we separated users into different groups based on their cognitive style and working memory capacity (Table 1).

Table 1: Cognitive Factors of Participants

Cognitive Factor	N	%
Wholists	24	34.3
Intermediates	13	18.6
Analysts	33	47.1
Verbals	32	45.7
Intermediates	20	28.6
Imagers	18	25.7
Low Working Memory	17	24.3
Medium Working Memory	42	60
High Working Memory	11	15.7

The dependent variables of the study utilised as indicators of differences between the two versions were: i) Task completion performance (efficiency), ii) Task accuracy (effectiveness), and iii) User satisfaction.

4.2.1 Task Completion Performance

Results revealed that users performed faster in the personalised environment with a mean of 66.25 sec for completing all three tasks compared to 74.33 sec for completing all three tasks in the original environment. Table 2 and 3 respectively summarise the means of overall performances across all three tasks per cognitive styles and working memory group in both Web environments.

Table 2: Means of Overall Performance per Cognitive Style Group

Cognitive Style	Original		Personalised	
	Mean	Std. Dev	Mean	Std. Dev
Wholist	78.30	23.89	65.73	26.32
Intermediate	76.09	42.68	53.67	24.45
Analyst	70.75	26.51	71.58	31.62
Verbal	79.56	30.10	66.96	28.26
Intermediate	68.87	24.13	69.76	30.23
Imager	71.11	32.10	61.08	29.02

The analysis of variance (ANOVA) indicates that users belonging to the Wholist and Intermediate classes performed considerably faster in the personalised version of the environment than in the original version (Wholist: $F(1,47)=2.999$, $p=0.09$, Intermediate: $F(1,25)=2.699$, $p=0.11$). In contrast, users belonging to the Analyst class performed slightly faster in the personalised environment than the original ($F(1,65)=0.013$, $p=0.90$). Results indicate that the adaptation effects provided to Wholist and Intermediate users improved their task completion time and thus worth further investigation for improving user interactions in such environments. On the other hand, in the case of Analysts, the initial personalisation technique (i.e., tabbed menu) has shown a tendency towards improving the users' performance, nevertheless, additional adaptation types should be investigated in the future to examine whether interactions of this user class could be further improved in terms of task completion time.

With regard to the Verbal/Imager dimension, the analysis revealed that Verbals and Imagers performed considerably faster in the personalised version of the environment than in the original version (Verbals: $F(1,63)=2.977$, $p=0.089$; Intermediates: $F(1,39)=0.011$, $p=0.918$; Imagers: $F(1,35)=0.940$, $p=0.339$). Such a result suggests further investigation since all users completed their tasks faster in the personalised than in the original version indicating that adapting content presentation based on this cognitive style dimension improves task completion efficiency. In particular, the diagrammatical representation of content seems to have supported Imagers process information more efficiently than the plain text-based content as was in the case of Verbals.

Table 3: Means of Overall Performance per Working Memory Group

Working Memory	Original		Personalised	
	Mean	Std. Dev	Mean	Std. Dev
Low	77.97	22.37	62.59	24.79
Medium	68.15	26.66	63.29	30.41
High	92.31	39.73	83.19	25.71

Finally, regarding the Working Memory dimension results have shown that users with limited working memory capacity performed faster in the personalised version suggesting that the tool for storing the summary of each product improved their task completion performance ($F(1,33)=3.604$, $p=0.067$). Users with intermediate and enhanced working memory capacity did not perform significantly different in either of the two environments since these two user classes did not receive any tool for comparing different products as was in the case of users with limited working memory capacity.

4.2.2 Task Accuracy

In order to assess the significance and possible impact cognitive factors may have on the adaptation of content and functionality of Web applications in terms of task effectiveness, a comparison has been performed between the correct answers the users provided in each version (i.e., original and personalised). Users in the personalised version were consistently more accurate in providing the correct answer for each task. In particular, users in the original version had a mean of 2.21/3 correct answers, while in the personalised version the same mean slightly rose to 2.29/3. A further analysis was conducted that aimed to compare the average correct answers per user group in each version. In regard with the Wholist/Analyst dimension, Intermediate users were considerably more accurate in completing the tasks (personalised version: 2.31/3 correct answers, original version: 1.92/3 correct answers), whereas in the other two user classes, the task accuracy was not significantly different.

In the case of the Verbal/Imager dimension, Verbals were considerably more accurate in the personalised version than in the original version (personalised version: 2.47/3 correct answers, original version: 2.25/3 correct answers), whereas Imagers and Intermediates the opposite. Finally, users with limited and enhanced working memory were remarkably more accurate in the personalised version, respectively, with 2.41/3 and 2.1/3 correct answers, compared to 1.94/3 and 1.62/3 correct answers in the original version. In the case of users with intermediate working memory capacity, no significant differences in accuracy were observed between the two environments (personalised: 2.2/3, original: 2.4/3). The results reveal that the supportive tool provided to users with limited working memory capacity has improved the users' task accuracy, improving accuracy levels compared to intermediate and enhanced working memory users.

To this end, although the difference of accuracy between the two versions was not significant in many cases, results are encouraging for the proposed mechanism, implying that adaptation on the basis of these cognitive factors (cognitive style and working memory capacity) provides adaptation effects that benefits users within an eCommerce environment. A further analysis with a greater and more diverse sample is required in order to draw even more concrete conclusions.

4.2.3 User Satisfaction

A questionnaire was utilised to retrieve the users' preference regarding the two environments (i.e., original vs. personalised).

Results revealed that 51 users (71.83%) preferred the personalised environment and 18 users (25.35%) preferred the original environment, while 1 user had neutral preference. A binomial statistical test was conducted (H_0: $p(\text{original})=0.5$ and $p(\text{personalised})=0.5$) indicating that there is significant preference of users toward the personalised environment ($p<0.001$). This result supports the proposed adaptation framework since the adaptation effects provided to the users based on their cognitive characteristics have improved not only the usability of interactions but provided as well a positive user experience.

A further analysis was performed to investigate the relationship between the users' performances and preferred environment, e.g., investigate whether users that performed better in the personalised version have actually responded in the questionnaire that they indeed prefer the personalised version. The analysis showed that out of 21 users that performed slower in the personalised version, 18 users (85%) preferred the personalised environment, and out of 49 users that performed faster in the personalised version, 34 users (69%) preferred the personalised environment, whereas 15 users preferred the non-personalised environment.

5 SYSTEM PERFORMANCE

To evaluate system performance we executed two different simulations: (i) users interacted with the environment with the original content which did not have any adaptation or personalisation, and (ii) users interacted with the adapted and personalised environment. The simulations were run on Mozilla Firefox, Google Chrome, Internet Explorer and Apple Safari. The system performance was measured in terms of average loading time and speed index based on the simulations run on all of these Web browsers. The loading time refers to the average time (sec) for loading all elements of the Web-site, and the speed index refers to the average time (sec) at which visible parts of the page are displayed. The summary of the evaluation is reported in Table 4.

Table 4: Summary data of simulation scenarios

	Load Time	Speed Index	DOM Elements
Original Content			
Page View	2.098s	1.680s	85
Personalised Content			
Page View	2.273s	1.858s	93

The main observation is that the personalised version of the environment invokes more functions and modules, compared to the original environment. The additional functions and modules involve for example a module that retrieves the user profile, a module that dynamically adapts the content adaptation and an extra functionality is built which provides to the user additional navigation support. The load time of the original content was 2.098 sec while the load time of the personalised content was 2.273 sec. This difference is expected since the system uses more functional components in the case of personalised content which consume more network resources causing the load time delay. However, the load time difference reported is not significantly different between the two simulations to be perceivable to the users, even though further user studies are needed to confirm this. The speed index of the original version is 1680ms compared to 1858ms of the personalised version. Given that higher functionality is offered in the case of the personalised content in comparison to the original one, this difference is considered acceptable.

6 DISCUSSION

The preliminary results reported for the user study revealed that the personalisation process improved task efficiency, effectiveness and user satisfaction compared to the baseline original content of the commercial Web environment. In particular, the personalisation provided seems to have benefited primarily the Wholist and Intermediate users, and also users with limited working memory capacity. This might be explained by the fact that Wholists tend to rely more on information provided from the outside world and therefore require more guidance in navigation, in comparison to Analysts, as similarly discussed in the authors' previous work [2]. Thus, the added navigational support provided from the personalised version of the system, for additional guidance, has affected positively the users' performance. On the other hand, the performance of Analyst users in both versions did not have considerable differences, indicating that this additional support was not that beneficial to them. Furthermore, users with limited working memory performed faster in the personalised version. Such a result increases the external validity of the work and is in agreement to the results of previous work (e.g. [2]), where results have revealed that users with limited working memory are positively affected by the adaptation and personalisation effects introduced.

Another important finding was the fact that presenting the content in a diagrammatical representation (for Imagers) has a main effect on the attractiveness of the Web environments. Furthermore, the analysis showed that there is a noticeable relationship between the Wholist/Analyst dimension and the control and efficiency factors of the Web environment, indicating that the adaptive navigation control tools improved the usability of the Web environment.

Finally, the comparison of system performance between the original and the personalised version was not significantly different, indicating that the additional user modelling and adaptation processes were efficiently executed. In this respect, the performance difference could not be considered as a main trade-off given the added value shown on the users' task efficiency and effectiveness, as well as user satisfaction by employing personalisation techniques.

The limitations of the reported study are discussed next. The first limitation is related to the fact that participants were only university students with an age between 17 to 27 years which introduces subjectivity to the results. In addition, as the observations are user-dependent, carrying out a single assessment of users' cognitive factors might not fully justify the users' classification into specific cognitive-based groups since individuals might be influenced by other circumstances over time such as emotions, urgency, etc.

A practical limitation of this work is that to provide the adaptations, a prerequisite is for users to be available and have the time to complete the psychometric tests, which practical-wise might not be always the case. Accordingly, we suggest that implicit user modelling approaches could be utilised [6, 7] to automatically elicit the users' cognitive styles based on their navigation behaviour and overcome this limitation. Another practical implication of personalisation is the pre-condition that it is user-dependent as the process of tagging is not automated, but it depends entirely on the Web authors. In order for the personalisation to take place, the content needs to be semantically enriched by the Web content provider and the user has the responsibility of enabling the Web browser extension implemented for parsing and adapting the annotated Web objects. However, this is not an important limitation, but more a pre-condition, as the proposed adaptation framework has been realised as a prototype system primarily aiming to investigate the added value of the approach.

7 Conclusion

This paper presented a semantic Web adaptation framework with the aim to personalise content and functionality of Web environments based on human factors. The adaptation mechanism and adaptation effects of the proposed framework have been evaluated with a user study so as to assess users' performance (efficiency and effectiveness) and preference towards an adapted (personalised) and non-adapted (original) version of the same Web environment by utilising a usability measurement. It was demonstrated that users' information finding ability was considerably more accurate and efficient in the personalised version rather than the original version of the same environment. The observation was made in terms of both providing correct answers to the questions asked (task accuracy) and in task completion time (performance). Regarding user preference, users preferred the personalised version of the environment and results indicate that the majority of users could find the information they were seeking much easier and faster.

Future research prospects include conducting further studies with a larger and diverse sample with the aim to establish a more rigid connection between cognitive processing factors and information processing in generic Web applications. Given the multidimensional nature of current Web applications, which in many cases include untagged and undefined parts of data, future work of the authors includes investigating methodologies for automatically annotating and adapting unstructured content. Finally, further user studies in other domains of the World Wide Web will be conducted such as social networks, as well as compare the proposed adaptation framework to other existing frameworks that similarly approach personalisation with the aim to further increase the validity and added value of the proposed adaptation framework.

Acknowledgements

The work is co-funded by the PersonaWeb project under the Cyprus Research Promotion Foundation (ΤΠΕ/ΠΛΗΡΟ/0311(ΒΙΕ)/10), and the EU projects SocialRobot (285870) and Miraculous-Life (611421).

References

[1] P. Brusilovsky, A. Kobsa and W. Nejdl, *The Adaptive Web: Methods and Strategies of Web Personalization*. Springer, 2007

[2] P. Germanakos, N. Tsianos, Z. Lekkas, C. Mourlas and G. Samaras, G. "Realizing Comprehensive User Profile as the Core Element of Adaptive and Personalized Communication Environments and Systems," *The Computer Journal, SI on Profiling Expertise and Behaviour*, vol 52, no. 7, pp. 749-770, 2008

[3] K.A. Papanikolaou, M. Grigoriadou, H. Kornilakis and G.D. Magoulas, "Personalising the Interaction in a Web-based Educational Hypermedia System: the case of INSPIRE," *Journal User-Modeling and User-Adapted Interaction*, vol. 13, no. 3, pp. 213-267, 2003

[4] M. Belk, P. Germanakos, E. Papatheocharous, M. Constantinides and G. Samaras, "Supporting Adaptive Interactive Systems with Semantic Markups and Human Factors," in Proc. *Semantic and Social Media Adaptation and Personalization Workshop*, pp. 126-130, 2012

[5] M. Hori, K. Ono, M. Abe and T. Koyanagi, "Generating Transformational Annotation for Web Document Adaptation: Tool Support and Empirical Evaluation," *Journal Web Semantics: Science, Services and Agents on the World Wide Web*, vol. 2, no. 1, pp. 1-18, 2004

[6] S. Chen and X. Liu, "An integrated approach for modeling learning patterns of students in Web-Based instruction: A cognitive style perspective, " *Journal ACM Transactions of Computer-Human Interaction*, vol. 15, no. 1, pp. 1-28, 2008

[7] M. Belk, E. Papatheocharous, P. Germanakos and G. Samaras, "Modeling users on the World Wide Web based on cognitive factors, navigation behaviour and clustering techniques," *Journal*

Systems and Software, vol. 86, no. 12, pp. 2995-3012, 2013

[8] K. Reinecke, and A. Bernstein, "Improving performance, perceived usability, and aesthetics with culturally adaptive user interfaces," *Journal ACM Transactions of Computer-Human Interaction*, vol. 18, no. 2, article 8, 2013

[9] A. Li, L. Sbattella, and R. Tedesco, "PoliSpell: An adaptive spellchecker and predictor for people with dyslexia," in Proc. *User Modeling, Adaptation and Personalization*, pp. 302-309, 201

[10] P. Dolog and W. Nejdl, "Semantic Web Technologies for the Adaptive Web," In P. Brusilovsky, A. Kobsa, W. Nejdl (Eds.) *The Adaptive Web: Methods and Strategies of Web Personalization*, pp. 697-719, 2007

[11] T. Berners-Lee, J. Hendler and O. Lassila, "The Semantic Web," *Scientific American*, vol. 284, no. 5, pp. 34-43, 2001

[12] A. Maedche, B. Motik, L. Stojanovic, R. Studer and R. Volz, "Ontologies for Enterprise Knowledge Management," *Journal Intelligent Systems*, vol. 18, no. 2, pp. 26- 33, 2003

[13] H. Wache, T. Vögele, U. Visser, H. Stuckenschmidt, G. Schuster, H. Neumann and S. Hübner, "Ontology-Based Integration of Information - A Survey of Existing Approaches," in Proc. *Ontologies and Information Sharing Workshop*, pp. 108-117, 2001

[14] S. Gauch, J. Chaffee and A. Pretschner, "Ontology-Based User Profiles for Search and Browsing," *Journal Web Intelligence and Agent Systems*, vol. 1, no. 3-4, pp. 219-234, 2003

[15] J. Heflin, J. Hendler and S. Luke, "SHOE, A Knowledge Representation Language for internet Applications," (Tech. Rep. CS-TR-4078), Institute for Advanced Computer Studies, University of Maryland, College Park, 1999

[16] N. Guarino, C. Masolo and G. Vetere, "OntoSeek: Content-Based Access to the Web," *Journal Intelligent Systems*, vol. 14, no. 3, pp. 70-80, 1999

[17] S. Dill, N. Eiron, D. Gibson, D. Gruhl, R. Guha, A. Jhingran, T. Kanungo, S. Rajagopalan, A. Tomkins, J. Tomlin and J. Zien, "SemTag and Seeker: Bootstrapping the Semantic Web via Automated Semantic Annotation," in Proc. *World Wide Web Conference*, pp. 178-186, 2003

[18] N. Noy, M. Sintek, S. Decker, M. Crubezy, R. Fergerson and M. Musen, "Creating Semantic Web Contents with Protégé-2000," *Journal Intelligent Systems*, vol. 2, no. 16, pp. 60-71, 2001

[19] J. Kahan M. Koivunen, "Annotea: an Open RDF Infrastructure for Shared Web Annotations," in Proc. *World Wide Web Conference*, pp. 623-632, 2001

[20] Google RDFa, Retrieved February 06, 2013, from http://support.google.com/webmasters/bin/answer.py?hl=en&answer=146897

[21] H. Chang, C. Wang, T. Shih, L. Chao, S. Yeh and Lee, "A Semiautomatic Content Adaptation Authoring Tool for Mobile Learning," in Proc. *Advances in Web Based Learning Conference*, pp. 529-540, 2008

[22] M. Grigoriadou and K. Papanikolaou, "Authoring Personalised Interactive Content," in Proc. *Semantic Media Adaptation and Personalization Workshop*, pp. 80-85, 2006

[23] Y. Kuo and Y. Huang, "MEAT: An Authoring Tool for Generating Adaptable Learning Resources," *Journal Educational Technology & Society*, vol. 12, no. 2, pp. 51-68, 2009

[24] E. Papatheocharous, M. Belk, P. Germanakos, and G. Samaras, "Embracing cognitive factors and fuzzy logic in adaptive interactive systems," *Journal of Engineering Intelligent Systems*, vol. 21, no. 1, pp. 1-18, 2013

[25] R. Riding, "Cognitive Styles Analysis," *Learning and Training Technology*, Birmingham, UK, 2001

[26] R. Riding and I. Cheema, "Cognitive Styles – An Overview and Integration," *Journal Educational Psychology*, vol. 11 no. 3-4, pp. 193-215, 1991

[27] A. Baddeley, "Working Memory: Theories, Models, and Controversies," *Annual Review Psychology*, vol. 63, pp. 1-29, 2012

[28] RDFa Primer, Viewed online December 01, 2012, from http://www.w3.org/TR/xhtml-rdfa-primer

[29] J. Kirakowski and B. Cierlik, "Measuring the Usability of Web site," in Proc. *Human Factors and Ergonomics Society Annual Meeting*, 1998

AUTHORS' BIOGRAPHIES

Marios Belk is currently a Ph.D. Candidate at the Department of Computer Science, University of Cyprus. He obtained his B.Sc. and M.Sc. in Computer Science in 2007 and 2009 respectively. His research interests lie in the areas of HCI, Adaptive Interactive Systems and Usable Security. His research work has been published in accredited scientific journals and conferences, such as Elsevier JSS, ACM CHI, UMAP, INTERACT, including also a best paper award (Springer SouthCHI 2013). Marios has professional and research experience (2006-current) in the areas of user experience design, development and evaluation of user-centric interactive systems and also actively participates in numerous National and EU funded research projects.

Dr. Panagiotis Germanakos is a Research Scientist, and co-founder and Deputy Head of the Semantic and Cognitive Research Adaptivity Technologies (SCRAT) Research Group, of the Department of Computer Science, University of Cyprus (since 2003), and Senior User Experience Researcher at SAP AG (since 2013). He was an ERCIM Post-doctoral Research Fellow in the Web Applications for the Future Internet Research Group in IIT-CNR (2011-2012). He obtained his PhD from the National & Kapodistrian University of Athens (2008) and his MSc in International Marketing Management from the Leeds University Business School (1999). His B.Sc. was in Computer Science (1998) and also holds a HND Diploma of Technician Engineer in the field of Computer Studies (1996). His research interest is in Web Adaptation and Personalization Environments and Systems based on enhanced user modeling encompassing visual, cognitive and emotional processes, implemented on desktop and mobile/wireless platforms. He has over 100 publications including co-edited books, chapters, articles in journals, and conference contributions, and his work has been awarded, amongst others, with a best paper award (SouthCHI 2013) and a best student paper award (AH 2008).

Dr. Efi Papatheocharous is currently researcher at the Swedish ICT AB, Swedish Institute of Computer Science (SICS). Prior to this she was visiting Lecturer at the Department of Computer Science, University of Cyprus. Her Ph.D. studies were focused primarily in Software Engineering with specific research interest in Computational Intelligence and Software Cost Estimation. She obtained her M.Sc. from the University of Manchester in Advanced Computer Science with ICT Management, in 2005, her B.Sc. in Computer Science from the Computer Science Department, University of Cyprus, in 2004. She has been collaborating in a number of research projects at a National and European level and co-authored more than 30 papers published in books, journals and presented in international conferences.

Dr. Panayiotis Andreou is currently a Post-doctoral Researcher at the Department of Computer Science of the University of Cyprus. He was also a post-doctoral researcher at ID-Mind, Lisbon, Portugal in 04-08/2012 and at the Department of Computer Science at the University of Cyprus 2011-12. His main research interests include Data Management for Systems and Networks, Information Systems, Energy-efficient Distributed Processing, ICT services for eHealth and AAL. He has a long term participation in research projects funded from national and international organizations, including the European Union and the Cyprus Research Foundation (RPF). Specifically he has been participating in a number of IST projects related to mobile, wireless sensor networks and distributed computing, such as SocialRobot, CoLiving, IPAC, CONET, mPower, LinkCare, HealthService24, and also RPF-funded projects like: PersonaWeb, FireWatch, MELCO, EKPAIDEION, DITIS.

Dr. George Samaras is a Professor at the Department of Computer Science, University of Cyprus. He received a Ph.D. and M.Sc. in Computer Science from Rensselaer Polytechnic Institute, USA, in 1989 and 1985 respectively. He obtained his B.Sc. degree in Mathematics at the University of Athens, Greece (1982). His broad research interests span the areas of Mobile and Wireless Computing, Sensor Networks, Database Systems, Transaction Processing, Commit Protocols and Resource Recovery, Personalization and Context-based Systems, WWW Information Retrieval. He has published more than 220 articles in conferences and journals and co-authored two books and a number of book chapters, and his work has been awarded with three best paper awards (ICDE 1999, AH 2008 and SouthCHI 2013).