Adaptation to Learning Styles in E-Learning: Approach Evaluation

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Abstract: It is obvious that we all have different approaches to learning. Psychologists call these individual differences *learning styles* (LS). Researchers provide recommendations for possible *instructional strategies* to support some LS in educational settings and, in particular, in web-based environments. The problem with most existing implementations is that the systems are bound to a certain LS model, and the LS representation it involves is defined and implemented by the designers of the system. The purpose of our approach is to separate definition of strategies from the system implementation and to allow authors or psychologists to define their own strategies in a domain- and LS-model independent way. We define a language for specifying instructional strategies and strategies for monitoring a learner's preferences, and a way of applying and visualizing them in the AHA! (Adaptive Hypermedia Architecture) system. This paper presents the results of our approach evaluation from the point of view of LS authoring easiness and satisfaction with the resulting adaptation.

Introduction

Learning styles and their effect on learning have been studied very carefully in (Coffield et al, 2004). The review shows that this is a complex research field. Despite the field's long history it poses a lot of questions to which the answers are still unclear. One of these questions is whether it is reasonable to apply knowledge about a learner's LS in order to (try to) improve learning outcome. At first glance it seems quite logical that matching the learner's LS with the applied teaching method (or instructional strategy) will increase that learner's performance. However results of experiments with various LS do not provide unequivocal answers. A number of experiments show improved performance in matched conditions, others do not show any significant difference. Moreover, some psychologists (Holodnaya, 2002) consider learning in mismatched conditions in some cases to be beneficial in the sense that this helps in developing new skills. Opinions of different researchers vary from strongly recommending the use of (adaptation to) LS in learning (see in Coffield, 2004) to completely ignoring the learner's LS (Freedman, 1980).

Despite these contradictions we consider application of LS in learning to be useful and deserving further research. In our view it is good for the learners to be aware of their LS and to know what their strengths and weaknesses are. We consider it important to provide the learners with a variety of instructional strategies and letting them either choose the one they are most comfortable with or letting them try some unfamiliar strategies.

A number of systems have been implemented recently to provide support for LS (see the review in Stash et al, 2004). One of the main problems with the existing approaches is that the implementers of the systems chose a particular LS model and implemented the corresponding LS into their systems. In our view the task of defining which LS to apply in an application and the LS representation should be left to the author of an online course (application) or to a psychologist, instead of having the designers of the system define the LS representation and the corresponding adaptation. In (Stash et al, 2005) we considered the importance of making the authoring process of creating such an application as simple and intuitive as possible. As one of the solutions for this we discussed the reuse of *static* and *dynamic behavior*, focusing on the latter one. We defined a language for specifying different types of adaptive behavior to represent various LS and showed their application in the AHA! system (De Bra et al, 2005). In (Stash et al, 2005) we compared the defined LAG-XLS ("LAG-excels") language with a more generic language for AH – LAG (Layers of Adaptive Granulation Model) (Cristea and Verschoor, 2004) – as its theoretical basis. In this paper we outline what type of strategies can be created in LAG-XLS, how they are applied and visualized in AHA! applications, and we present the evaluation results of our approach.

Adaptation to Learning Styles in AHA!

LAG-XLS allows three types of adaptive behavior (Stash et al, 2005): *selection of items* to present (e.g. media types); *ordering* information by type (e.g., examples, theory, explanation); and creating *different navigation paths* (e.g. breadth-first vs. depth-first). Strategies are defined as XML (Extensible Markup Language) files using a predefined DTD (Document Type Definition). XML was chosen as it is an extensible language and a W3C standard. LAG-XLS also allows for the creation of *meta-strategies,* tracing users' preferences for certain types of information or reading order.

Creating an AHA! adaptive application consists of defining the domain/adaptation model (usually with the Graph Author tool, Figure 1), followed by writing application content, consisting of creating XHTML pages (De Bra et al, 2005). We extended the system by allowing for the possibility of applying *adaptive strategies,* as specified in LAG-XLS, to the domain model (see Figure 1). The authors can create their own strategies or reuse existing ones. We pre-defined *adaptation strategies* for the following learning styles (Coffield, 2004; Felder and Soloman, 2000): Active versus Reflective, Verbalizer versus Imager, Holist (Global) versus Analytic, Field-Dependent versus Field-Independent (FDvsFI); strategies for inferring user preferences (*adaptation meta-strategies*) for textual or pictorial information (TextVersusImagePreference), and navigation in breadth-first or depth-first order (BFversusDFPreferences). An author can also create variations of these predefined strategies. The requirements for doing this are to use elements as defined in the LAG-XLS DTD, and to ensure that the domain model concepts have the attributes required by the strategies (Stash et al, 2005). Authors choose which strategies to apply in a particular application, and in which order of preference (in case of application of several strategies, order can be important).

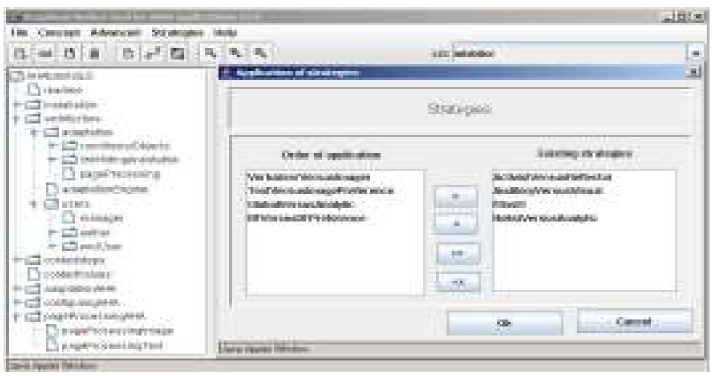

Figure 1: Graph Author, strategies application: authors select strategies and application order

Visualization of strategies application in AHA!. Student experiments were performed with two applications: "AHAtutorialLS": a tutorial about AHA! using learning styles, and a smaller example called "WritingApplets". The learner sets his/her preferences (e.g. what his/her LS is) via a registration form. Figure 2 shows the presentation of the "AHAtutorialLS" material to a user with a visual preference (*imager* style) and preference for getting an overview of all of the material at a high level before introducing the details (*global* style). Based on the visual preference, the topic about the "adaptation process in AHA!" is presented through an image. In the left frame, the user can see the table of contents. There, links to topics are annotated (*recommended topics*: blue with green bullets; *not recommended*: black with red bullets; *recommended & visited topics*: purple with white bullets) so that a user is first guided to concept pages at the same level in the hierarchy as the current concept, and afterwards to lower level concepts. In the example, after reading about the "adaptation process in AHA!", the link to the same level topic "adaptation engine" is presented as desirable.

Figure 3 shows the presentation of the same application to a user with a preference for textual material (*verbalizer* style) and for studying each topic in detail before going to the next one (*analytic* style). To him/her, the "adaptation process in AHA!" topic is presented with text. The adaptive link annotation in the table of contents is also different. After reading about the current topic the user is guided towards more details on the same topic; therefore, the link to the page on "conditionalObjects" is annotated as desirable.

If a learner does not choose any preference via the registration form the system will present all links in the left frame as desirable. For topics that can be presented differently for users with visual or textual preference, a "default" representation is shown.

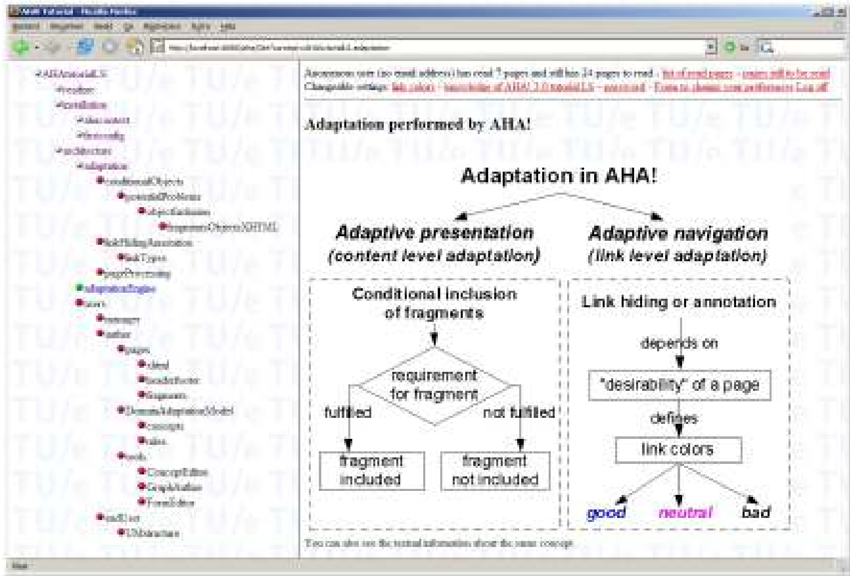

Figure 2: Presentation of the application to the user with *imager* and *global* styles

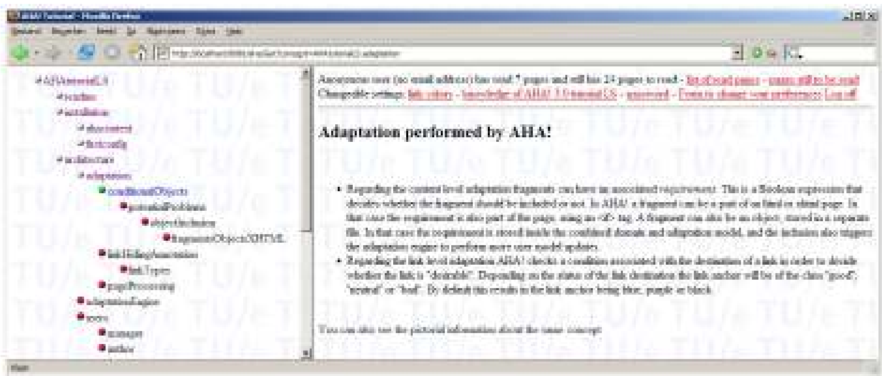

Figure 3: Presentation of the application to the user with verbalizer and analytic style

The learner can also let the system trace preferences. In the "AHAtutorialLS", the system can, after a number of browsing steps, identify preferences for text versus images and for navigation order. AHA! also allows learners to change their user model settings via special forms. Therefore, if a learner does not agree with the system's assumptions about his/her preferences he/she can inspect his/her user model and make changes in it.

In the "WritingApplets" example, a learner with the *active* learning style is shown an activity first, then an example, explanation and theory whereas for the learner with the *reflective* style this order is different – he/she is shown an example first, then an explanation and theory, and finally he/she is asked to perform an activity.

Empirical Evaluation of LAG-XLS

Evaluation Settings

To evaluate our approach, we tested the application of (meta-)instructional adaptation strategies created in LAG-XLS and applied to AHA! within an Adaptive Hypermedia (AH) course (which is currently available at http://wwwis.win.tue.nl/2ID20/, but changed from the time the experiment was done). The course was given to a group of 34 students composed of 4th year undergraduate students studying Computer Science, combined with 1st year Masters students in Business Information Systems at the Eindhoven University of Technology.

The Experimental Assignment

The experimental steps of the LAG-XLS assignment were as follows.

1. The students had to perform the assignment in groups of 2-3 people in 4 weeks.
2. They had to install the AHA! system version that supports LS on their notebooks. The distribution contained two example applications – "AHAtutorialLS" and "WritingApplets" – and a number of strategies to apply:
   - Two *instructional* strategies were used: VerbalizerVersusImager and GlobalVersusAnalytic; as well as two *monitoring* strategies: TextVersusImagePreference and BFvsDFpreference (breadth-first versus depth-first preference). These had to be applied to the "AHAtutorialLS" application. The instructional strategy ActivistVersusReflector had to be applied to the "WritingApplets" example.
   - The students were asked to work with the system as *authors* as well as as *end users*. As *authors* they used the Graph Author tool – to see the concept structure of the courses and to select strategies to apply to a particular course. As *end users* they had to experience the result of applying the strategies, while browsing through the course. They had to analyze how the same course is presented with different preference settings corresponding to different LS, as well as with the option of automatic preference tracing.
3. After the above steps were completed, the students had to fill out a questionnaire to report on their experience of working with the system.
4. The students were also asked to fill out the Felder-Solomon "Index of Learning Styles Questionnaire" (ILS) (Felder and Soloman, 2000). This psychological questionnaire maps a set of 44 questions over 4 dimensions representing learning preferences and styles. For the LAG-XLS language, dimensions of interest are represented by the values extracted for such LS as *active* versus *reflective*, *sensing* versus *intuitive*, *visual* versus *verbal*, *sequential* versus *global*. The aim was to examine if the students' preferred settings for working with the applications (as selected by them when using the LAG-XLS system) corresponded to the LS revealed by the ILS questionnaire. Moreover, these tests were aimed at checking if the LAG-XLS AHA! system's inferred preferences matched those of the ILS questionnaire.
5. Finally, after experimenting and analyzing the existing strategies, the students were asked to create their own strategies, or a variation of the existing (predefined) strategies, in the LAG-XLS language, and to apply them in the provided applications.

Experimental quantitative results

Figures 4 and 5 present the comparison of students' stated preferences corresponding to LS (based on the provided LS description and LS representation in the given AHA! applications) and the ILS questionnaire results.

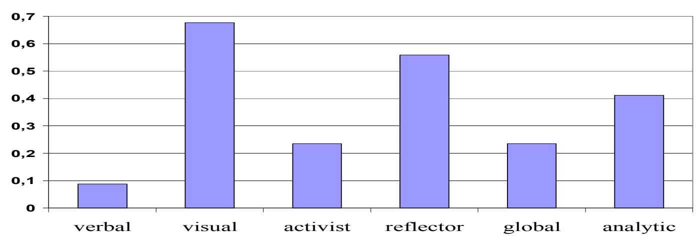

Figure 4: Students' average stated preferences (praxis - via LAG-XLS questionnaires) (percentage representation)

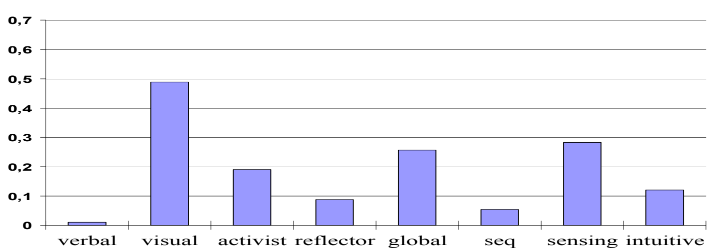

Figure 5 : ILS questionnaire results : average (theory - via ILS questionnaires) (percentage representation)

Surprisingly, results show that masters students still have little understanding about their own knowledge processing abilities; they seem to posses little meta-knowledge on their preferences, as reflected in the differences between the two figures. Especially notable is the difference between stated "analytic" (equivalent in this assignment with "sequential") preference and the ILS questionnaire results, showing a "global" tendency. Preferences also differ in the "active versus reflector" group. In the ILS, the activist tendency is stronger, whereas in actual use, the "reflector" tendency dominates. The students' comments (following section) partially explain this gap between theory and praxis. One point in which both questionnaire results coincide is the students' strong image preference. However, its intensity is, again, different in praxis and theory.

The students' prior knowledge is shown in Figure 6. As most of them are computer science students, unsurprisingly, their XML knowledge was far greater than their prior knowledge on learning styles. The fact that most students had never heard of LS before may be another explanation for the fluctuating results on learning preferences.

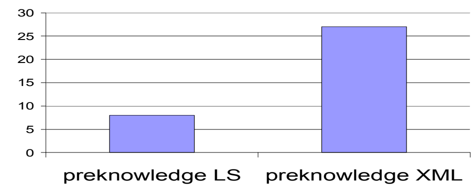

Figure 6: Students' pre-knowledge (expressed in number of students claiming that knowledge)

Figure 7 depicts the students' general impression of their first encounter of learning styles in combination with AH. Students considered the implementation of *adaptive instructional strategies* and (*monitoring*) *meta-strategies* useful for adaptive educational systems (82%). Less strong, but still positive was their conviction about this experimental process being of a *pleasant* nature (67%). Most of the students having reservations also gave some justifications, as is shown and discussed in the next section. Figure 8 also shows that a majority of the students considered the work *easy*, although the percentage of students with that opinion is slightly lower (54%). This difference shows that although students realized the necessity and importance of adaptive strategies in AH and enjoyed the challenging programming work they did not consider it trivial. Therefore reuse of ready-made, custom-designed strategies is necessary to be made available to AH authors to reduce creation time and costs.

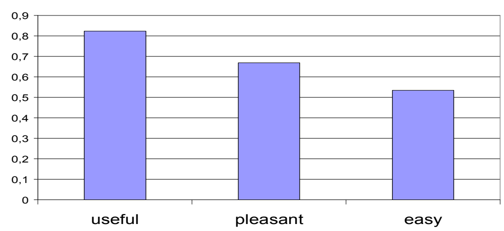

Figure 7: Overall impression of instructional strategies and experiments (in percentage)

Figure 8 shows the average declared percentage of understanding and problems that students encountered. An ideal distribution should create a filled pentagon. A good distribution should at least have all the corners of the pentagon at values above 0.5, as is almost the case here. The students *understood the application strategies* – important as the core of the LAG-XLS language understanding - and were greatly *satisfied with the presentations*. They *understood the AHA! Graph author* very well. However creation of their own strategies was the most difficult problem (only 47% had no problems with editing). When they figured out editing, their strategy changes worked well (75%).

Figure 9 contains the comparison of selected preferences in LAG-XLS and the *strategies* that were applied, as well as the *meta-strategies* that deduced these preferences. All strategies and meta-strategies were considered appropriate by the majority (over 65%) of students. The "winning" *strategy* is the "verbalizer vs. imager", which the students considered most accurate. Following are the "global vs. analytic" (73%) and "activist vs. reflector" strategy (67%). From the *meta-strategies*, the one liked best by students was the "text vs. image" meta-strategy. Actually, for the latter, most students noticed that it traced their behavior within *3 navigation steps*. The "BFvsDFPreference" strategy was a more complex strategy, as, especially for a user with a breadth-first preference, it had to analyze a larger number of steps till the conclusion was made. The number of steps the students experienced was between 7 and 14, with an average of *13 steps*.

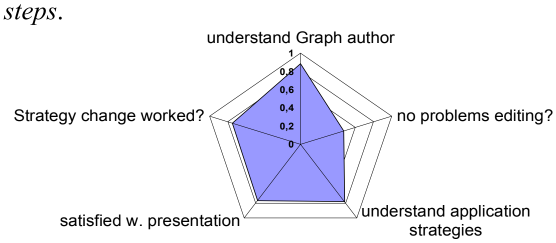

Figure 8: Understanding the system and working with it (in percentage)

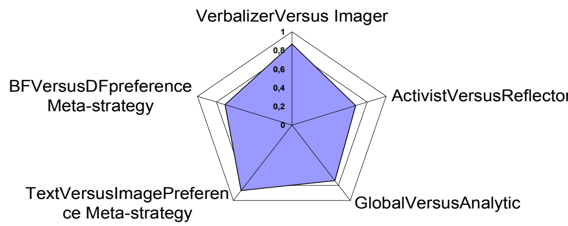

Figure 9: Students comparison of questionnaire results versus praxis results whilst working with the system (praxis via questionnaires versus praxis deduced by system – in percentage)

Finally, Figure 10 compares the average percentage of the performance of the *meta-strategies* as evaluated via the students' answers. The students were less satisfied with the performance and accuracy of their own strategies, and preferred the already implemented strategies. Clearly, both pre-implemented strategies scored above average, showing the advantage of reuse.

Figure 10: Tracing the correctness of the monitoring strategies (percentage representation)

3.4 Experimental Qualitative Results

The students were asked to also detail their own judgements and explain their understanding of the process of using the AHA! system together with the implementation of learning styles via the LAG-XLS language. Below are some sample comments.

1. When asked if they thought that application of different instructional/monitoring strategies for educational AH is useful, students replied:

- "yes", because: "*I believe that the correct application of learning styles can be a good aid in studying. Presenting information in a user preferred form makes the user work and study more efficiently.*"; "*Since each person is unique, and does his/her best when anything is tailored to his/her unique needs. Perception skills vary from person to person, so if it is possible to give each person, the best possible method of learning suited to him/her, it is the best possible educational method.*"; "*Adapting a big amount of information to the best way the user perceives could lead to saved time and a better understanding of the studied problem.*"; "*When you know what kind of person you are (or the computer knows) it saves time, because you don't have to look for what you want, you automatically get it. And if you want more or other information on some subject then you normally* *would, you can just click on a link or something and still get it*." One of the students considered applying LS in AH a good thing but correctly noticed – "*It is very easy to fool the system. The system doesn't check if the content is understood by the reader*" – a typical AH problem.

- "no", because "*In theory the adaptive hypermedia could adjust to the preferred learning style of the student and ensure the most benefit from the learning experience. However, in practice, I believe the system has too many weak chains to be successful; it depends highly on competent authors, a wide availability of learning material in many different forms, and the ability of a computer program to (correctly) reason about a human behind the terminal.*" Here, the student correctly identifies the authoring problem: adaptive hypermedia is more time-consuming and costly than regular hypermedia – the price paid for adaptation (Brusilovsky, 2003).

2. In explaining why their own selection and meta-strategy for learning style detection in LAG-XLS were different from the results of the ILS questionnaire, students answered: "*I generally like to see the global picture first and then go into the details. However in the tutorial, this raises a problem for me. If I read the high level concepts first and then go into the details, I have forgotten what the high level contents were when reaching its details and then I have to read back into it. That is annoying, so I prefer to read depth-first. So actually I'm quite unsure what I prefer. Maybe I do prefer depth first. It's a bit hard to tell really.*" The described problem may be caused by the fact that the example application "AHAtutorialLS" was created by the authors of the system who might not have enough psychological knowledge about how to correctly structure the application in order to support the global and analytic LS. However the system provides the necessary functionality to present the application either in breadth-first or in depth-first order as recommended by the psychological research to support global and analytic LS correspondingly. *"My pictorial preference in the Tutorial was not representative of my general preferences (which were shown by the questionnaire). In this specific Tutorial application the pictures however were so good that these were preferred by me."* Other students also mentioned that LS preferences can vary in different domains.

3. When asked about another strategy that they would like to apply but doesn't work in LAG-XLS or that they would have liked to see implemented, but didn't know how to, students replied:

- *"developing an entirely new strategy is impossible without completely altering the entire Tutorial application … We looked at the XML-files and of course we could make small alterations which change the number of steps after which a preference is derived, but we did not think that this was what you were looking for, since the general appearance of the system would be exactly the same, and the results are easily predicted."*
- *"GoodReadingVersusFastReading – a strategy that is able to track if a reader really does an effort to study/read the educational material presented. That way the system could 'warn' the user when he or she just seems to be clicking trough the material instead of actual 'learning' a matter".* This is an interesting strategy, for its realization additional AHA! programming is necessary to check the time spent on reading AHA! application pages.
- *"DetailedVersusSummarised – a strategy that shows only the default content for the user who likes summaries, default content, images and links to those who likes details and a pair monitoring strategy for inferring a preference for summaries or detailed presentation.* This strategy can be implemented as a variation of the existing Verbalizer versus Imager strategy.

Thus most students were only able to create variations of the existing strategies by using different names for presentation items and by increasing/decreasing the number of steps required by the monitoring strategies to achieve a threshold. The students did not come up with any completely new strategies.

4. When asked to give some more suggestions for possible improvements of the current LAG-XLS implementation, students answered: to improve the AHA! installation; to have more help explaining the effect and application of strategies.

Discussion and Conclusion

Numerous experiments have been carried out by different researchers to find out the correlation between matching educational course presentation with the learner's LS and his/her outcome performance. The purpose of this study was slightly different. We assumed in the beginning of the paper that the application of LS is a useful endeavour (this was also confirmed by a number of students involved in the experiment). And we concentrated more on the evaluation of the presented approach from the point of view of easiness of authoring, expressivity of LAG-XLS for creating a variety of strategies and of the students' satisfaction with the resulting presentation/adaptation.

The evaluation results show that students understood the process and liked being involved in it, in spite of the fact that it was not a simple task. It is very reassuring that our students understood the basics of learning styles application, although they are computer science students, with little or no knowledge in this field prior to the course. The students were satisfied with the resulting presentations. This exercise shows also the challenges of the *end-user* side, the *learner*: theory and praxis do not always match in identification of learning styles. The end-user rarely has meta-knowledge of this type. Some of the students correctly identified this gap. However the most difficult part of the assignment was the evaluation of the LAG-XLS expressivity. The students could mainly think of some modifications to the existing strategies. However, the majority was not able to create new strategies from scratch. The cause of this is yet to be determined: a possible explanation is the short time they had; another one, the fact that the problems with the system installation detracted from the quick application of the potential of the language; finally, it might just be that they were aiming too high (see comment on what the teacher might want). On the other hand, for this part of the experiment it would be more interesting to involve LS specialists, instead of computer scientists, focusing mainly on the *qualitative aspects* instead of the *technical aspects* of the language.

It is clear that the creation process of adaptive behaviour in itself requires a lot of psychological and/or pedagogical knowledge. As we are not psychologists, the main aim of our research is to allow the authors with experience in pedagogical psychology to design different types of strategies and apply these strategies to the applications. Moreover, the question about how to structure the application and organization of the materials to correctly suit different learning styles is left for the author of the application or psychologist.

For further research, we also aim to extend the adaptation language enabling the author to define more complex variations of these strategies. We are planning to apply OWL (Web Ontology Language) as it provides a number of useful constructs “oneOf”, “intersectionOf”, “unionOf”, etc. Furthermore, the LAG-XLS language should be usable for more general purposes, other than just specifying instructional strategies for learning styles.

Acknowledgements

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