

University of Birmingham Research at Birmingham

Usability and Effectiveness Evaluation of Adaptivity in E-Learning Systems

Alshammari, Mohammad; Anane, Rachid; Hendley, Robert J.

DOI:

10.1145/2851581.2892395

License:

None: All rights reserved

Document Version
Peer reviewed version

Citation for published version (Harvard):

Alshammari, M, Anane, R & Hendley, KJ 2016, Usability and Effectiveness Evaluation of Adaptivity in E-Learning Systems. in *CHI EA '16 Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. Association for Computing Machinery, pp. 2984-2991, CHI 2016 Conference on Human Factors in Computing Systems, San Jose, CA, United States, 7/05/16. https://doi.org/10.1145/2851581.2892395

Link to publication on Research at Birmingham portal

Publisher Rights Statement:

© ACM, 2016. This is the author's version of the work. It is posted here by permission of ACM for your personal use. Not for redistribution. The definitive version was published in Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, http://doi.acm.org/10.1145/2851581.2892395

Checked 5/7/2016

General rights

Unless a licence is specified above, all rights (including copyright and moral rights) in this document are retained by the authors and/or the copyright holders. The express permission of the copyright holder must be obtained for any use of this material other than for purposes permitted by law.

•Users may freely distribute the URL that is used to identify this publication.

•Users may download and/or print one copy of the publication from the University of Birmingham research portal for the purpose of private study or non-commercial research.

•User may use extracts from the document in line with the concept of 'fair dealing' under the Copyright, Designs and Patents Act 1988 (?)

•Users may not further distribute the material nor use it for the purposes of commercial gain.

Where a licence is displayed above, please note the terms and conditions of the licence govern your use of this document.

When citing, please reference the published version.

Take down policy

While the University of Birmingham exercises care and attention in making items available there are rare occasions when an item has been uploaded in error or has been deemed to be commercially or otherwise sensitive.

If you believe that this is the case for this document, please contact UBIRA@lists.bham.ac.uk providing details and we will remove access to the work immediately and investigate.

Download date: 16. Apr. 2024

Usability and Effectiveness Evaluation of Adaptivity in E-Learning Systems

Mohammad Alshammari

School of Computer Science
University of Birmingham
Birmingham, B15 2TT, UK
m.t.m.alshammari@cs.bham.ac.uk

Rachid Anane

Faculty of Engineering and Computing Coventry University Coventry, CV1 5FB, UK r.anane@coventry.ac.uk

Robert J. Hendley

School of Computer Science University of Birmingham Birmingham, B15 2TT, UK r.j.hendley@cs.bham.ac.uk

Permission to make digital or hard copies of part or all of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for third-party components of this work must be honored. For all other uses, contact the Owner/Author.

Copyright is held by the owner/author(s). CHI'16 Extended Abstracts, May 07-12, 2016, San Jose, CA, USA ACM 978-1-4503-4082-3/16/05. http://dx.doi.org/10.1145/2851581.2892395.

Abstract

Designing effective and usable adaptive e-learning systems represents a challenge because of the complexity which arises when meeting the needs of learners. This is compounded by the lack of well-designed experimental evaluations of adaptive e-learning systems in general, and of their usability and effectiveness in particular. This paper offers an experimental evaluation of the effect of adaptation, taking into account both the perceived usability level and learning effectiveness. A controlled experiment was conducted with 75 participants and produced significant results. They indicate that an adaptive version has a significantly higher level of perceived usability and learning effectiveness than a non-adaptive version.

Author Keywords

Usability; effectiveness; adaptivity; learner-system interaction; e-learning; experimentation

ACM Classification Keywords

H.5.m. [Information interfaces and presentation (e.g., HCI)]: Miscellaneous; K.3.1 [Computers and Education]: Computer Uses in Education;

Introduction

As a means of enhancing learner-system interaction, instructional material can be adapted to the learner's needs by, for instance, providing personalized learning

paths, changing the interface layout or generating relevant material links [1,12]. However, designing effective adaptive systems is seen as a challenging task [17]. Adaptive systems may, for instance, violate standard usability principles such as consistency and learner controllability [17,18].

When a system is not sufficiently usable, learners may become frustrated and focus on the e-learning system rather than on the learning content [7]. An e-learning system can be usable in terms of its usage but not in terms of the underlying pedagogical perspective and vice versa. This issue may, therefore, lead to less effective and less efficient learner-system interaction. Both usability and learning effectiveness are important issues that should be taken into account when designing and evaluating adaptive e-learning systems (AESs) [9,18]. This points to a better understanding of where adaptivity in e-learning systems is useful, and where it is harmful [7].

Many AESs have been designed and implemented. However, many suffer from a lack of useful experimental evaluation [1]. More particularly, usability and learning effectiveness evaluations are often not considered as key criteria in the iterative design process of these systems. Zaharias argues that "very little has been done to critically examine the usability of e-learning applications" [25].

This paper provides an initial experimental evaluation on the effect of adaptation in learning by testing the AdaptLearn system [3,6] against a non-adaptive version of the same system. The main aim is to determine whether adaptivity influences perceived

usability and enhances learning given the fact that both systems have the same interface layout.

Background

This section presents brief outline of learner characteristics such as learning style and learner knowledge. It also covers the concept of adaptivity in e-learning systems.

Learner Characteristics

Learners may differ in their characteristics such as goals, knowledge, skills and learning style, motivation and emotion [14]. These characteristics can be classified into cognitive (knowledge level, intellectual abilities and skills), conative (wants, intentions, goals and learning style) and affective (learner's emotions and motivation) categories [22]. Matching these characteristics is essential to learner-system interaction in e-learning systems.

Learning style and knowledge level have often been considered the most important learner characteristics to be integrated in AESs [12]. Learning style characterizes the way in which a learner obtains or perceives information in a learning environment for meaningful information connection and retention in memory [19]. Learner knowledge refers to the extent to which a learner understands, applies and recalls specific information related to a particular topic.

Adaptivity in E-Learning Systems

Adaptivity in the context of learner-system interaction is defined as the process of tailoring the presentation of learning material and its sequencing to meet the learner's requirements [12]. For example, instructional strategies can be adapted to meet the learning styles

and preferences of learners. Systems that adapt according to different user characteristics such as preferences and skills are typically called adaptive systems or user-adaptive systems [5]. User-adaptive systems have been defined as "the technological component of joint human-machine systems that can change their behavior to meet the changing needs of their users, often without explicit instructions from their users" [15].

Brusilovsky [13] argues that adaptivity in e-learning systems is very important in order to meet the learner's characteristics such as knowledge level and learning style so that an AES can provide the learner with relevant learning material and facilitate navigation between them. AESs are an improvement to the dominant, 'one size fits all' approach to the development of e-learning systems. A system may highlight appropriate information, recommend what that learner studies or construct personalized learning paths [12].

Adaptivity Approach

An AES, called AdaptLearn, was designed based on learning style and learner knowledge [3,6]. A screenshot of AdaptLearn is presented in Figure 1. AdaptLearn is used in this work to investigate the effect of adaptation in learning. It offers two main adaptive techniques: personalized learning paths and adaptive quidance.

Personalized learning paths are generated for individual learners. These paths provide links to learning material in a customized order, hide links to material which is not appropriate to an individual learner or generate

links to more relevant material as needed. The ordering, generation or removal of links are designed to meet learner needs in order to enhance learning and to facilitate the interaction with the system [13]. Although these adaptive techniques may violate some usability standards such as consistency and learnability [18], they still have significant potential to enhance learning and learner satisfaction when appropriately incorporated in AESs [7]. The provision and recommendations of learning material may help learners to accomplish their learning tasks successfully and support learner-system interaction [13].

The other technique, adaptive guidance aims to direct learners and offer recommendations and feedback as learners progress through their learning tasks. For example, when constructing or modifying a learning path, the system provides recommendations by highlighting which items to study and in which order. In addition, feedback on learning progress and motivational and award messages are also provided.

Evaluation Methodology

A between-subjects experimental design, in which each participant experiences only one condition, was used in the experiment; it is considered more appropriate than a within-subjects design because it avoids the problems of carryover and learning effect from one condition or factor to another; these are usually associated with a within-subjects design, in which each participant experiences more than one condition [24].

Hypotheses and Variables
Two hypotheses are put forward for this research:

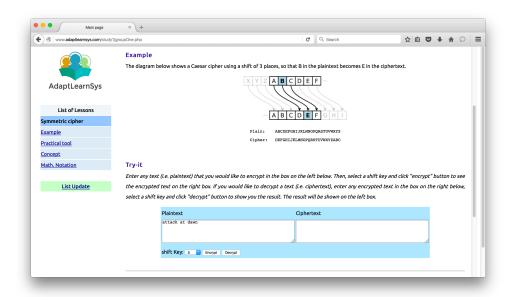


Figure 1. A screenshot of the AdaptLearn interface.

- H1. An adaptive e-learning system based on learning style and knowledge level yields significantly higher levels of perceived usability than a non-adaptive e-learning system.
- H2. An adaptive e-learning system based on learning style and knowledge level is significantly more effective than a non-adaptive e-learning system.

Two experimental conditions were proposed, an adaptive condition and a non-adaptive condition. In the former, participants interacted with the AdaptLearn system. In the non-adaptive condition, participants interacted with the same system but without the feature of adaptivity. The perceived level of usability

and learning effectiveness are the main dependent variables measured in the experiment.

Measurement Tools

A reliable and validated instrument called the Index of Learning Style (ILS) questionnaire was used to identifying the learning style of learners [16].

The perceived level of usability is measured by the system usability scale (SUS) questionnaire [10], a quick, reliable and widely used test of system usability in both academia and industry [23]. SUS has 10 questions, each offering five responses with anchors ranging from "strongly disagree" to "strongly agree".

Learning effectiveness is measured using a pre-test and a post-test. Each test involves 22 multiple-choice questions. Each question in the tests has five options, with the fifth option being "I do not know". Three domain experts took part in checking the validity of the learning content and the pre- and post-tests.

Procedure

The experiment involved eight sessions of about 85-110 minutes. Participants were welcomed and informed of the experimental procedure. They were asked to access the system through an Internet browser and completed a demographic data form and the ILS questionnaire using the system. Then, the system randomly assigned participants to the adaptive or nonadaptive group and directed them to complete a pretest. The next step involved the study by participants of learning material on computer security, as the application domain of the system [4]. When each learning lesson is completed, a post-test was provided by the system to learners, so that the scores of these tests could be used to measure the learning effectiveness at the end of interaction with the system. At the very end of the learning session the participants completed the SUS questionnaire.

Results

The experiment was conducted with 75 participants, 43 males (57.3%) and 32 females (42.7%). The adaptive group involved 39 participants whereas the non-adaptive group had 36 participants. The participants were undergraduate students in a computer science degree program. The mean age of the participants was 22.21 (SD=3.13), the maximum age was 36 and the minimum age was 19.

Usability

Hypothesis H1, which concerns perceived usability level, was tested. The usability scores for the adaptive system (Mean=79.46, SD=13.14) and the non-adaptive version (Mean=71, SD=13.67) should both be regarded as acceptable [3], as the average score of each system is larger than 70 [8]. This may imply that both systems are useful and valuable in learning and the learners found them easy to use.

In this experiment, the two versions (adaptive and nonadaptive) were also compared in order to gain a deeper insight into their usability and to establish whether the provision of adaptivity has any significant impact on usability. As there was homogeneity of variance between the study groups as assessed by Levene's test for equality of variances, F=0.07, p=0.79 and as data was normally distributed, an independent sample *t*-test was conducted to compare the two conditions by using an alpha level of 0.01. It was found that there was a statistically significant difference between the general usability score of the two versions, t(73)=2.73, p<0.01, d=0.63 [3]. H1 is therefore confirmed; it can be inferred that the adaptive e-learning system based on learning style and knowledge level yields significantly higher levels of perceived usability than a non-adaptive e-learning system.

Learning Effectiveness

It was found that the participants who used the adaptive version had higher learning effectiveness scores (Mean=86, SD=17.20) than participants who used the non-adaptive version (Mean=65.03, SD=19.85). Here, effectiveness is defined as the learning gain (the difference between the post- and pre-tests).

As there was homogeneity of variance between the study groups as assessed by Levene's test for equality of variances, F=1.37, p=0.24 and as the data was normally distributed, an independent sample t-test was also run. There was a statistically significant difference between learning effectiveness scores of the adaptive version and the non-adaptive version with a large effect size, t(73)=4.90, p<0.001, d=1.13. H2 is therefore confirmed; it can be concluded that the adaptive e-learning system based on learning style and knowledge level is significantly more effective than a non-adaptive e-learning system.

Discussion

This paper is concerned with the experimental evaluation of adaptivity in terms of learning effectiveness and perceived level of usability. This involved a controlled experiment set in a realistic learning environment with a number of participants. This conforms to a large extent to the approach which is advocated as appropriate in the evaluation of AESs [1,11]. This research contrasts with some of the related work where the experiments were limited in scope, and where the size of the sample was very small [1,11,21]. More importantly, this is one of the few studies which considers a combination of usability and learning effectiveness of adaptivity. This experiment provides more evidence and offers results on the perceived usability level and learning effectiveness and on the importance of adaptivity in e-learning systems to enhance learner-system interaction.

Although the adaptive system and the non-adaptive system used in the experiment displayed the same interface layout, significant results related to learning effectiveness and the perceived usability level of the

adaptive version were generated; adaptivity in elearning systems enhances both the perceived level of general usability and learning. The high level of perceived usability may lead to learners who are more satisfied, engaged and more motivated to use the AES [2,7,25]. It may be the case that a highly usable AES may improve learning and help learners to focus mainly on their learning tasks rather than system functionality [20].

This experimental evaluation is useful because it sheds some light on the potential benefits of adaptivity. Adaptivity may influence learners to think that the system would support them dynamically in accordance with their knowledge and preferences. Learners may also find that an adaptive system which provides personalized feedback and recommendations based on their interaction with the system is easier to use. The recommendations of the adaptive system may also heighten their intellectual curiosity and improve satisfaction and engagement. It may be the case that once learners gain a deeper appreciation of the adaptive system, they may find it more useful. In contrast, learners may find the non-adaptive system rigid and unresponsive to their needs; they may thus be less likely to use the non-adaptive version as a tool for learning.

The experimental evaluation was based on a short-term study, and although the sample was adequate it was not very large. In addition, few learning resources were incorporated in the system. A long-term evaluation with more participants and with more objective measures of usability is desirable in future experiments.

References

- 1. Yavuz Akbulut and Cigdem Suzan Cardak. 2012. Adaptive educational hypermedia accommodating learning styles: A content analysis of publications from 2000 to 2011. *Computers & Education* 58, 2: 835–842.
 - http://doi.org/10.1016/j.compedu.2011.10.008
- M Alshammari, R Anane, and R J Hendley. 2015. Students' Satisfaction in Learning Style-Based Adaptation. Advanced Learning Technologies (ICALT), 2015 IEEE 15th International Conference on, 55–57. http://doi.org/10.1109/ICALT.2015.56
- 3. Mohammad Alshammari, Rachid Anane, and Robert J Hendley. 2015. Design and Usability Evaluation of Adaptive e-learning Systems Based on Learner Knowledge and Learning Style. In *Human-Computer Interaction--INTERACT 2015*. Springer, 584–591.
- 4. Mohammad Alshammari, Rachid Anane, and Robert J Hendley. 2015. The Impact of Learning Style Adaptivity in Teaching Computer Security. Proceedings of the 2015 ACM Conference on Innovation and Technology in Computer Science Education, 135–140.
- Mohammad Alshammari, Rachid Anane, and Robert Hendley. 2014. Adaptivity in E-Learning Systems. The 8th International Conference on Complex, Intelligent, and Software Intensive Systems (CISIS 2014), 79–86. http://doi.org/10.1109/CISIS.2014.12
- Mohammad Alshammari, Rachid Anane, and Robert Hendley. 2015. An E-Learning Investigation into Learning Style Adaptivity. The 48th Hawaii International Conference on System Sciences (HICSS-48), pp11–20. http://doi.org/10.1109/HICSS.2015.13

- 7. Carmelo Ardito, Maria Francesca Costabile, Marilena De Marsico, et al. 2006. An approach to usability evaluation of e-learning applications. *Universal access in the information society* 4, 3: 270–283.
- Aaron Bangor, Philip T Kortum, and James T Miller. 2008. An empirical evaluation of the system usability scale. *Intl. Journal of Human--Computer Interaction* 24, 6: 574–594.
- 9. David Benyon. 1993. Adaptive systems: a solution to usability problems. *User modeling and User-adapted Interaction* 3, 1: 65–87.
- 10. John Brooke. 1996. SUS-A quick and dirty usability scale. *Usability evaluation in industry* 189: 194.
- 11. Elizabeth J Brown, Tim J Brailsford, Tony Fisher, and Adam Moore. 2009. Evaluating learning style personalization in adaptive systems: Quantitative methods and approaches. *Learning Technologies, IEEE Transactions on* 2, 1: 10–22.
- Peter Brusilovsky and Eva Millán. 2007. User models for adaptive hypermedia and adaptive educational systems. The adaptive web: 3-53.
- 13. Peter Brusilovsky. 2007. Adaptive navigation support. *The adaptive web*: 263–290.
- 14. Fathi Essalmi, Leila Ayed, Mohamed Jemni, Kinshuk, and Sabine Graf. 2010. A fully personalization strategy of E-learning scenarios. Computers in Human Behavior 26, 4: 581–591.
- 15. Karen M Feigh, Michael C Dorneich, and Caroline C Hayes. 2012. Toward a Characterization of Adaptive Systems: A Framework for Researchers and System Designers. Human Factors: The Journal of the Human Factors and Ergonomics

Society.

- 16. Richard M Felder and Joni Spurlin. 2005. Applications, reliability and validity of the index of learning styles. *International Journal of Engineering Education* 21, 1: 103–112.
- 17. Cristina Gena and Stephan Weibelzahl. 2007. Usability engineering for the adaptive web. *The adaptive web*: 720–762.
- 18. Kristina Höök. 2000. Steps to take before intelligent user interfaces become real. *Interacting with computers* 12, 4: 409–426.
- 19. James W Keefe. 1979. Learning style: An overview. *Student learning styles: Diagnosing and prescribing programs*: 1–17.
- 20. Konstantina Orfanou, Nikolaos Tselios, and Christos Katsanos. 2015. Perceived usability evaluation of learning management systems: Empirical evaluation of the System Usability Scale. The International Review of Research in Open and Distributed Learning 16, 2.
- 21. Özcan Özyurt and Hacer Özyurt. 2015. Learning style based individualized adaptive e-learning environments: Content analysis of the articles published from 2005 to 2014. *Computers in Human Behavior* 52: 349–358.
- 22. John A Self. 1994. Formal Approaches to Student Modelling. Student Modelling: The Key to Individualized Knowledge-Based Instruction NATO ASI S: 295–352.
- 23. Thomas S Tullis and Jacqueline N Stetson. 2004. A comparison of questionnaires for assessing website usability. *Usability Professional Association Conference*, 1–12.

- 24. Stephan Weibelzahl. 2001. Evaluation of adaptive systems. *User Modeling 2001*: 292–294.
- 25. Panagiotis Zaharias and Angeliki Poylymenakou. 2009. Developing a usability evaluation method for e-learning applications: Beyond functional usability. *Intl. Journal of Human--Computer Interaction* 25, 1: 75–98.