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Usability of Profile Based Student Authentication and Traffic Light System in Online Examinations

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Abstract— **There has been an increased interest in effective approaches to student authentication, given that online examinations are a crucial component of online learning. The work presented here, is part of an ongoing programme of research on the extent to which challenge questions are an effective approach to student authentication in online examination contexts, where face-to-face invigilation is not in use. Although the use of challenge questions shows great potential, there are some concerns about its usability in particular relating to memorability. This paper summarizes the findings of an empirical study in which, 23 participants used a framework developed by the authors namely "Profile Based Authentication Framework" (PBAF). Findings from the empirical study suggests that memorability, questions clarity, varied writing syntax and case variation can cause usability issues leading to failed authentication. A traffic light scheme was implemented to improve the usability of challenge questions for online examination authentication.**

Keywords—Online examination, profile, challenge questions, authentication, security, usability, traffic light system

I. INTRODUCTION

There has been an increased growth and popularity in the use of online learning in various sectors of education and training [5]. Given that online examinations are important component of online learning, it is critical to identify effective approaches to student authentication in online examinations. Student authentication is one of the key challenges to online examinations. The implementation of reliable and secure approaches to student authentication is vital to ensure stakeholders' trust in the assessment process. In online examinations, face-to-face invigilation is often replaced with online authentication systems and therefore security becomes a critical factor to the credibility of online examinations. The invigilation of examinations in the online contexts are largely different from conventional face-to-face settings [9]. A diverse range of authentication techniques have been implemented to secure online examinations. A typical authentication system verifies user's identity based on information [6], objects [3] and characteristics[10]. The solution proposed here (Profile Based Authentication, PBAF) is based on the use of challenge questions in order to verify a student's identity. The challenge questions used in the work reported here cover questions concerning personal and academic data of individual student. In order to investigate the usability issues relating to the use of PBAF, we conducted an empirical study involving *23* students. Based on the data gathered and analysed as part of this study, we designed and analysed a traffic light system for student authentication and this is presented later in this paper.

II. BACKGROUND

Online examinations are an extremely important feature of online learning [8]. A number of authors acknowledge that student authentication in the online examinations can face many security threats. As in [1], it can be a real challenge to verify identity of an individual in online environments. Some argue, that online examinations can be more vulnerable to academic dishonesty than traditional face-to-face examinations [2]. Student authentication in online environments is an active research area and a large number of authentication techniques have been developed, which can be implemented to enhance the security of online examinations. Examples of such authentication techniques include proctored examinations, user id and password, and biometric features such as fingerprint, audio or voice recognition, signature recognition and face recognition. As in [12], these various techniques have their own strengths and limitations in terms of cost, usability and security when applied to online learning environments.

In addition to the authentication techniques mentioned above, the use of "challenge questions" is also an important authentication and credential recovery technique [7]. The challenge questions approach has been widely used by leading email providers such as Yahoo, Google, Microsoft and AOL as part of the credential recovery process, when users need to reset or retrieve lost credentials [11]. A set of questions are initially stored during the registration process and individuals are queried to answer the questions during authentication or recovery process. Challenge questions are likely to be reliable and unique as it pertains to the information known to individual users. However, the memorability of challenge questions, and lack of clarity may cause security and usability issues [4].

The authors have recently, designed a *Profile Based Authentication Framework (PBAF)*, a "challenge questions" approach to student authentication in online examination settings [12]. As mentioned earlier, *PBAF* uses challenge questions with *user-id and password* for student authentication in online examinations. The proposed solution uses *profile questions* for building individual student's *profile* over time. The profile information is then used to generate random

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challenge questions, which, in turn, are used to support student authentication during online examinations. However, as referenced above, the use of challenge questions as authentication technique may pose usability challenges. The usability of any authentication approach is highly important for reliability and security [7]. Therefore, to achieve effective online examination authentication, usability issues needs to be addressed.

III. PROFILE BASED AUTHENTICATION CONTEXT

The PBAF is a multi-modal authentication approach implemented on MOODLE Learning Management System (LMS).

Students are provided with a unique username and password for logging into the learning environment. Upon successful login, students are asked to answer profile questions in order to gain access to learning resources. The profile questions are used to collect answers in order to build and update their individual profiles. The authentication process is triggered when a student requests to access an online examination. The student is then redirected to answer a set of challenge questions randomly selected from their profile. A brief description of how the PBAF approach to student authentication works can be found below:

- *System Configuration:* The PBAF can be configured on the LMS from a web interface. A customized interface can be used to add questions to the library for use as profile and challenge questions. The number of profile and challenge questions requested at the profile building and authentication phases can be setup from the system configuration. The system can be configured to collect profile questions on each visit or once per 24 hours on the date change.
- *Profile Questions:* The profile questions are presented to students to build their profiles. The students are required to supply answers to profile questions on each visit to be able to access the learning resources.
- *Challenge Questions:* The PBAF generates and presents random challenge questions before any online examinations can be accessed. When the challenge questions are answered, the framework invokes the authentication process to verify the student's identity against their profile answers.
- *Authentication:* The authentication algorithm uses string comparison to match the answers with the stored information. The students are allowed to access the online examinations, if they provide exact answers to the challenge questions. Students failing to supply exact answers are denied access to the online examinations.

IV. METHODOLOGY

Our study focused on the usability of profile and challenge questions in the context of online examination authentication. We performed the experiment in an online environment and the methodology was approved by the University's research ethics board.

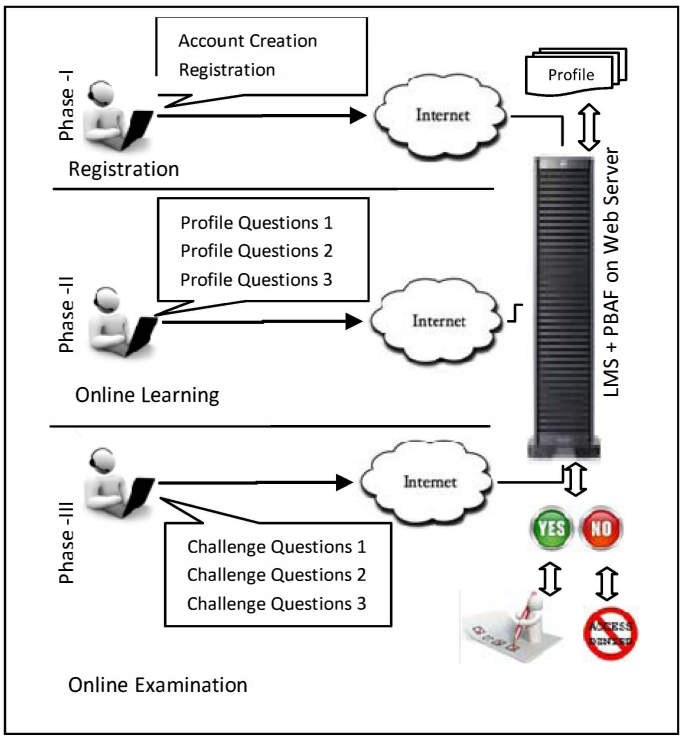

Figure 1. PBAF Experiment

A. Participants Recruitment

We recruited a blend of local and international undergraduate and postgraduate students from a UK and overseas Universities. The participants were formally informed of the objectives of research and sent an electronic copy of the guidance notes. They were informed of the registration procedure, access dates for learning, examination and the finally usability questionnaire. We invited a total of 30 potential participants by email, 23 of them volunteered to participate in the experiment by signing up on the online course.

B. Aims of the study

We planned to analyse if the answers from participants to the profile questions at "Phase-II Online Learning" can be recalled at the authentication "Phases III & IV Online Examination", and identify any usability issues during the process. To do this, we needed to collect and analyze participant's data from the PBAF implementation as explained in section III. The profile and challenge questions are the same objects used in different contexts. We designed a collection of 20 objective questions, with 10 questions each from their personal and academic domains.

As in [7], collection of sensitive user information can raise privacy and ethical issues. All the participants were volunteers and informed about the intended use of the data collected. Most of the personal and academic questions compiled for the experiment were based on *University of Hertfordshire* admission application form. As part of the experiment, we ran a survey to take participants feedback on the usability of PBAF application and our proposed approach.

TABLE I. SUMMARY OF PARTICIPANTS AND ANSWERS

Participants	
Experiment Phases	***Participants***
Phase I (Registration)	23 (77%)
Phase II (Profile Questions)	18 (60%)
Phase III (Challenge Questions)	13(43%)
Answers	
Experiment Phases	***Answers Received***
Phase II (Profile Questions)	274
Phase III (Challenge Questions)	66

C. *Experiment setup*

Our experiment was organised into four phases as illustrated in "Fig. 1" and "Fig. 2". All the four phases were performed over the Internet in a simulated environment on a LMS as explained in Section-III. The PBAF prototype was developed in PHP and integrated on the LMS deployed on a web server for the purpose of this empirical study. An online simulation course was created and the profile questions were added to the PBAF questions library. Likewise, a simulation online examination was added to the online course. It should be noted that, the online course and examination were purposely designed for this study and not actual University course. The participants were invited to answer profile and examination questions by using simulation environment. The experiment focuses on collection of answers to profile questions and authentication results. The experiment was performed in the following phases:

1) Phase I- Registration of participants.

As in "Fig.1", Phase-I of the experiment is a registration phase. The participants created their accounts and completed online registration on the course. The "registration" process involves selection of user-id and password for login. The participants were given seven dates to visit the online course and complete the profile questions between 20th June to 20th July 2012, with a space of three days between each visit.

2) Phase II- Online Learning

Phase-II of the experiment is a learning process simulation. In Phase-II, participants visited the online course and were redirected to answer the "profile questions". The number of "profile questions" requested is configurable and can be set to a value from 1-10. For the purposes of the study reported here, the number of questions was set to 3. This would allow the authors to collect sufficient data for preliminary analysis, without causing fatigue to the participants. Phase-II was repeated on seven dates and a three days gap.

3) Phase III- Online Examination

After completion of Phase-II, the participants were notified by email to login and access the online examination link. As in [11], a single question may not be sufficient to authenticate students, citing security and usability challenges. Hence, we set 3 challenge questions for online examination authentication, the same number as profile questions. However, the number of challenge questions is configurable for future experimentation on different frequencies. In Phase-III, the participants visited the online examination link and were redirected by the PBAF system to answer three challenge questions selected randomly from their profiles.

4) Phase IV – Traffic Light System

Subsequent upon analysis of the data, we requested the participants to re-visit the online examination link in Phase-IV of the experiment as illustrated in "Fig. 2". We enabled the traffic light system in Phase-IV of the experiment.

5) Usability Survey

On completion of experiment, we requested the participants to respond to an online survey questionnaire based on their experience of the PBAF authentication approach. The questions were designed to collect participant's feedback on the user interface and usability of PBAF components.

D. *Usability Analysis*

The data collected in our experiment were stored in a relational database. The participants answered the questions at different phases were recorded in the database for *usability analysis* in term of:

i. *Memorability of Answers*: For the memorability analysis, we asked the participants in Phase-III of online examination to login and access the *online examination link*. During this phase, the algorithm redirected unauthenticated students to answer a randomly selected challenge question from their profile. We used a simple pattern matching algorithm to compare the answers with the stored information. We stored the answers in a database table for audit. In Phase-IV, we incorporated a traffic light system in the challenge questions authentication and invited all the participants for a repeat access to online examination. All the transactions were recorded for later analysis.

ii. *Suitability of Answers*: The participants were informed to use realistic information in their profile questions, so it can be recalled subsequently, in authentication phase. The answers for the profile and challenge questions in Learning, Examination and Authentication were stored and analysed for multiple words, varied writing syntax and unrealistic answers.

V. EXPERIMENT RESULTS

Among the total invitees, 23 participated in the initial registration and 18 participated in different phases of experiment by providing answers to 274 questions as in "TABLE I. Summary of Participants and Answers". We designed a string comparison algorithm for authentication phase, which compares the two answer strings to find a match. The algorithm performs exact match check of text, numbers, special characters, capitalisation and spaces between the two answer strings. The participants were required to provide exactly the same answers, supplied for the profile questions during Phase-II of the experiment. The system locked out participants who could not provide exact answers to all the challenge questions. A total of 13 participants answered 66 challenge questions in Phase-III of the experiment and completed the authentication. In Phase-III, 64% participants managed to answer exactly the same as in Phase-II, whereas 36% answers were incorrect due to various usability issues. These are discussed below.

A. *Memorability of Answer Results:*

Results on memorability are based on analysis of answers received in Phase-III of the experiment. Of the 66 answers received, 23% unmatched due to memorability problem. Of all the 41% unmatched answers, 56% answers provided by the participants to challenge questions were entirely different than the answers previously submitted for example answer to a question, "*What were your grades in your highest qualification before starting this course"* has an answer "A+" at Phase-II and "85%" at authentication Phase-III. Although, both Phase-II and Phase-III of the experiment were taken place in a month time, memorability issue still contributes 56% and forms a larger part of the unsuccessful answers.

B. *Suitability of Answer Result:*

The answer suitability results are based on Phase-III of experiment. Of all the 41% unmatched answers submitted by the participants, 44% of answers had suitability issues for example varied writing syntax, multiple words answers. Of the unmatched answers, 11% answers provided by the participants to challenge questions were formed from multiple words. For example, answers to *"What is the name of your last school attended"* and *"What was your highest qualification before starting this course",* consist of multiple words. Of the total incorrect answers submitted by the participants, 33% partly matched the actual answers and had variations in writing syntax in Phase-II and Phase-III of the experiment. We observed that, in some instances, multiple words and syntactic usability issues were caused due to questions ambiguity.

C. *Traffic light system*

To effectively use the PBAF system, we implemented a traffic light system, as shown in "Fig.2". As highlighted in "TABLE II Authentication and Traffic Light System", we observed that, of all the participants only 23% submitted exact answers to all the 3 challenge questions and authenticated successfully. A total of 38% participants provided exact answer to 2 challenge questions and 31% participants submitted exact answer to 1 challenge question. However, 8% participants provided no matching answers to challenge questions in the authentication phase due to memorability and syntactic usability difficulties mentioned above. The PBAF locked out participants who submitted exact answers to '0' out of '3', '1' out of '3' and '2' out of '3' challenge questions. Hence, the 69% participants above failed to submit exact answers to all their 3 questions largely because of usability issues. As in "Fig.2", to balance the usability issues, we employed a traffic light system and asked the participants to re-authenticate in Phase-IV.

TABLE II. AUTHENTICATION AND TRAFFIC LIGHT SYSTEM

Authentication Before Traffic Light System				
Attempt	***3/ 3 correct***	***2/3 correct***	***1/3 Correct***	***0/3 correct***
1	23%	38%	31%	8%
Authentication After Traffic Light System				
	Green		**Amber**	**Red**
	2-3/3 Correct		***1/3 Correct***	***0/3 correct***
1	61%		31%	8%
2	19%		12%	0%
3	12%		0%	0%

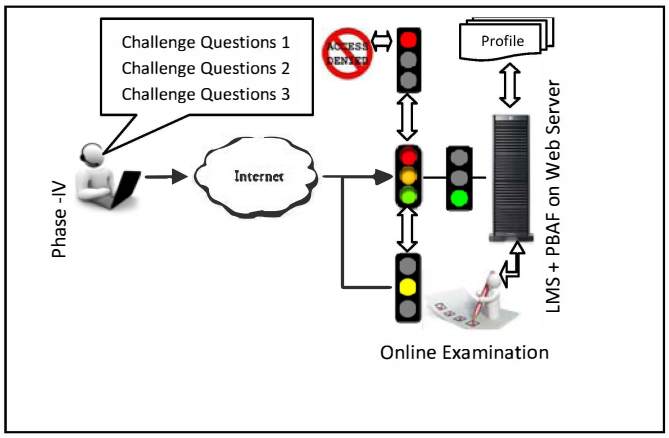

Figure 2. Traffic Light System in PBAF

Based on the data collected in Phase III, of all the unmatched answers, 64% usability issues were caused by capitalisation, question clarity and varied writing syntax for example dates syntax, address syntax. Based on the results of Phase-III, in order to address some of the usability issues, we setup the PBAF system to allow participants to access the online examination if 2 out 3 answers were matched and those participants were classified as green. The PBAF system was setup to redirect those participants provided 1 out of 3 exact answers, to answer more challenge questions and classified as amber. The participants providing no answers to match their profile questions were classified as red and locked out. The above classification is setup to analyse PBAF system performance by compensating usability issues. Further experimentation is needed on different frequencies to ascertain number of questions for the above classification in the context of usability and security.

The implementation of a traffic light system improved authentication and minimised the impact of usability issues. As in "TABLE II-Authentication and Traffic Light System", authentication success rate for participants has increased from 23% to 92%. In the first authentication attempt, 61% participants provided 2 to 3 exact answers to challenge question and authenticated. The 31% participants were redirected to answer more questions and 8% were locked out. In the second authentication attempt, of the remaining 31% redirected participants, 19% provided 2-3 exact answers. In the third attempt, 12% participants, who were asked to answer more questions, authenticated. The traffic light system can provide an enabling environment by implementation of PBAF and reducing usability issues. However, we are aware that with the implementation of traffic light system, *security analysis* of PBAF is needed on a larger sample size. We have made the values for green, amber and red classification configurable in the PBAF application for future evaluation on different settings.

TABLE III. ONLINE USABILITY QUESTIONNAIRE

Software Usability Questions	*Mean*	*Median*
It was easy to use the software.	1.5	1
It was easy to use the Registration Form on initial login.	1.4	1
The interface of this system was aesthetically pleasant.	2.5	2
I am satisfied with the layout of questions posed soon after the login.	2.4	2
Overall, I am satisfied with the use of the software application.	1.5	1
PBAF Authentication Questions	***Mean***	***Median***
I could effectively carry on with the learning activities while answering the questions.	2.2	2
I was able to complete answering the questions quickly which were posed on each login.	1.8	2
*I was distracted by the number of questions asked after the login.	3.2	3
*The number of occurrences of questions asked after login should be once per day instead of one per user session.	2.5	3

*SCALE REVERSED

D. Online Survey Questionnaire

It was also important for this work to identify any potential issues when answering the challenge questions. To this end, a post-experiment usability survey was designed. A total of 15 participants completed a post-experiment usability survey. The questionnaire was based on a five-point Likert scale, where 1 indicated strong agreement and 5 measured as strong disagreement.

"Table III - Online Usability Questionnaire" shows a summary of participant responses to the post-experiment usability survey. It can be seen that, in general, participants found the software easy to use, and also that they were able to answer challenge questions quickly. However, participant responses suggest that some may have found the use of challenge questions somewhat distracting. The participants response to questions related to overall satisfaction i.e. *"it was easy to use the software"* and *"overall, satisfaction on the use of software"*, was positive and given a score of 1.5 mean(1 median), where a lower score indicates a higher satisfaction. The participants had a mixed response to questions related to *"aesthetic interface"* and *"questions layout"* hence, scored 2.4 and 2.5 mean. The questions on interruption of learning activities received an average score. The participants indicated that the learning activities can be carried on easily while answering the profile questions and given a score 2.2 and 1.8 mean (2 median) to the relevant questions. To a question "*number of questions asked during profile building was a distraction*", 62% participants indicated "Not a distraction", 32% "a slight distraction", and 6% suggested "a great distraction". Given that 62% suggests a higher acceptance, however a combine effect of users concern makes 38%, indicates a further test on reduced number of questions.

The overall feedback looks satisfactory both on the conceptual and interface design with indications to improve the layout.

VI. CONCLUSION

The PBAF technique is knowledge based feature, which employs challenge questions as repeat authentication in addition to user-id and password for student authentication in the online examinations.

The findings from the empirical study reported here suggest, that challenge questions based authentication in online examination can be an effective feature, if the usability issues are minimised. PBAF uses personal and academic information for student authentication. Participants responded positively to a post experiment online survey on the usability of PBAF application interface and the proposed authentication feature in the context of online learning and examinations. Further analysis is necessary on the design of questions, privacy and security. Furthermore, analysis on the number of questions posed during the learning and authentication process is needed on a larger sample size.

Our results revealed that participants could not provide 100% exact answers to a set of 3 challenge questions largely because of usability such as different syntactic representation, and memorability issues. The implementation of a traffic light system improved authentication outcome from 23% to 92%, by enabling multiple chances. Given the fact that PBAF adopts repeat authentication, multiple attempts flexibility can raise security risks. The usability in terms of multi-word answers can be minimised by removing potential questions with multiple answers and optimised questions design. The usability issues generated by capitalisation can be addressed by tweaking the comparison algorithm. The findings from Table III suggest that there may be some degree of disruption, answering questions during the learning process.

Future work would be directed for an in depth security analysis of PBAF against collusion and in the context of a traffic light system.

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