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Technology Acceptance Model- Based Usability Testing of a Fingerprint Attendance Register System

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Abstract: Institutions of higher learning in Kenya have traditionally used paper-based attendance registers, which have been seen to lack validity for decision-making. There is a trend to adopt Biometric attendance registers in a number of institutions, however, they still have usability issues. This study uses a modified Technology Acceptance Model (TAM) to investigate the usability of the fingerprint biometric students' attendance register system. The original TAM used perceived usefulness, and perceived ease of use, as the test factors for acceptance of technology. Researchers have modified the TAM to include more test factors such as attitude toward use, and trust and security. In this study, we use the extended TAM-TRA model. The model includes the attitude toward, trust, and security in using the technology, in addition to the original perceived usefulness, and perceived ease of use, to conduct usability of the fingerprint attendance register system. These are important factors in the successful implementation, acceptance, and adoption of such systems. The study applies quantitative and qualitative surveys and observations, to collect data from sampled users of the fingerprint biometric attendance register system and test its usability using the modified TAM. A class of twenty students at the Technical University of Mombasa interacted with the fingerprint biometric attendance register system, and for each student, the usability tests were carried out, recorded, and analyzed. The perceived usefulness, perceived ease of use, attitude toward use, trust, and behavioral intention to use, scored 88.75%, 70%, 77.5%, 65%, and 77.5% levels of acceptance respectively. The contribution of this paper is in the insight to organizations that seek to improve the acceptance of their biometric recognition systems.

Keywords: Usability; Perceived Usefulness; Perceived Ease of Use; Attitude Toward Using; Trust, Security; Behavioural Intention to Use.

1. INTRODUCTION

Advancements in technology have led to a heavy reliance by governments on digital systems, [1] [8]), that are integrated into our daily life activities at both personal and organizational levels. Organizations rely on technology to manage information and human resources. Biometric technology for example has been widely adopted in the identification of bonified staff in the workplace and also in staff attendance management [25] [21]

Biometric technology is presented by researchers as a measure of the human physiological and behavioral characteristics which provide reliable identification of a person [26]. The technology uses unique and accessible parts of a person's biological makeup such as the face, retina, iris, voice, and fingerprint for verification purposes [12]. It is a system of recognizing image patterns acquired from the biometric data of the person presented for identification. The features of the image are extracted and then compared against the previously stored template images in a database [6]. Depending on the area of application, biometric systems may be used either for *the identification or verification* of persons [16] [2]

The use of fingerprints in biometric systems increased rapidly because of the special strengths fingerprints provide, compared to other human physiological traits. Fingerprint based biometric systems are found to be easy to use, and cheaper to implement [23]. In addition, these systems consume less power and they can easily be implemented in a mobile environment [23]. In schools, colleges, and universities, biometric technology, such as fingerprint attendance register systems, has been used to manage students' attendance with rewarding success and accuracy [23].

However, the success in implementing fingerprint students' attendance register systems does not depend only on its functions, but also on its usability and acceptability by the target users. A product has good usability if both the experts and the novice can use it with ease [11]] [7].

Theoretical models have been suggested that measure usability and acceptance of new technology, such as the Technology Acceptance Model (TAM) (Meennapa Rukhiran, 2023) [1], Theory of Reasoned Action (TRA)[27] [14], Motivational Model (MM) [19], Theory of Planned Behavior (TPB) [5], Combined TAM and TRA (C-TAM-TRA) [16], Model of PC Utilization (MPCU), Innovation Diffusion Theory (IDT) [13], Social Cognitive Theory (SCT) [10], and Unified Theory of Acceptance and Use of Technology (UTAUT) which is an integration of several technology acceptance theories [19].

This study aims to carry out usability and acceptance tests of a fingerprint biometric student attendance register system using the extended TAM-TRA model. These tests were conducted on a proposed fingerprint college students' attendance register for the Technical University of Mombasa. After this introduction, the next section is the related work on TAM-Based Usability Testing of a Fingerprint Attendance Register System. Section 3 provides the methodology used to implement the TAM-based testing model for a fingerprint attendance register system. Section 4 gives the test results,

followed by a discussion in section 5, and conclusions in section 6.

1.1 Research Highlights

- A modified TAM-TRA model was realized.

- Successful use of the model on the register system was made

- System effectiveness, satisfaction, and efficiency were found

- Above average scores of usability parameters were achieved.

2. RELATED WORK

Usability was defined by researchers as "the quality of a product that makes it easy to understand, learn, use and attractive to users" [11]. It has also been defined as the extent to which a given product can be used by specific users to obtain predefined goals effectively, efficiently, and satisfactorily [22]. In the field of Human-Computer Interaction (HCI), researchers investigated factors that increase the usability of a product [4]. These factors included effectiveness, efficiency, accessibility, satisfaction, affordance, anthropometry fit, and privacy concerns [11]. Of these factors, effectiveness, efficiency, and satisfaction were identified as key factors of usability (Anh Tho To, Thi Hong Minh Trinh, 2021), [11].

On a stable weighted super-matrix scale, used to show the relative ranking of a given set of usability criteria from a field study test, privacy was the most important concern for biometric recognition systems, and of these systems, fingerprint recognition scored highest [11]. The International Organization for Standardization (ISO) recommended that usability metrics could include effectiveness, efficiency, and satisfaction [18]. Effectiveness was defined as the accuracy and completeness with which users achieved specified goals. Efficiency had to do with the time it would take for a process to complete a given task. Satisfaction was used to describe the comfort or freedom of discomfort and acceptability of the product by the users (ISO, 2010), [18][11].

In investigating the usefulness of fingerprint biometric attendance registers at Nyamagana Municipality of the United Republic of Tanzania, using the Theory of Planned Behaviour, it was found that to change employees' behavior at work, their attitudes and social norms (social pressure) toward the desired behavior should be addressed first. [17].

Research on the measure of adoption of Information and Communication Technology (ICT) led to the development of various models to predict and understand the acceptance of technology. A notable model was the Technology Acceptance Model (TAM) (Aceron, 2021). TAM is a model that analyzes the factors influencing and motivating users to adopt identification management systems. The acceptance test factors used in the TAM model include the intention of the user to use the technology, the attitude toward using the technology based on trust, the perceived usefulness, and the perceived ease of use [3].

TAM is based on two primary factors that affect the intention to use a given technology [24]. These factors were the Perceived Usefulness (PU) of the product and the Perceived Ease of Use (PEU) of the product. PU was described as the extent to which a person was convinced or believed that a given technology would improve job performance. PEU was described as the extent to which a person was convinced. believed that using the given technology would be effortless [15]. Early Technology Acceptance Model questionnaires consisted of 12 items, six testing on PU and six on PEU. The responses were then weighted on a 1-7 scale from extremely unlikely, quite likely, slightly, neither, slightly, quite unlikely, and extremely unlikely. The responses could either be all verbal or all numbered 1-7. The severity of the likelihood could be from lowest to highest or from highest to lowest [15].

Modifications on TAM were made to include not only the likelihood ratings of PU and PEU but also to measure User Experience (UX) by using Experiential ratings. [15] in research that used a modified TAM, used three questionnaires that rated PU and PEU in four versions of responses. These versions were the use of weightings of the responses on a 1 – 7 scale starting from extremely likely to extremely unlikely for both verbal and numeric verbal left-right, verbal right-left, numeric left-right, and numeric right-left in the order of severity. The following formulae were used:

PU = (Average (Tam01, Tam02, Tam03, Tam04, Tam05, Tam06) – 1) (100/6)

PEU = (Average (Tam07, Tam08, Tam09, Tam10, Tam11, Tam12) – 1) (100/6), Where Tam01 – Tam12 ranged from 1-7 on the weighted scale. [15].

The results were then subjected to an analysis of mean differences, factor analyses, regression analyses, and analysis of response errors. The numeric L-R version of scoring responses with a magnitude of agreement increasing from left to right gave the most significant Likelihood-To-Recommend (LTR) the product for use [15].

In investigating user acceptance factors related to biometric face recognition technologies, [16] also used questionnaires to elicit students' perceptions and test hypotheses on biometric facial recognition for the use of an examination attendance register.

In a usability evaluation of an integrated electronic medication management system for an outpatient Oncology unit of a major teaching hospital, five UTAUT constructs were identified [22]. These constructs are performance expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), and Behavioral (BI) [22]. Performance Expectancy is the degree to which a user of a given system believes that using the system results in gains in job performance. Effort Expectancy (EE) is the extent of ease associated with using the system. Social Influence (SI) is the degree to which a user perceives that others are recommending him or her to use the new system [22]. Facilitating Conditions (FC) is the extent to which the user

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believes that an organizational and technical infrastructure exists to support the use of the system. Behavioral Intention (BI) is the willingness of respondents to use the system [11]. **To** adopt a conceptual framework for the usability testing of a fingerprint biometric attendance register these constructs were considered:

Performance Expectancy can be directly related to the biometric attendance register's Perceived Usefulness (PU) [11]. It is the factor that predicts the gains (or usefulness) of the biometric technology. Effort Expectancy is the Perceived Ease of Use (PEU) [11]. It predicts the effort used in terms of how difficult, or how easy the system is to use in taking enrolment and the attendance of students in a class session. An increase in PEU directly influences the PU [3][4].

The Social Influence (SI) construct according to [15]), and [11], is the Attitude Toward Using (ATU). It was used to predict the influence other potential users have on the current user of the biometric attendance register that could affect the perceived usefulness. Facilitating Conditions (FC): - This construct was redefined as the Trust (T). It was used to predict the level of trust the users had in the organization to obtain and maintain the required infrastructure for the biometric system [4]. Behavioral Intention (BE) is referred to as the Behavioral Intention to Use (BIU). It was used to predict whether the users would prefer the biometric attendance register to the traditional paper-based attendance register [3][4].

The security (S) construct was added to the traditional TAM-TRA model. The aim was to separate the Trust construct from the Security [3][4]. In our case, Security is the level of confidence the user has in the system to protect attendance data as provided for in the laws and policies on data protection and privacy. This construct has a direct influence on the users' willingness to use the biometric attendance register. It is effective in measuring user confidence in the biometric system. It is an external factor in the user's willingness to use the system.

3. METHODOLOGY

Surveys, observations, and interviews were conducted to collect data from students as the primary users of the biometric attendance registers. The students were allowed to interact with the fingerprint biometric attendance register system. Online Google form questionnaires were then given to the students to fill out and submit. The data collected was analyzed and the results were recorded.

3.1 Usability Testing

The usability test model, which is a modified extended TAM-TRA model is shown in Figure 3.1. From research, PU and PEU constructs are grouped under effectiveness, ATU and TS fall under satisfaction, while BIU, considering the average time to perform the tasks, can be considered as efficiency. The main tasks in this study were affixing the fingerprint on the sensor during enrolment and class attendance.

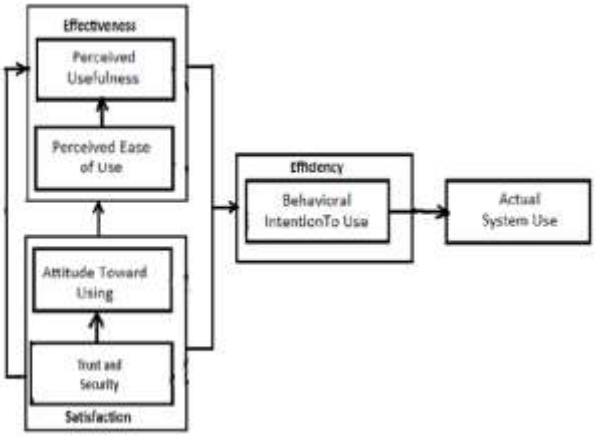

Figure 3.1 The Extended TAM-TRA model with regrouped test factors adopted from [16].

3.2 Data collection

Interviews were conducted using Google form online questionnaires. A group of 20 students at the Technical University of Mombasa were allowed to interact with the fingerprint attendance register system and then filled out the questionnaire shown in Table 3.

Table 3. The adopted questionnaire for effectiveness, satisfaction, and efficiency.

Classification	Question
Perceived Usefulness (Effectiveness)	My names were correctly displayed on the system
	The system was able to take student attendance
	Taking attendance was effective with this system.
	Once attendance has been taken, no changes can be made
Perceived Ease of Use (Effectiveness)	The biometric attendance register was easy to use
	My fingerprint was captured on the first attempt
	There were at least two unsuccessful attempts
	Parents and guardians can access the attendance records.
Attitude Towards Use	Attendance reports can be printed from the system
	In this biometric system, a student cannot

(Satisfaction)	fake attendance.
	You prefer the biometric register to the paper register.
	No fear of disease infections with this attendance register
Trust and Security (Satisfaction)	Attendance can be taken on day one of the semester.
	The biometric register is foolproof and data is secure.
	The biometric register is likely to be hacked by students
	Student data in the biometric register is protected by law
Behavioral Intention to Use (Efficiency)	The biometric register may cause queues during attendance.
	Fingerprint sensors in every classroom are too expensive
	Internet is not fast and sufficient throughout the university
	The biometric register is fast and prevents cheating in exams

A Likert scale was used for the questionnaire responses. The answers were: Strongly Agree (SD), Agree (A), Neutral (N), Disagree (DA), and Strongly Disagree (SD). During analysis, the total responses for SA and A were added and presented as A. DA and SD were added together and presented as DA.

3.3 Determination of effectiveness, satisfaction, and efficiency

The test factors in the adopted TAM-TRA model were the Perceived Usefulness (PU) and Perceived Ease of Use (PEU), used in the original TAM, the Attitude Toward Using (ATU), Trust and Security (TS), and the Behavioural Intention to Use (BIU) [14]. PU and PEU were grouped as tests for the effectiveness of the biometric attendance register system. ATU and TS were classified under the test for satisfaction whereas BIU was the efficiency test.

According to [18], the effectiveness of the attendance register was determined by the scores for PU and PEU.

Effectiveness can be calculated from the usability metrics format:

$$Effectiveness = \frac{\varphi}{\omega} X\ 100\%$$

where φ *= Number of tasks completed successfully and*

ω *= Total number of tasks undertaken.*

The test for satisfaction was calculated from the scores for ATU, and TS

Since there is a direct relationship between effectiveness and satisfaction, then:

$$Satisfaction = k\frac{\varphi}{\omega} X\ 100\%$$

Where k is a constant, assuming all factors remain constant in both the test for effectiveness and satisfaction, k was taken as 1[18.

Efficiency can also be calculated using the formula for time-based efficiency:

$$Efficiency) \ = \frac{\sum_{j=1}^{R} X \sum_{i=1}^{N} \frac{n_{ij}}{t_{ij}}}{NR}$$

Where:

N = The total number of tasks, or goals, R = The number of users

n_{ij} = The result of task i by user j; if the user completes the task, then N_{ij} = 1, if not, then N_{ij} = , t_{ij} = The time spent by user j to complete task i. If the task is not completed, then time is measured till the moment the user quits the task [18].

4. RESULTS

Students who were the target users of the fingerprint biometric register interacted with the system and filled in questionnaires to test its usability and adoption. The five test parameters were Perceived Usefulness, Perceived Ease of Use, Attitude Towards Using, Trust and Security, and Behavioural Intention to Use. Of these test parameters, the first two were tests for effectiveness, the next two tested for satisfaction, and the last tested for efficiency. The results for each test are shown in Tables 4.1, 4.2, and 4.3.

Table 4.4 summarises the calculated values of each test factor's usability levels.

Table 4.1. Results for usability test on effectiveness.

Test Parameter	**Question**	**A**	**N**	**DA**	**Total**
Perceived Usefulness (PU) (Effectiveness)	My names were correctly displayed on the system	16	3	1	20
	The system was able to take student attendance	20			20
	Taking attendance was effective with this system.	19		1	20
	Once attendance has been taken, no changes can be made	16	3	1	20

Perceived Ease of Use (PEU) (Effectiveness)	The biometric attendance register was easy to use	18	2		20
	My fingerprint was captured on the first attempt	14	1	5	20
	There were at least two unsuccessful attempts	9	2	7	20
	Parents and guardians can access the attendance records.	15	5		20

Table 4.2. Results for usability test on satisfaction.

Test Parameter	**Question**	**A**	**N**	**DA**	**Total**
Attitude Toward Using (ATU) (Satisfaction)	Attendance reports can be printed from the system	17	3		20
	In this biometric system, a student cannot fake attendance.	19		1	20
	You prefer the biometric register to the paper register.	16	1	3	20
	No fear of disease infections with this attendance register	10	4	6	20
Trust and Security (TS) (Satisfaction)	Attendance can be taken on day one of the semester.	20			20
	The biometric register is foolproof and data is secure.	13	6	1	20
	The biometric register is likely to be hacked by students	10	6	4	20
	Student data in the biometric register is protected by law	9	9	1	19

Table 4.3. Results for usability test on efficiency.

Test Parameter	**Question**	**A**	**N**	**DA**	**Total**
Behavioral Intention to Use (BIU) (Efficiency)	The biometric register may cause queues during attendance.	16	4		20
	Fingerprint sensors in every classroom are too expensive	12	7	1	20
	Internet is not fast and sufficient throughout the university	17	3		20
	The biometric register is fast and prevents cheating in exams	17	2	1	20

Table 4.4. Summary of usability outcomes.

Test Group	Test factor	Total positive responses	Total possible responses	% Level of Usability
Effectiveness	PU	71	80	88..75
	PEU	56	80	70
Satisfaction	ATU	62	80	77.5
	TS	52	79	65
Efficiency	BIU	62	80	77.5

5. DISCUSSION

The three tests that were conducted on the fingerprint biometric attendance register were effectiveness, satisfaction, and efficiency. These tests used five parameters: PU, PEU, ATU, TS, AND BIU. The high score for effectiveness of 88.75% for PU and 70% for PEU showed that the biometric attendance register was useful and easy to interact with even without prior knowledge of such systems. Key considerations in the use of biometric registers were the ability to capture the fingerprint, accurate display of students' information, and the ability to take students' attendance without undue changes in the attendance record. A score of 88.75% indicated that the register was effective in enrolment and taking attendance. The lower score of 70% for PEU could have been due to variations in internet speeds and speeds within the classroom. Overall, the effectiveness test was high.

On satisfaction, the usability test on ATU, scored 77% while TS scored 65%. The score reflected the confidence and redness of the students to use the technology. The test considered factors on attitude and expectations from the attendance register. Tests on Trust and Security focused on whether the biometric attendance register was foolproof and whether their personal information was secure. The 77.5% score on BIU was an indicator that the fingerprint attendance register was efficient. The average time a student took to interact with the register system was four seconds. Some of the factors that could affect behavior and efficiency could be the crowding of students at the classroom door waiting to take attendance. Although these crowds were not witnessed, any system for students' attendance must be efficient and avoid time wastage during attendance.

6. CONCLUSION

The usability of the fingerprint attendance register was tested and scores were calculated. The fingerprint biometric attendance register was deployed to a class sample of twenty students. Firstly, the students enrolled in the system and validated their records. A class session was then activated and students took attendance in turn. While the students took attendance, observations on the system's effectiveness and efficiency were made. The number of attempts to affix the

fingerprint during attendance and the display of correct students' records were keenly observed and recorded. Upon taking attendance, students were given online questionnaires to fill out and submit.

Data collected from the interactions of students on the attendance register and from the questionnaires were tabulated and analyzed. Usability tests for the effectiveness of the system, level of satisfaction with the use of the register, and its efficiency were calculated and tabulated. The usability tests showed a considerably high score in effectiveness, satisfaction, and efficiency. A PU score of 88.75% and a PE score of 70% were obtained. These were strong indicators of the effectiveness of the register system. ATU and TS scored a considerable high of 77.5% and 65% respectively. On efficiency, BIU scored 77.5%. These scores gave a good indicator that the biometric attendance register was efficient and satisfactory to use.

The results obtained help to reveal important factors that should be considered in conducting usability on biometric attendance registers. These include gender, social influences, age, and experiences with similar technologies. Emerging issues on privacy and security of information are also factors to be considered. Overall, the usability test results obtained gave a strong indicator that biometric attendance register technologies are effective, efficient, and secure for use.

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