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BIOMETRIC AUTHENTICATION SYSTEMS FOR

SECURED E-TRANSACTIONS IN SAUDI ARABIA

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PhD

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BIOMETRIC AUTHENTICATION SYSTEMS FOR SECURED E-TRANSACTIONS IN SAUDI ARABIA

An empirical investigation of the factors affecting users' acceptance of fingerprint authentication systems to improve online security for e-commerce and e-government websites in Saudi Arabia

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Abstract

Keywords: Authentication, Biometric, E-commerce, E-government, E-transactions, Fingerprint, Saudi Arabia, Security, Technology acceptance, User acceptance.

Security is becoming an increasingly important issue for business, and with it comes the need for appropriate authentication; consequently, it is becoming gradually more important to develop secure e-commerce systems. Fraud via the web, identity theft, and phishing are raising concerns for users and financial organisations. In addition, current authentication methods, like passwords, have many problems (e.g. some users write them down, they forget them, or they make them easy to hack). We can overcome these drawbacks by using biometric authentication systems. Biometric systems are being used for personal authentication in response to the rising issue of authentication and security. Biometrics provide much promise, in terms of preserving our identities without the inconvenience of carrying ID cards and/or remembering passwords.

This research is important because the securing of e-commerce transactions is becoming increasingly important. Identity theft, hacking and viruses are growing threats to Internet users. As more people use the Internet, more identity theft cases are being reported. This could harm not only the users, but also the reputation of the organisations whose names are used in these illegal acts. For example, in the UK, online banking fraud doubled in 2008 compared to 2007. More users took to e-shopping and online banking, but failed to take necessary protection. For non-western cultures, the figures for web security, in 2008, illustrated that Saudi Arabia was ranked ninth worldwide for users who had been attacked over the web. The above statistics reflect the significance of information security with e-commerce systems.

As with any new technology, user acceptance of the new technology is often hard to measure. In this thesis, a study of user acceptance of biometric authentication systems in e-transactions, such as online banking, within Saudi society was conducted. It examined whether Saudis are practically willing to accept this technology. This thesis focuses upon Saudi Arabia, which has developing economy. It has achieved a rapid rate of growth, and therefore makes an interesting and unique case study.

From an economist's point of view, Saudi Arabia is the powerhouse of the Middle East. It has the leading regional economy, and, even though it is still relatively young. It has a young and rapid growing population; therefore, this makes Saudi Arabia an attractive potential market for all kinds of e-commerce applications. Having said that, with more than half of population under the age of 30 are more to be expected to take the risk of accepting new technology.

For this work, 306 Saudi participants were involved in the experiments. A laboratory experiment was created that actively tested a biometric authentication system in combination with a survey. The Technology Acceptance Model (TAM) was adopted in the first experimental phase as the theoretical basis on which to develop the

research framework, the model has proven its efficiency as a good predictor for the biometric authentication system.

Furthermore, in a second experimental phase, the Unified Theory of Acceptance and Use of Technology (UTAUT) with moderating variables such as age, gender and education level was examined as a proposed conceptual framework to overcome the limitations of TAM. The aim of the study was to explore factors affecting users' acceptance of biometric authentication systems. The findings from Structural Equation Modelling (SEM) analysis indicate that education level is a significant moderating factor, while gender and age do not record as significant.

This thesis added new knowledge to this field and highlighted the importance of the perceptions of users regarding biometric security technologies. It helps determine the factors affecting the acceptance of biometric technology. To our knowledge, this is the first systematic study of this issue carried out by academic and non-biased researchers in Saudi Arabia.

Furthermore, the thesis presents security technology companies and developers of information security products with information to help in the determination of what is significant to their user base when taking into account the introduction of new secure systems and products.

Publications and Contributions

Chapter in Book

- F AL-Harby , R Qahwaji and M Kamala : "*End-Users' Acceptance of Biometrics authentication Systems in e-commerce: Applying the UTAUT Model* " *Globalization, Technology Diffusion and Gender Disparity: Social Impacts of ICTs*, IGI-Global**. Under review**.

Journal Publications

- F AL-Harby , R Qahwaji and M Kamala: "*Towards an Understanding of the Intention to Use Biometrics Authentication Systems in E-Commerce: Using an Extension of the Technology Acceptance Model*" International Journal of E-Business Research (IJEBR), 2010, **accepted**.

Conference Contributions

- F AL-Harby, R Qahwaji, & M Kamala, *Users' Acceptance of Secure Biometrics Authentication System: Reliability and Validate of an Extended UTAUT Model.* The Second International Conference on Networked Digital Technologies (NDT 2010), *Springer Lecture Notes in Computer Science ,* Prague, Czech Republic.

- F Al-Harby, R Qahwaji, and M Kamala, "*Biometric system characteristics and attitudes towards implement biometrics technology in online banking* " In Proceedings of The 4th Saudi International Conference SIC2010, July 30-31, 2010, University of Manchester, UK.

- F Al-Harby, R Qahwaji, and M Kamala, "*The effects of gender differences in the acceptance of biometrics authentication systems within online transaction*", CYBERWORLD 2009, Published by IEEE computer society pp. 203-210, September 7 – 11, 2009, Bradford, UK

- F Al-Harby, R Qahwaji, and M Kamala, "*The Role of User Self-Efficacy for the Acceptance of Biometrics Fingerprint Authentication System in E-commerce: The Use of UTAUT Model*", In Proceedings of the Saudi International Conference SIC, June 5-6, 2009, University of Surrey, UK. ISBN:978-1-84469-020-6

- F Al-Harby, R Qahwaji, and M Kamala, "*Biometrics User Authentication: Is fingerprint recognition the most suitable method for web applications' security?* " In Proceedings of the Saudi International Conference SIC June 5-6, 2009, University of Surrey, UK. ISBN:978-1-84469-020-6

- F Al-Harby, R Qahwaji, and M Kamala, "*Secure Biometrics authentication in e-transaction: A brief review of the literature*". In The 2009 International Joint Conferences on e-CASE and e-Technology. pp 3169- 3175. Singapore. ISBN: 978-986-83038-3-6.

- F Al-Harby, R Qahwaji, and M Kamala, "*The feasibility of biometrics authentication in e-commerce: user acceptance*", in IADIS International Conference WWW/INTERNET. Isaías, M.B. Nunes, and D. Ifenthaler, Editors. October 2008, p.p 527-531.IADIS Press: FREIBURG, GERMANY. ISBN: 978-972-8924-68-3.

- F Al-Harby, R Qahwaji, and M Kamala, "*Biometrics Authentication System for Secured e-transaction: an Empirical Study*", Proceedings of the Ninth Informatics Workshop, pp 42-45, University of Bradford, UK. ISBN: 9781851432516.

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List of Abbreviations

Theoretical Abbreviations (Literature Review):

ANX	Anxiety
ATMs	Automated Transaction Machine
ATU	Attitude Toward Usage
B2B	Business-to-business
BI	Behaviour Intention
BSC	Biometrics system characteristics
C-TAM-TPB	Combined TAM and TPB model
E-Commerce	Electronic Commerce
EE	Effort Expectancy
E-Government	Electronic Government
E-Mail	Electronic Mail
E-Payment	Electronic Payments
E-Transaction	Electronic Transaction
FC	Facilitating Conditions
G2B	Government-to-business
G2C	Government to Citizen
GDP	Gross Domestic Product
HCI	Human Computer Interaction
IBG	International Biometric Group
ICT	Information and Communication Technology
IDT	Innovations Diffusion Theory
IS	Information System
IT	Information Technology
KSA	Kingdom of Saudi Arabia

MM	Motivational Model
MPCU	Model of PC utilization
n	Sample Size
NPA	New Product Attributes
PE	Performance Expectancy
PEOU	Perceived Ease of Use
PINs	Personal Identification Numbers
PU	Perceived Usefulness
SCT	Social Cognitive Theory
SE	Self-efficacy
SI	Social Influence
SN	Subjective Norms
TAM	Technology Acceptance Model
TAM2	Technology Acceptance Model 2
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
UBB	United Banker's Bank
URL	Uniform Resource Locator
UTAUT	Unified Theory of Acceptance and Use of Technology
WWW	World Wide Web

Practical and Analytical Abbreviations (Experiments and Results):

AMOS	Analysis of Moment Structures
AVE	Average Variance Extracted
GPS	Global Positioning Systems
H	Hypothesis

p	p-value (Probability Value)
PC	Personal Computer
SDK	Software Development Kit
SEM	Structural Equation Modelling
SPSS	Statistical Package for the Social Sciences
USB	Universal Serial Bus
β	Coefficients beta weight

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Chapter 1. Introduction

1. 1 Introduction

Only a decade ago, the majority of individuals did not have access to the Internet at home. Shopping took place in physical shops; utility bills were paid at the bank or post offices. The recent widespread use of the Internet at residences and businesses has meant these services can easily be carried out from the home or office at any time.

Currently, web-based transactions, such as e-services, e-commerce, online banking and e-payment, widely use Personal Identification Numbers (PINs) to verify a user to a system. Identification of a PIN does not, however, guarantee verification of the individual's identity. Any person can gain access to a PIN, a card or any other key that is being used to gain access to a system. This means that systems which are dependent on high access security cannot always rely on these sorts of methods, as they cannot certify that a user is who he or she claims to be. Biometrics can be used to achieve secure access to a log-in system instead of passwords. By integrating advanced biometric verification in an Internet application, secure, low-risk and suitable transactions can be implemented. However, using biometrics raises concerns about the user's awareness of a potential invasion of their privacy. Over the past few years, in an effort to increase security and user experience, research on biometrics to determine an accurate authentication has shown significant improvement(James, Prim et al. 2006).

Although biometric authentication systems are one of the future directions that should be investigated to secure online businesses, there are some obstacles to their

widespread adoption. Not all biometric systems are popular due to privacy issues and other sociological factors, and certain individuals prefer fingerprints, while others, face recognition. However, the major obstacle is that of acceptance, because it matters little how secure or efficient a system is if nobody is willing to use it. New technology may not be successful if the user will not accept it. It needs to be easy to use, convenient and should provide the user with a feeling of control (Coventry, De Angeli et al. 2003).

The acceptance of new and innovative technologies is often difficult to gauge. For this work, our research was accomplished through examining consumer acceptance of biometric authentication within e-commerce applications in Saudi Arabia.

1. 2 Motivation

The securing of e-commerce transactions is becoming increasingly important. Identity theft, hacking and viruses are growing threats to Internet users. As more people use the Internet, more identity theft cases are being reported. This could harm not only the users but also the reputation of the organisations whose names are used in these illegal acts. Over 8.4 million Americans had their personal information compromised during 2007[1]. This figure includes only cases with known data breaches; it does not include those not reported or discovered. For the same year, the loss caused by referred complaints was $239.09 million. In 2007, the latest UK statistics estimated losses due to online banking fraud at £22.6 million[2].

The use of biometric authentication is a response to the rising issue of security. Biometric devices have the obvious benefit of not falling prey to many of the well known vulnerabilities of traditional methods (James, Prim et al. 2006). While a

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[1] www.privacyrights.org
[2] http://www.computing.co.uk/computing/news/2221020/lords-say-crime-nust-reported

biometric device uses a unique biological trait to distinguish an individual, it is very difficult and often impossible for the identifier to be lost, stolen, duplicated, or given away (Liu and Silverman 2001; James, Prim et al. 2006). This advantage makes biometric authentication an attractive opportunity for individuals and organisations that wish to adopt a new security technology.

Online banking, online shopping and ATMs are among the many e-commerce applications to which biometrics may be applied (Liu and Silverman 2001). Several companies look forward to using biometric technologies for authentication as it could reduce losses (James, Prim et al. 2006). Biometric technology can help prevent illegal financial transactions and identity theft (Jain, Hong et al. 2000; Herman 2002).

Developing a secure e-commerce system is becoming gradually more important. Fraud via the web, identity theft, and phishing are raising concerns for users and financial organisations. In the UK, online banking fraud doubled in 2008 compared to 2007 as more users took to e-shopping and banking online, but failed to take necessary protection. According to figures released by the payments group (Apacs)[3], there was an increase in card fraud losses of 14% in 2008; however a more shocking 132% increase in online banking fraud totalling £52.5 million[4] also took place in 2008. For non-Western culture, figures for web security in 2008 illustrated that Saudi Arabia was ranked ninth worldwide for users who had been attacked over the web[5].

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[3] http://www.ukpayments.org.uk/resources_publications/key_facts_and_figures/card_fraud_facts_an d_figures/-/page/645/

[4] http://www.thisismoney.co.uk/credit-and-loans/id-fraud/article.html?in_article_id=480715&in_page_id=159

[5] http://coeia.edu.sa/index.php/ar/

All the above statistics reflect the significance of information security with e-commerce systems.

Biometric technologies are one of the most significant innovations in the IT industry and it has grown from a $600 million market in 2002 to a $4 billion market in 2007 (Mordini and Petrini 2007).

The adoption and acceptance of new technology is often hard to gauge. For this work, research was conducted of user acceptance of biometric authentication systems in e-commerce within Saudi society. This research focuses upon Saudi Arabia, which has a diverse immigrant population, a Sharia legal system and a developing economy (Al-Somali, Gholami et al. 2008), and therefore makes an interesting and unique case study. From an economist's point of view, Saudi Arabia is the powerhouse of the Middle East. It has the leading regional economy, and, even though it is still relatively young, it has achieved a rapid rate of growth. It has a young and rapid growing population, 54.3% of the whole population are males, 45.7% are female and, approximately, just over half of the population is under the age of 20. Therefore, this makes Saudi Arabia an attractive potential market for all kinds of e-commerce applications (Png, Tan et al. 2001). Having said that, with 60% of the population under the age of 30 are more to be expected to take the risk of accepting new technology (Straughn and Albers-Miller 2001).

A robust literature review has revealed a limited amount of research related to authentication on e-commerce (Koufaris 2002; Tamilia, Senecal et al. 2002; James, Prim et al. 2006). In order to shed more light on these perspectives, a study based on Davis' (1986) Technology Acceptance Model (TAM) was performed to examine the influences of using biometric authentication systems in e-commerce application.

There is a lack of research, particularly in developing countries, on aspects influencing user acceptance of biometric authentication technology within e-commerce applications.

1. 3 Aims

The thesis aims to examine the extent to which prospective Saudi users of a biometric authentication system accept that their information is stored and used in a correct and secure way; particularly, we are not testing all users but rather users within a certain cultural context. Under any conditions, are they encouraged to use such a system? An indication will be gained as to whether more information is required for the regular user before such a system is implemented. This study might be beneficial to many groups, such as: current and potential users; developers of biometric authentication systems who are concerned about user interaction; and IT managers considering and/or planning the implementation of biometric authentication systems for their establishment, or as an enhancement or replacement of traditional authentication systems. The major purpose of this research is to investigate whether there is the possible for user acceptance of biometric methods in e-commerce and e-government among future users in Saudi Arabia.

One more purpose is to investigate and analyse the established biometric methods available today which may be suitable for implementation in Saudi Arabia. Issues under discussion will be: do Saudi users accept biometric authentication methods in their daily use of e-transactions and online business?

The final aim of this study is to understand the factors which are specific to humans and influences functioning of technological systems (Stanton, Salmon et al. 2005)

that are significant in explaining the intention to use a biometric authentication system within e-commerce and e-government applications.

1. 4 Objectives

The research objectives were addressed through two experimental studies: (1) the feasibility of using biometric authentication: the initial experiment, (2) user acceptance: using an extension of TAM (Technology Acceptance Model) (experimental phase I) and applying the UTAUT (Unified Theory of Acceptance and Use of Technology) (experimental phase II).

The objectives of the initial study are to: (a) provide an indication of the current degree of familiarity with the concept of biometrics in Saudi Arabia, (b) find an answer for the centrally important question of whether Saudis are likely to accept and be encouraged to use biometric authentication systems, and (c) discover which biometric authentication method is most suitable for Saudis.

The second experiment included two experimental phases to investigate the acceptance of biometric authentication systems and the factors affecting the use of such systems. An experiment was designed, which included the development of a fingerprint log in to an authentication system. The experiment also had a survey instrument to measure the likelihood of individual adoption of such technology. Moreover, the study exploited several constructs extracted from theoretical models anticipated in the current literature of information systems (IS) to assess user acceptance of technology such TAM and UTAUT.

1. 5 Method

The survey of the first study was designed according to the methods introduced in Churchill (1999). In Churchill (1999), three types of research design methods, which depend on the research questions and aims, were presented. These are exploratory research, descriptive research and causal research.

The initial investigation was a cross-sectional survey of a sample of three hundred and four Saudi participants. The purpose was to investigate a small sample of people from a chosen population, and then draw conclusions from the results and apply these to the larger population. The advantages of examining a sample are reduced costs, time efficiency, and ease of testing. The method used in this survey was electronic mail. E-mail was used for its low cost and reduced transfer time.

The second study integrated a laboratory experiment that actively tested a biometric authentication system in combination with a survey. The Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) were adopted as the theoretical bases on which to develop the research framework. In particular, we built a biometric authentication system whereby users could register and enrol into their accounts with their fingerprints. Once a user had registered, the next time he/she logged in to the system, the user could simply scan his/her fingerprint and the system would grant access.

At the beginning of any experiment session, preliminary questions were asked to determine the participants' familiarity with biometrics and their comfort level in performing the experiment. The participants were then asked to complete the tasks. Upon completion of these tasks, the participants were asked to answer a list of questions about their perceptions of the fingerprint system. The results of the

experimental (phase I) were analysed by regression analyses, moreover, Structured

Equation Modelling (SEM) was used to analyse the second phase of the experiment.

Conclusions were drawn to generalise the results observed during the experiment.

Figure 1 shows structure of the thesis, experimental phases and steps followed in the

research method.
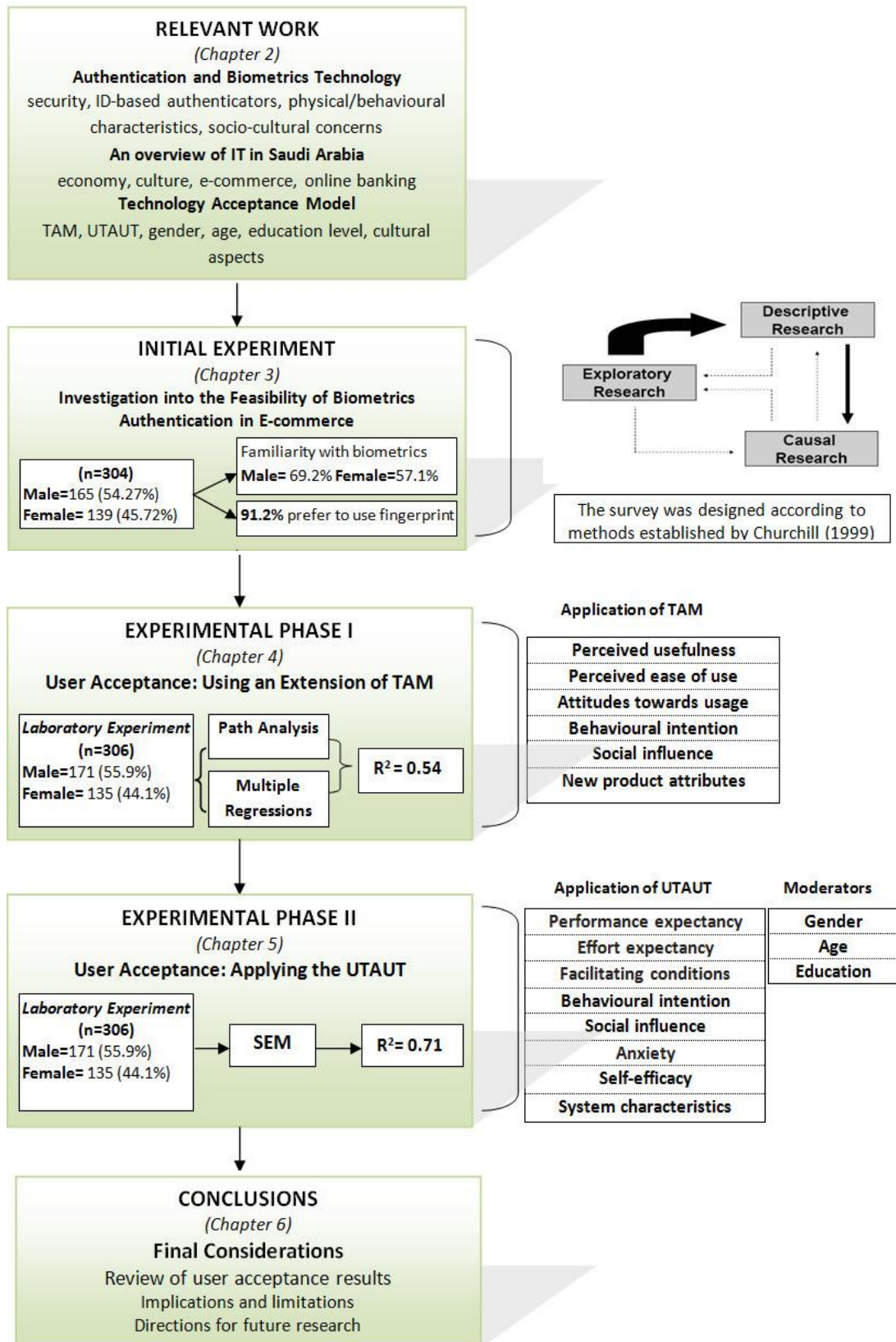
Figure 1: Structure of the thesis

1. 6 Thesis Contribution

This thesis will significantly make empirical and methodological contributions to e-transaction and e-commerce security research. A brief overview of the contributions is provided below.

- It will add new knowledge in this field and highlight the importance of the perceptions of users regarding biometric security technologies.

- It will help determine the social and cultural aspects that affect the acceptance of biometric technology.

- The thesis will present security technology companies and developers of information security products with information to help in the determination of what is significant to their user base when taking into account the introduction of new secure systems.

- This research contributes to discover findings on the characteristics, and attitudes of user acceptance of biometric authentication systems.

- This thesis illustrates that usefulness (performance expectancy) is still the most important concern in the behavioural intentions to use the system.

- These findings will be of great relevance for e-commerce providers targeting Saudi or similar users.

- Bankers and IT providers would benefit from assessing their websites' security perceptions by actual users, as it provides insight for areas of improvement.

- It is hoped that the study will contribute to wider understanding regarding the authentication methods to secure online applications within e-commerce, e-government and e-learning.

- Research findings will explain the differences across age, gender and education level in their acceptance to use the biometrics technology in their daily life within e-commerce.

- The findings of this work shows that making decisions with regards to the development or design of any technological system, including: games, e-learning and e-commerce, which are solely based on advanced models of culture are unlikely to be adequate. An evaluation of the culture and context of use is required to ensure that the system is successful when released across many markets. Organisations should seriously consider cultural differences before releasing any system.

1. 7 Thesis Outline

This thesis produced a total of six chapters and five appendices. The following subsections illustrate the rest of thesis chapters and appendices.

Chapter 2 (Literature Review and Theoretical Background): This chapter consists of a literature review and hence explores the background to the subject in further detail, laying a theoretical base on which further exploration can take place. This deeply explores the subject of authentication methods within e-transaction systems and the use of biometrics, explains the significance of information security in general and considers how it is perceived by the different disciplines. It then relates to the online environment in Saudi Arabia with consideration being paid to the high demand to apply many online services. The chapter sheds more light on the

evaluation approaches used to measure user acceptance factors. Several user acceptance evaluation studies are presented and categorised into application of TAM and UTAUT. This is followed by a general critical evaluation to spot relevant and critical issues and prepare for the experimental chapters.

Chapter 3 (The Feasibility of Using Biometrics Authentication: The Initial Experiment): This chapter investigates the feasibility of biometric authentication systems in online services and their user acceptance in Saudi Arabia. Additionally, it explores whether Saudis practically and culturally are willing to accept biometric authentication technology. A survey was developed to investigate the level of user acceptance for biometric authentication systems and this is discussed here.

Chapter 4 (User Acceptance: Using an Extension of TAM – Experimental Phase I): This chapter reports on an experiment conducted of user acceptance of a biometric authentication system in the online environment within the Saudi society. The experiment included the development of a fingerprint authentication system. A laboratory experiment was created that actively tested a biometric authentication system in combination with a survey which was used to measure the likelihood of the user's acceptance of this technology. The Technology Acceptance Model (TAM) was adopted as the theoretical basis on which to develop the research framework and was extended to study the intention to use biometric authentication systems in e-commerce applications across Saudi Arabia.

Chapter 5 (User Acceptance: Applying the UTAUT Experimental Phase II): This chapter details the second phase of the experimental studies. Based on the outcomes of Chapter 4, it was realised that other factors may also play an important role in the user's intention to accept and use the biometric system, such as facilitating

conditions, anxiety, self-efficacy and system characteristics. Moreover, the TAM missed the significant sources of variance and the moderator factors, such as gender, age and educational level. To overcome these limitations, a study based on Venkatesh et al. (2003), which involved the use of the Unified Theory of Acceptance and Use of Technology (UTAUT), was conducted to examine the acceptance of a biometric system to secure online systems, and included all the above factors. Hence, we considered the major UTAUT constructs in determining acceptance intentions and behaviour, performance expectancy, effort expectancy, social influence and facilitating conditions.

Chapter 6 (Conclusions and Recommendations): This chapter presents the conclusions drawn and summarises the findings of the study, along with theoretical, methodological and practical implications. The limitations of the study and suggestions for further research are also discussed.

Appendices: Appendices relate to relevant work, surveys and experimental results are included in the attached CD.

Chapter 2. Literature Review and Theoretical Background

2. 1 Introduction

This chapter aims to survey the state-of-the-art authentication methods available for e-business in general, e-business in Saudi Arabia, and finally the technology acceptance models. The goal is to justify the need for this work and identify and review the gaps in the knowledge and research. This chapter will therefore focus on three main areas: firstly, the authentication methods and biometrics; secondly, an overview of Saudi Arabia; and finally, a discussion of technology acceptance models.

2. 2 Authentication Methods and Biometrics

The process of authentication is the process of verifying and confirming an identity. It is accomplished by using any one, or a combination, of the following traditional identification techniques: knowledge-based (something you know, e.g., a secret password), object-based (something you have, e.g., a token), and ID-based (something you are, e.g., a biometric) (O'Gorman 2003; Laurie, Annie et al. 2007).

2.2.1 Knowledge-Based Authenticators

Knowledge-based authenticators, such as passwords, are pieces of information known only by the user (Laurie, Annie et al. 2007). Passwords are widely used and are associated with high rates of user acceptance (Furnell, Dowland et al. 2000). Passwords can be perceived as less convenient than other authentication methods as they require memorisation, a task made more complicated when users have to remember several passwords (Reid and Magnuson 2005).

2.2.2 Object-Based Authenticators

Typically, object-based authenticators or tokens are small physical devices carried by a user for authentication purposes, such as smart cards. There are two basic types of tokens: manual and automated. Manual tokens, such as paper ID documents and passports, require human intervention for the identification process. Examples of automated tokens include magnetic-stripe cards; memory cards; smart cards and devices that generate one-time pass codes, whose identification is carried out by computers or systems without human intervention (Ashbourn 2000; O'Gorman 2003). Threats to privacy are a major concern for token users, especially in terms of third-party disclosure, targeted marketing, and the potential for tracking (Strickland and Hunt 2005). Moreover, one major threat for token users was unauthorised access by individuals that borrow, steal or found this token. This can never happen with biometrics.

2.2.3 ID-Based Authenticators

ID-based authenticators can consist of ID documents and biometrics. They are characterised by uniqueness to an individual (O'Gorman 2003). For the purposes of this research, we are only focusing on biometrics.

2.2.4 Biometric technology

Biometrics are defined as measurable physiological and/or behavioural characteristics that can be utilised to verify the identity of an individual. Biometrics include fingerprint verification, hand geometry, retinal scanning, iris scanning, face recognition, and signature verification (Ashbourn 2000). Generally, physical and behavioural characteristics used by biometrics include the following taxonomy (Zhang 2000):
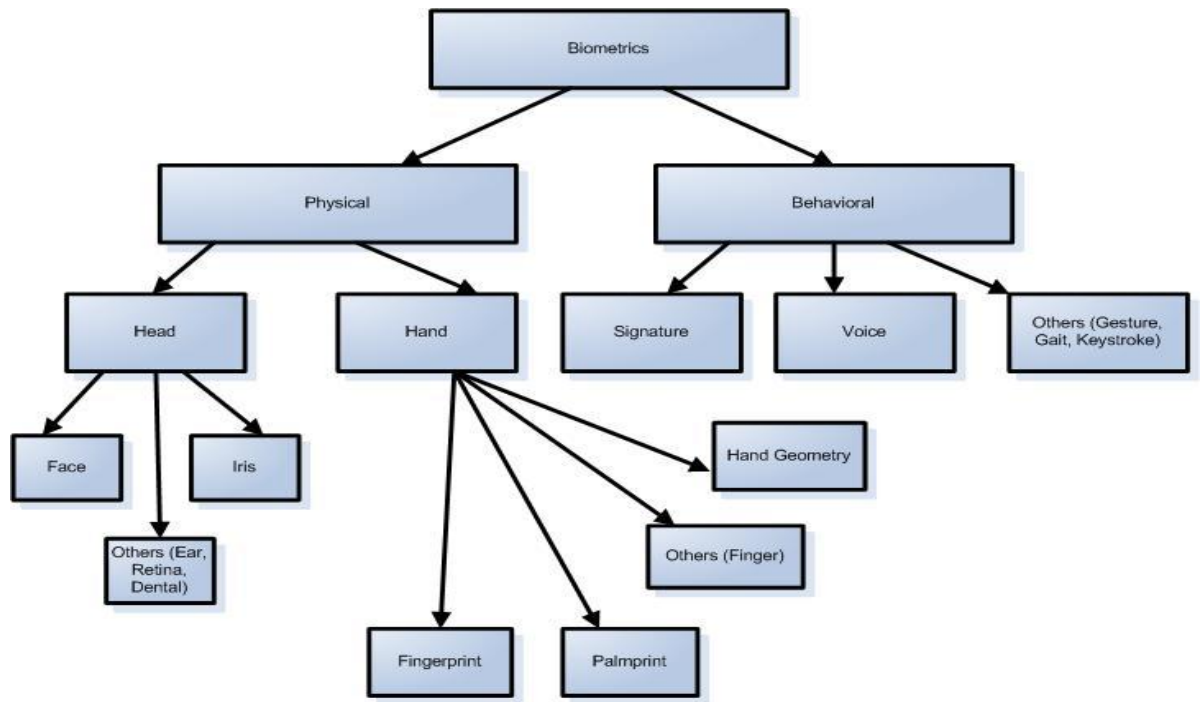
Figure 2: Physical and behavioural characteristics used by biometrics (Zhang 2000)

Biometric authentication aims to identify an individual using either a biological feature they possess (physiological characteristic like a fingerprint), or something they do (behavioural characteristic, like a signature) (Wayman and Alyea 2000). There is increasing interest in using biometrics: the International Biometric Group (IBG) predicts the market for biometrics to rise from $2.1 billion in 2006 to $5.7 billion in 2010[6], driven by large-scale government programmes and dynamic private-sector initiatives. However, general awareness of biometric technologies is low because of their limited applications (Furnell and Evangelatos 2007).

2.2.5 Strengths, Weaknesses and Suitable applications

Allan (2002a) provides a list of some of the strengths, weaknesses and suitable applications for each biometric methodology:

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[6] http://www.biometricgroup.com/
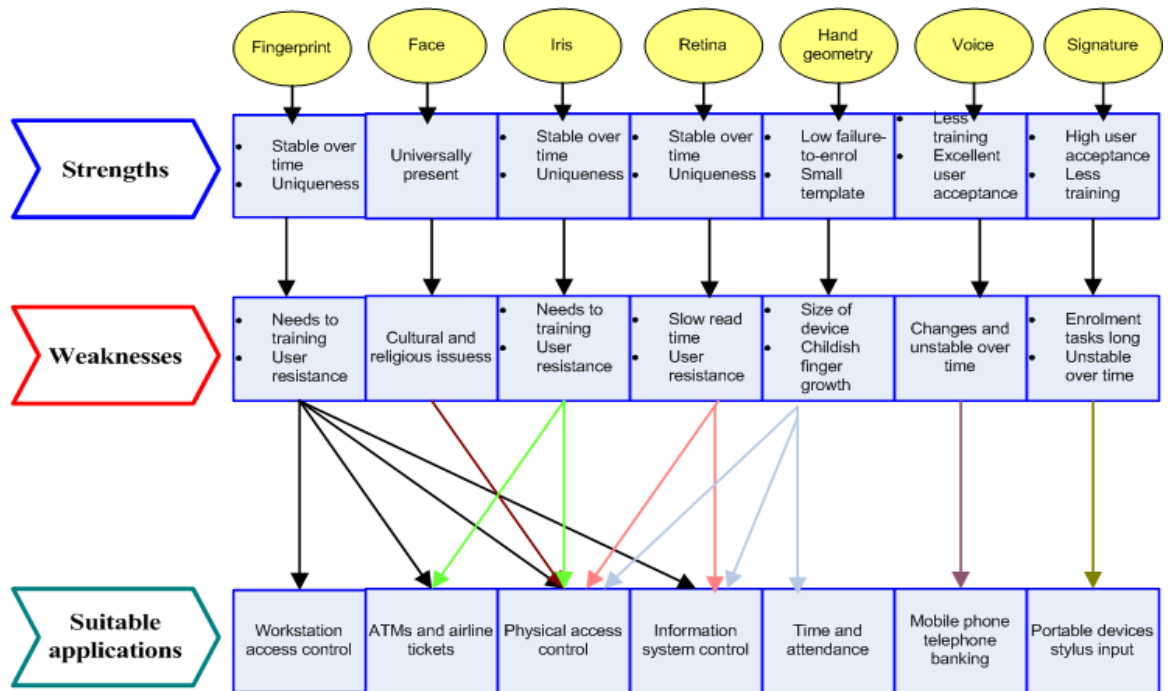
Figure 3: Strength, Weaknesses and Suitable Applications

Source: Adapted from source - Allan, A. (2002) "Biometric Authentication: Perspective." Gartner Research, ID Number: DPRO-95808.

2.2.6 Comparison of biometrics

Today there are several biometric characteristics that are in use in various applications. Each biometric has its own strengths and weaknesses, and suitable applications for each biometric methodology. There are no particular biometrics which may successfully meet the requirements of all applications. Depending on the application's usage and the biometric characteristic's features we are able to suitably match a particular biometric to an application (Prabhakar, Pankanti et al. 2003). Explain that the fingerprint- and iris-based techniques are more accurate than the voice-based technique. Nevertheless, in a phone banking application, the voice-based technique might be preferable as the bank could integrate it seamlessly into the existing telephone system. The following table briefly compares five biometrics according to seven parameters (Prabhakar, Pankanti et al. 2003).

BIOMETRIC	FINGERPRINT	FACE	HAND GEOMETRY	IRIS	VOICE
Barriers to universality	Worn ridges; hand or finger impairment	None	Hand impairment	Visual impairment	Speech impairment
Distinctiveness	High	Low	Medium	High	Low
Permanence	High	Medium	Medium	High	Low
Collectibility	Medium	High	High	Medium	Medium
Performance	High	Low	Medium	High	Low
Acceptability	Medium	High	Medium	Low	High
Potential for circumvention	Low	High	Medium	Low	High

Figure 4: Comparison of Biometrics (Prabhakar et al. 2003)

2.2.7 Features of Biometrics

A human characteristic can be used for biometrics in terms of the following parameters (Jain 2004) :
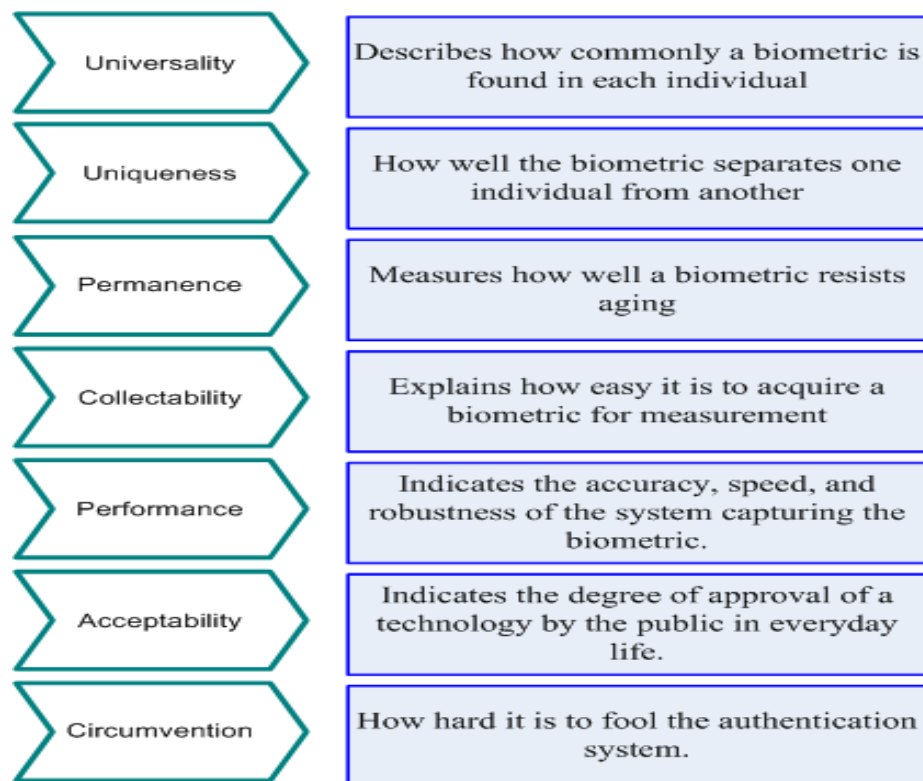
Figure 5: Features of Biometrics Systems

2.2.7.1 Choosing fingerprints

The most widely used method of biometric authentication is fingerprint recognition. Fingerprints are well known to be unique for each person, and, for this reason, they are considered a secure method of authentication (Jain 2004). Fingerprints are one of the oldest and most accepted forms of personal authentication. The choice of fingerprints over other biometric technologies has been due to the low cost, ease of use, reliability and high accuracy (Jain 2004). Although, fingerprints require physical interaction with the sensor, not like face or speech recognition, choosing fingerprints could also make it easier to overcome cultural issues that may arise if other features such as speech or faces are used.

2.2.7.2 Benefits of using a fingerprint biometrics system

Many benefits can be gained from using fingerprint biometric authentication within e-commerce applications, such as ease of use (since no data input, such as user ID or password, are required from the user), and reducing data vulnerability. Another benefit is increased security and decreased risk of viruses, as the browser is built in such a way that there is no need to type the Uniform Resource Locator (URL). As a result, phishing would be reduced due the lack of data input by a user.

Online banking is a possible application for biometric authentication (Liu and Silverman 2001). Many financial institutions hope that the use of biometric technologies for authentication may reduce the amount of money spent on fraud cases (James, Prim et al. 2006). Biometric authentication systems can help to circumvent illegal e-transactions and identity theft (Jain, Hong et al. 2000; Herman 2002). Nowadays, many financial institutions use biometrics methods to secure their services, such as the United Banker's Bank (UBB), Affinity Plus Federal Credit

Union, the California Commerce Bank, LendingTools.com, the Dutch bank ING, and Banco Azteca, Mexico.

To fight these security concerns, especially ID theft, fraud, and phishing, several organisations have approved new legislation, as well as innovative technological advances like biometrics. Many organisations are paying attention to biometric authentication technology; included financial institutions, government agencies (e.g. border controls at many countries for example but not limited to UK and USA, and retail organisations such Pay By Touch services[7]).

2.2.8 Biometrics and Socio-Cultural Concerns

Pikkarainen et al.(2004) stated that on a study focus on the planning of an online banking website and service, privacy was found to have a relatively weak relationship with the acceptance. Concerns about biometrics do exist. Once a digitized fingerprint or any other characteristic is stolen, it is compromised forever. According to William Rogers, a publisher of the Biometric Digest, stated in a quote (Fox 2002):

"The whole key to biometrics is selling it to members of the public, convincing them

to give up some privacy for greater security."

The perception of usability and acceptance of the biometric applications are higher when the perceived benefits are higher than the perceived privacy risks (Schmidt, Das et al. 2008).

Woodward et al. (2001) study identified three main socio-cultural concerns with regard to biometrics: information privacy, physical privacy, and religious objections.

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[7] ftp://ftp.software.ibm.com/software/solutions/pdfs/ODC00294-USEN-00.pdf

2.2.8.1 Information Privacy

Some concerns relating to information privacy were identified. The first concern was "function creep", which is the process of using information for something other than the function for which it was initially intended. The next concern is "tracking", where many people share the given access to data relating to an individual, enabling governments to develop "Big Brother" type institutions. The final concern is the misuse of data, especially in an online environment (Prabhakar, S. Pankanti et al. 2003).

2.2.8.2 Physical Privacy

Many biometrics have a certain stigma attached to them and can prevent people from using the system comfortably. In the last decade, fingerprinting, for example, has an undeserved stigma due to its association with criminal activities, and because of this, users feel that they are being criminalised when asked to give a fingerprint, especially if it is mandatory(Woodward, Webb et al. 2001; Prabhakar, S. Pankanti et al. 2003); nowadays due to growing use of fingerprint systems by many countries at border controls it is becoming part of the norm.

There are concerns relating to physical harm caused by the biometric sensors (e.g., the laser used in retinal scanning). Another concern raised within the iris recognition industry is whether eye infections, such as conjunctivitis, are transferable by the camera. Users of touch-based biometric scanners also often fear the transmission of illness and bacteria through the use of scanners (Prabhakar, S. Pankanti et al. 2003).

2.2.8.3 Religious Objections

Different countries have different cultures and religious beliefs which govern business and social practices, and people will be hesitant to adopt practices considered contrary to their cultural or religious dictates. Some religious Christians,

for example, believe biometrics represent the "mark of the beast" as described in Revelations, and this could result in prohibiting their use (Prabhakar, S. Pankanti et al. 2003). In addition, facial recognition of women would be prohibited in some Muslim countries, such as Saudi Arabia.

2.2.9 Critique of Relevant Literature Regarding Biometrics

A review of the recent literature has shown that while a biometric authentication system assures cost savings and higher levels of security, they are not a panacea. Various factors influence how biometric authentication systems will perform within online applications such as socio-cultural concerns. In addition, the literature review revealed the lack of research concerning the factors affecting the acceptance of biometric authentication systems. Investigation in this field could assist in explaining why users and organisations are willing, or not, to accept biometric authentication systems. Moreover, it could facilitate IT decision makers to decide what aspects of biometric authentication technologies are of concern to them and consequently propose suitable solutions to secure their institutes. Furthermore, IT companies could benefit from this study by addressing what is important to their users before launching new security technologies.

While there is a lack of scholarly research concerning the aspects influencing the acceptance of biometric systems, there are solid theories and previous research on technology adoption in general. To our knowledge, this is the first study to be carried out for Saudi Arabia.

The next part of this chapter highlights the main characteristics of Saudi Arabia which comprises the context for an empirical study.

2. 3 An Overview of the Characteristics of Saudi Arabia

Many governments and financial institutions worldwide are implementing strategies to secure e-transaction services, including e-government and e-commerce applications, to their citizens and businesses in order to support the information security of the public and private sector.

However, amid the rapid implementation of e-transactions, there is no common model that can be applied worldwide, since each country has its own characteristics in terms of economic, political, cultural and social factors which might influence the implementation of new technology in the target country (AL-Shehry 2008). Hence, this section presents some brief information about Saudi Arabia, which is the main focus of the case study. This is followed by a focus on its plan concerning IT and e-transactions.

2.3.1 Location, Size and Population

The official language in Saudi Arabia is Arabic. Nevertheless, English is commonly spoken in the private sector. Saudi Arabia is situated in the south-western part of the Asian continent and occupies 2,149,690 sq km[8]. With Africa on one side and Iran and South Asia on the other, it is in the middle of the strategically important Indian Ocean area (AL-Shehry 2008). Concerning the population figures[9] in Saudi Arabia, the total population is about 22,673,538, with an annual growth rate of 2.5%. In this society 54.3% of the whole population are male, 45.7% are female and more than half of the population is under the age of 20. This high concentration of young people might allow Saudi Arabia to implement new technologies more easily because young people might be more willing to accept the technology.

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[8] https://www.cia.gov/library/publications/the-world-factbook/geos/sa.html
[9] CDSI Statistical Year book (2006)

2.3.2 The Saudi Arabian Economy

According to the World Fact Book (2008)[10], Saudi Arabia possesses more than 20% of the world's proven petroleum reserves and is the largest exporter of petroleum. The petroleum sector accounts for roughly 45% of GDP and about 40% of GDP comes from the private sector. The government is encouraging private sector expansion – particularly in power generation, telecommunications, natural gas exploration, and petrochemicals – to decrease the Kingdom's dependence on oil exports and to increase employment opportunities for the growing Saudi population.

2.3.3 The Culture of Saudi Arabia

Saudi culture is characterised by many aspects such as religion, the tribal system, and modernisation (Al-Farsy 2003). Obviously, Saudi Arabia contains the two Holy Mosques for Muslims in Mecca and Medina (Al-Farsy 2003). Al-Saggaf (2004) stated that religion plays a central role in defining this culture; acting as a major power in determining the social norms, patterns, traditions, obligations, privileges and practices of society. According to Hofstede's (2001) study, national culture affects organisational culture, and these issues are significant when implementing e-commerce systems in Saudi Arabia. The effect of culture can be shown clearly in the adoption of the Internet in 1999 after a long discussion and consultation within the Saudi authorities. At last, a filter system was set up. The reason for having such a filter system was designed to filter offensive materials (for example, pornography) and also for other cultural, religious and political reasons (Al-Saggaf 2004; AL-Shehry, Rogerson et al. 2006).

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[10] https://www.cia.gov/library/publications/the-world-factbook/

2.3.4 E-transactions in Saudi Arabia

Nowadays, e-transactions are high on the Saudi agenda. Many projects are carried out in the fields of finance, commerce, education, and government. On the other hand, e-transaction services in Saudi Arabia, such e-commerce and e-government, are still relatively small scale when compared to developed countries like the USA and the UK (Sadiq, Sait et al. 2004). Regarding e-transaction services among organisations in the public and private sector, there are many projects in Saudi Arabia that have developed e-transaction activities in a diversity of ways, as the following Table 1 shows.

Project	Description of the main objective
e-Payment Gateway "Sadad"	Building the e-payment gateway to: • Facilitate G2B and B2B electronic payments. • Include G2C in future.
Smart Cards	Issuing national ID cards using smart card technology. This system: • Has a computer chip for storing personal identification information and thumbprints, as well as medical and driving records. • May also hold digital certificates.
e-Umrah	The e-Umrah project is designed to deal with approximately two million pilgrims who come to Saudi Arabia annually.
MOI (Ministry of Interior) Portal	This citizen portal. • Provides 20+ services electronically, including passports, birth certificates, driver licences, etc. • Offers 100 kiosks.
The Madinah e-Government Project	The Municipality of Almadinah portal offers: • G2B services. • G2C services.
Import/export processes	Supports international import/export processes. • Covers complete workflow (customs, general organisation of ports, cargo, customs clearance agents etc.) • It can speed up the process and cut down the cost by half.

Table 1: Electronic services within some public organisations in Saudi Arabia

Due to the rapid development of e-transactions during the last decade, e-commerce activities, such as online banking, have become widely accepted in industrialised

countries like the UK, and partially accepted in less industrialised countries such as Saudi Arabia. Table 2 shows a comparison of the levels of online banking use in the two countries (Alsajjan 2008):

Country	Population[11]	Number of Internet users	Registered banks[12]	The percentage of online banking users of total banks' users	Industry net income (£ mil)
UK	60,093,000	31,906,960	382 (2005)	85%	8440 (2004)
SA	22,673,538	6,400,000[13]	16 (2006)	20%	3429 (2006)

Table 2: A comparison of the levels of online banking use in UK and Saudi Arabia (Alsajjan 2008)

Based on the table above, the figure shows a large number of online banking users in both countries; usable and secure online banking will increase the total number of users in the recent future. Without the perception of security and usability, there will be little trust in online banking and e-transactions; thus impeding the use of systems which are increasingly significant to the nation's critical infrastructure (Supriya 2006; Mohammad and Oorschot 2008).

2.3.5 IT and Cultural Aspects

In addition to the importance of usability and security, cultural and social aspects play a significant role on the acceptance and trust for any new technology. Most user acceptance studies published in the top journals are based on data from North America, the UK, Europe, and Australia. The geographical areas of Asia, Africa and the Middle East have cultures and social aspects that were not considered adequately in these studies, where few user acceptance models are considered. It may therefore be significant for models that might be affected by cultural differences to be appraised in 'non-western' contexts.

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[11] Euromonitor (2006) & CDSI Statistical Year book (2006)
[12] UK Year Book (2007) & SAMA statistics (2008)
[13] The Saudi Communication and Information Technology Commission (2008)

Prior research into technology acceptance has been inconclusive when concerning the applicability of a western-developed model of technology acceptance to other cultures (e.g. (Mao and Palvia 2006; McCoy, Galletta et al. 2007; Schepers and Wetzels 2007). Investigative technology acceptance models in non-Western cultures, in particular in this field of advanced technology, are worth examination. The current study conducted in Saudi Arabia which is a non-Western culture.

In order to understand the usability, including the ease of use and affordability of the new technology, the time and money aspects involved in achieving access to key technologies in the Middle East need addressing. Wheeler (2004) conducted a survey indicating that access to IT is more affordable and more efficient in the Middle East than in Europe and North America; it can cost double what it costs in the Middle East and can take two to three times longer to obtain access. Moreover, Wheeler (2004) suggests that the Middle East has more of an information society than Europe in terms of the ease and affordability of access to IT.

With respect to online security, an effective and usable e-commerce website design can engage and attract online user acceptance (Nielsen 2001). Fogg (2002) stated that a high percentage of users evaluate the trust and acceptance of websites based on their overall design.

As illustrated previously, not many studies have covered Saudi Arabia despite its increasing importance. Considering that biometric technology, within e-commerce in the context of Saudi Arabia, is still in its early stages of development, little is known about user behaviours towards the acceptance of this new technology, or concerning the factors that influence their behaviours and attitudes towards it.

Taking into account cultural, economical, and social differences, the research into e-commerce use in more advanced countries may not actually present insights into the business use of e-commerce websites in developing nations. Culture can obstruct the use and implementation of e-commerce due to the differences in the way the systems are interpreted and understood. Therefore, the use of generalisations from the west-based research to the developing countries can lack external validity (Ravi, Richard et al. 2007; Al-Diri 2008).

Al-Diri et al. (2008) illustrated that it is very important to take cultural aspects into consideration when designing e-commerce websites. It is expected that when websites are appropriate and culturally sensitive, then, users will have increased access to content which will improve user experiences.

User perception of e-commerce website acceptance may be enhanced by experiencing usefulness, attractive design that is easy to use. E-commerce service providers should thus pay more attention to antecedents of adoption, such as the cultural background of the user if they want to be successful providers. Organisations and providers should be aware that there are different relations between e-commerce website design elements and cultures. Each culture may perceive and react differently to e-commerce website designs, ease of use, images, language, usefulness etc.

2.3.6 HCI and Culture Aspects

The cultural and social aspects of technology use are gradually becoming more recognised as significant issues by the Human-Computer Interaction (HCI) society (Kamppuri, Bednarik et al. 2006). There has been a tendency of moving beyond definitions of usability, that highlight effectiveness and usefulness, to incorporate

issues, such as: visual appeal, context and culture, in the usability appraisals (Sun 2002). Culture and context are particularly significant when exploring the acceptability and adoption of technology for a particular condition (Benyon, Turner et al. 2005; Chris, Kathy et al. 2009). A number of recent examples of interactive technologies have been considered with culture in mind, including: automated speech recognition systems (Stewart and Chakraborty 2008), and alphanumeric display interfaces (Songmei 2006). Regardless of this rising consideration, culture remains an under-researched area in the field of HCI (Kamppuri, Bednarik et al. 2006; Chris, Kathy et al. 2009) and the majority of usability studies do not take culture into account.

2.3.7 Hofstede's Cultural Dimensions

Several attempts have been made to define culture using a systematic approach. Within the context of this research, the definition of culture as anticipated by Hofstede (1980; 1984; 1990; 2001) was adopted. Hofstede (1984) described culture as the "the collective programming of the mind which distinguishes the members of one group from people from another". Hofstede presented five 'cultural dimensions' that have been used to measure differences among national cultures. There have been several reviews and replications of his work; his framework has been widely used across different disciplines, including information systems (e.g. (Simon 2001; Al-Gahtani, Hubona et al. 2007), e-commerce and HCI (Antonella De and Leantros 2006). Hofstede (1984) proposed that there are five constructs that characterised national culture, which are described in Table 3.

Hofstede's dimension	Definition
Uncertainty avoidance (UA)	Focuses on the level of tolerance for uncertainty and ambiguity within the society. High UA indicates a structured, rule-oriented society that institutes rules, regulations and controls in order to reduce the amount of uncertainty.
Power distance (PD)	Focuses on the degree of equality, or inequality, between people in the country's society. High PD indicates that inequalities of power and wealth are accepted practices and have been allowed to grow.
Masculinity (MAS)	Masculinity measures the degree to which 'masculine' values like assertiveness, performance, success and competition prevail over 'feminine' values like the quality of life, maintaining warm personal relationships, service, caring, and solidarity.
Individualism (IDV)	Focuses on the degree to which the society reinforces individual or collective achievement and interpersonal relationships. Low IDV typifies societies of a more collectivist nature with close ties between individuals. These cultures reinforce collectives where everyone takes responsibility for fellow members of their group.
Long-term orientation or Confucian dynamism (LTO)	Cultures typified by a long-term orientation are oriented towards future rewards, in particular perseverance and thrift, while a short-term orientation is characterised by values relating to both the past and present, in particular, the respect for tradition, preservation of ''face'' and the fulfillment of social obligations

Table 3: Measures of cultural dimensions

Moreover, Hofstede's cultural dimensions have been used to investigate the impact of cultural differences on technology acceptance (Straub, Keil et al. 1998; Al-Gahtani, Hubona et al. 2007). We also drew on Hofstede's dimensions to describe cultural differences between Saudi Arabia and other countries around the world, such as the USA, the UK, India and South Africa, to discuss cultural implications of biometric authentication technology on users' acceptance.

Table 4 shows country scores of these dimensions for Saudi Arabia, USA, UK, India, and South Africa. Thus, Saudi Arabia ranks much higher than others countries in uncertainty avoidance and power distance; approximately the same range in masculinity; and much lower than USA and UK in individualism.

Cultural Dimension	Saudi Arabia	USA	UK	India	South Africa
Uncertainty avoidance	68	46	35	40	49
Power distance	80	40	35	77	49
Masculinity	52	62	66	56	63
Individualism	38	91	89	48	56
Long-term orientation	N/A	29	35	61	N/A

Table 4: Hofstede country scores for Saudi Arabia, USA, UK, India and South Africa

There has been a significant amount of studies attempting to link behaviour and attitudes towards technology with Hofstede's cultural dimensions. It has been suggested that power distance scores are negatively linked to the uptake of technology (Didero, Gareis et al. 2008; Chris, Kathy et al. 2009). Moreover, high power distance scores had a negative impact on the acceptance of new technologies across countries (Al-Gahtani 2001; Everdingen and Waarts 2003). It has been argued that cultures with a high power distance score tend to have centralised decision making structures which have a negative effect on the technology acceptance. Erumban et al. (2006) stated that individualism is positively associated with technology acceptance; they argued that members of a collectivist society will be less likely to go against current norms and attitudes, while members of an individualist society will be more enthusiastic to accept new technologies even if they are not used by their peers. Everdingen et al. (2003; 2006) suggest that uncertainty avoidance is negatively associated with technology acceptance; they argue that in uncertainty avoiding cultures individuals will be less prepared to venture into the unknown territory linked with new technology. An attempt was made to associate the dimension of masculinity with positive attitudes towards technology, however the empirical findings presented mixed support (Everdingen and Waarts 2003; Erumban and Jong 2006; Chris, Kathy et al. 2009).

Based on the literature discussed above, we would anticipate biometric authentication technology to be more acceptable in countries with low power distance scores, low uncertainty avoidance scores and high individualism scores. The UK and USA show these characteristics under Hofstede's dimensions investigations into biometric technology have been conducted in these countries.

We would expect, hence, that biometrics technology would be perceived less positively in cultures which are collectivist, have high uncertainty avoidance scores or high power distance scores. Particularly, we would expect there to be a poor match among biometrics acceptance and collectivist cultures. Biometrics are an inherently characteristic technology, as access decisions are based on the physiology or behaviour of an individual (Chris, Kathy et al. 2009). Traditional authentication methods, such as passwords and cards can be shared among individual or family members. Within some cultures family members regularly perform tasks, such as banking, in place of the person who registered for the service (Aziz, Riley et al. 2008; Chris, Kathy et al. 2009) and biometric authentication systems would not support behaviour of this nature (Chris, Kathy et al. 2009). We consider that there is a poor fit among biometric authentication systems and countries where industry analysts forecast the greatest increase, as many developing and some Asian countries have high power distance and uncertainty avoidance scores and low individualism scores (Hofstede 1984; Hofstede 2001; Chris, Kathy et al. 2009). Significant reservation regarding biometrics technology was reported among western countries (Chris, Kathy et al. 2009), moreover, we expect that in many developed countries biometrics technology would be seeming even less acceptable.

Regardless, we predict that the perception of biometrics authentication technology across cultures will be negatively related to Hofstede's dimensions of power distance and uncertainty avoidance and positively related to the individualism score.

2.3.8 Critique of Relevant Literature Regarding the Overview of Saudi Arabia

From the literature review, it is obvious that Saudi Arabia has a unique environment in its economic, cultural and IT applications, as has been considered above. Thus, it would not be feasible to apply a ready-made model for the implementation of new technology without considering all these issues. Through analysing these conditions, it can be said that there are many strengths that could help to facilitate the implementation of this technology. These consist of:

- Saudi Arabia is a huge country, hence, the production of a new secure technology among e-transaction applications could facilitate and enhance communications between different parts of the nation among public and private sectors. This, consecutively, might lead to reductions in costs for government agencies and financial institutions. Moreover, it would make it easy for individuals to access government and financial institution services online.

- The population has a high percentage of young individuals; these account for more than half of the total residents. It could be argued that this fact is one of the most significant factors in the acceptance of new technology, such as biometric technology. This is expected since young people are more willing to accept new technologies and are better skilled with technology and the Internet.

- Each culture may perceive and react in a different way to e-commerce website design, the ease of use, images, language and usefulness, etc.

This research will consider these issues in its investigation, in order to determine the key issues that may assist or obstruct the acceptance of biometric technology among organisations in the public and private sectors of Saudi Arabia.

The next part of this chapter highlights user acceptance of technology and argues which factors should be considered in the acceptance of new technology, namely: social and cultural aspects, behavioural aspects and attitudes to change. These issues relate to those individuals who accept or reject decisions to implement biometric technologies within online applications.

2. 4 Users' Acceptance of Technology

This section shows variables affecting the acceptance of technology and its perceived ease of use and usefulness by the user. Thus, TAM and UTAUT are important works, as discussed below.

2.4.1 Technology Acceptance Model (TAM)

The Technology Acceptance Model was originally proposed by Davis (1986). The TAM model is one of the leading theories used to clarify the process of user acceptance of any technology. TAM, as shown in Figure 3, is one of the most utilised models for studying user acceptance of information systems (Davis 1989; Venkatesh and Davis 1996; Al-Gahtani 2001; Al-Somali, Gholami et al. 2008).
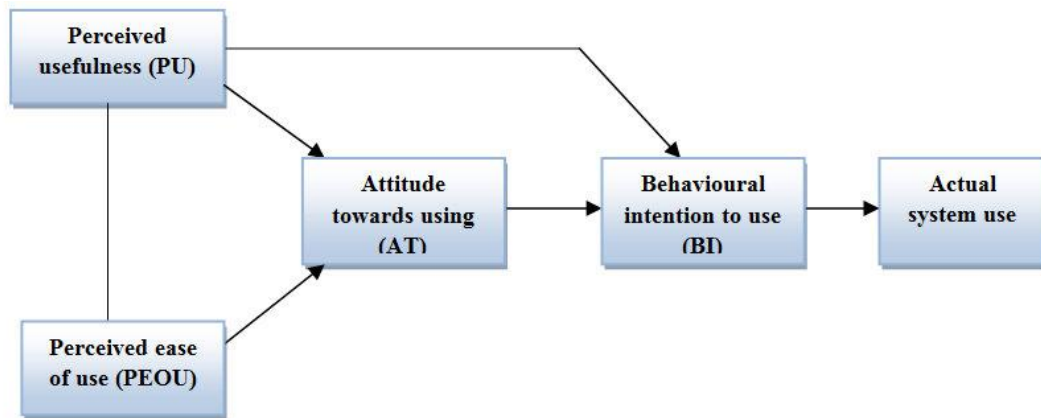
Figure 6: The TAM block diagram (Davis 1989)

2.4.2 Perceived Usefulness

Davis (1989) defines the perceived usefulness of a system as the degree to which a person believes that using the system would enhance his or her job performance. Attitude refers to a kind of perceptual symbol, which includes the evaluation of an 'attitude object' (e.g., self, others, incidents, activities, events or viewpoints). Intention refers to the willingness of an individual to perform certain behaviours (Zanna and Rempel 1988).

In the early 1960s, there were many academic debates on the influence of perceived usefulness on users' attitudes towards usage and intention to use. Katz (1960) indicated that attitude is the perceptual symbol that an individual constructs internally, hence, perception of usefulness affects attitude. Moreover, when an individual attempts to integrate his/her behaviour and attitudes, he/she will try hard to form an intention to take a certain action; thus, perception of usefulness will affect intention. According to the study of Barua et al. (1996), as soon as an individual uses a function of a system, the function's value (its usefulness) is determined by its cost and productivity. If the cost is lower, or the productivity (i.e., usefulness) is higher,

the value of the function will be greater, and, the attitude towards using it will then be more positive. Hence, the intention to use it will be higher.

From the above, it can be concluded that perceived usefulness affects user attitudes towards usage and intention to use. Field studies were carried out to support this finding. Moon and Kim (Moon and Kim 2001) illustrated that perceived usefulness has a positive effect on a user attitudes towards usage and the intention to use the world wide web. The study of (Atkinson and Kydd 1997) revealed that the greater the perceived usefulness, the more positive the attitudes of a user towards online information collection. As a biometric authentication system is an application of the web and e-commerce, and online information collection is one kind of online channel function, it can, therefore, be assumed that the same principle will apply.

2.4.3 Perceived Ease of Use

Davis (1989) has associated the "perceived ease of use" with the personal perception of simplicity in using a function. Based on Pintrich's study (1989), the greater the perceived ease of use of a product/service/system, the more positive the attitude formed towards usage will be. From these studies we can show that perceived ease of use has a positive effect on consumer attitudes towards usage. According to Barua et al. (1996), product/service functions with lower usage complexity will be associated with a lower cost, which increases the value of using this function. Thus, there is a positive correlation between perceived ease of use and perceived usefulness.

Moreover, Bandura (1977a) indicates that the higher the perceived ease of use of a function, the greater the final result (i.e., usefulness) will be. Accordingly, it can be inferred that perceived ease of use affects perceived usefulness. Field studies support this argument. The research conducted by Gefen (1997) indicates that perceived ease

of use has a positive influence on the user's attitude towards actually using (or sending) e-mails via the Internet, and the perceived usefulness of this action. Other research, conducted by Liao et al. (1999), revealed that customers will have a positive attitude towards using virtual banking if its usage is perceived to have a lower complexity. Also, Gefen (2003) reveals that perceived ease of use will strengthen online shoppers' intentions to continue using a website. Thus, the findings reveal a positive relationship between ease of use and the perceived usefulness as well as the attitude towards using the technology.

Many studies showed that an individual's behavioural intention will be affected by his/her attitudes, which ultimately determine the individual's actions and responses (Ajzen and Fishbein 1980; Ajzen 2005; Ajzen, Albarracín et al. 2007; Fishbein and Ajzen 2010). The Liao et al. (1999) study showed that an individual's intention to use online banking services is affected by his/her attitudes. It is clear that there is a positive relationship between attitudes towards the usage of online services and the intention to do so. Both Venkatesh and Davis (1996), and Pavlou (2003) also show that intention affects actual behaviour.

Finally, the perceived usefulness of a biometric in a particular situation plays a major role in user acceptance, as does the perceived ease of use of the biometric (Giesing 2003; James, Prim et al. 2006).

2.4.4 Social Influence

An extension of these studies examined the impact of social influence or subjective norms as predictors of behavioural intention to use. A subjective norm, originally developed from the Theory of Reasoned Action (TRA), predicts general behavioural intentions in strictly voluntary contexts; it assumes that people's perception that

others, important to them, approve or disapprove of certain behaviour has an impact on their actions.

Social influence acts as a determinant of behavioural intentions and usage behaviour. Social influence is defined as "the degree to which an individual perceives that important others believe that he or she should use the new system" (Venkatesh et al. 2003, p. 451). In this context, social influence is system/application specific, whereas subjective norm relates to non-system specific behaviour (Al-Gahtani, Hubona et al. 2007). Yogesh et al. (1999) revealed that social influences play a significant role in determining the acceptance and usage behaviour of new products/services or new technologies. Many theories have suggested that social influence is a direct determinant of behavioural intention (Venkatesh and Morris 2000).

Biometric devices, such as fingerprint scanners, can be intimidating to users at the beginning (James, Prim et al. 2006). The perception of a biometric fingerprint device will possibly affect the usage behaviour towards the biometric authentication system, in addition to having an impact on the perception of ease of use of the fingerprint device.

2.4.5 New Product Attributes (NPA)

Cultural and social factors are equally significant. While each developed country has its own culture and social society, with different behaviours and norms, there are several common characteristics. Starting with ethics and beliefs which fundamentally shape the culture, there are a number of factors which influence user behaviour including the family, religion, educational level, peers, media and experiences. In regards to attitudes and values, specifically within developed countries, differences relate to social and personal freedoms and dignity (Vrontis, Thrassou et al. 2007).

The severely competitive commercial environment does not allow large margins of qualitative variance involving company provider and user demand. This requires both the understanding of user needs, and the capability to satisfy them. Strong competition means that businesses can provide better value through obviously advanced quality, or lower cost or the best combination of these. Therefore, innovation accompanying products or services, greater customer care, special attention, convenience and other means are important (Naumann, Jackson et al. 2001). Basically, meeting individual expectations is often not sufficient. Businesses have to surpass anticipation to meet the fundamentals of quality (Naumann, Jackson et al. 2001; Vrontis, Thrassou et al. 2007).

A widespread way to improve and distinguish a product/service is by increasing the number of features included (Mukherjee and Hoyer 2001), providing better functionality for consumers. In this study, we examine how users balance their technology requirements for functionality and ease of use when evaluating products or services. Different methods are suggested in the literature to explore which attributes users apply to evaluator products (Snelders. D and J. 2000; Hossain 2007). It is obvious that product attributes are most significant to the users. In fact, during the decision to deal with a business, it is supposed that users not only believe the current value of the products or the services, but also take the future performance or future linked with the product or the service attributes into consideration (Chowdhury and Islam 2003; Hossain 2007).

The new product attribute factor is related to product characteristics. Factors such as product complexity, product intangibility, and the consumer's product association influence consumer or user behaviour towards acceptance of the technology.

The new added variable "new product attributes" was adopted from Mukherjee et al. (2001). The purpose of this variable was to measure the extent to which this technology could provide additional benefits and value to the process. Many high-tech innovations introduce attributes that are novel or totally unfamiliar to a large number of users. For example, recently introduced attributes, such as Global Positioning Systems (GPS) in cars, or biometric access controls in airports, are likely to have been novel to many users. Based on a recent study that examined the user acceptance of biometric technology in the hotel industry (Triplett, Laux et al. 2009) the "new product attributes" factor was adopted as an independent variable; their findings indicated that user acceptance of biometrics technology depended upon whether the new feature added value.

Companies frequently make efforts to develop and distinguish their products by adding additional features or attributes. These additional attributes may vary in their degree of familiarity to users. Many users may be unfamiliar with some of these attributes. Hence, it is important to investigate the impact of these new attributes on user decisions and acceptance.

Many researchers have revealed that adding familiar attributes to a product/service generally improves the product/service evaluation (Meyers-Levy and Tybout 1989; Nowlis and Simonson 1996; Hoeffler, Page Moreau et al. 2006). Nevertheless, other research indicates that adding familiar attributes may not always have a positive effect (Broniarczyk and Gershoff 1997). However, a study based on Mukherjee and Hoyer (2001) revealed that the positive effect of new attributes holds only in the case of low complexity products/services. Similarly, Hoeffler and Moreau et al. (2006) found that new attributes lead to lower effects for high-complexity products. For high complexity products/services, the addition of new attributes can negatively impact

the evaluation because of learning costs associated with these attributes (Hoeffler 2003; Alexander 2008). Extrapolating these findings to e-commerce and online applications, novel interactions can attract users, but if the application or service is for utilitarian tasks, novel attributes may lessen the usability of online applications or services.

Furthermore, the positive and negative effects of new attributes on product/service acceptance are affected by the perceived usefulness of the technology. In the same context, it is revealed that the negative effect of new attributes on the evaluation of high complexity products/services persists even after users are given explicit information about the benefits of the new attributes. It can be concluded that new attributes may contribute to technophobia, or user resistance towards technological innovation (Mukherjee and Hoyer 2001; Prakash 2009).

2.4.6 TAM and Cultural Aspects

Most of the previous cross-cultural studies have recommended using TAM, as it does not hold invariants across cultures (Straub, Keil et al. 1998; Pavlou and Chai 2002; Zakour 2009).

However, in their endeavour to better explain and predict IT use, few researchers (e.g. (Straub, Keil et al. 1998; Zakour 2009) have investigated the impact of cultural factors on the acceptance and behaviour of use. Hence, given this gap in the literature the current research aims to test the influence of culture on the acceptance and use of a new technology and system. By studying this technology use cross-culturally, we propose to shed light on the effect of the cultural context on usage behaviours, therefore, extending TAM to cross-cultural settings.

We draw upon an extension of the TAM, which integrates subjective norms/social aspects (Venkatesh and Morris 2000) as determinants of the behaviour and intention to use the IT. The significance attributed to subjective norms/social aspects in determining and predicting behaviour varies across cultures (Triandis 1977; Zakour 2009), thus, we anticipate that integrating subjective norms/social aspects will strengthen our perception of differences in behaviour and intentions to use and will allow a better capturing of cultural aspects on IT use.

Moreover, the cross-cultural TAM can be improved by taking into account a construct such as new product attributes which was adapted from Mukherjee et al. (2001). Mukherjee et al. (2001) suggests that the addition of novel attributes is likely to improve product evaluation and acceptance, since consumers interpret these attributes based on their background and as additional benefits provided by the provider/manufacturer. Introducing new product attributes enables a better capturing of cultural influence on the acceptance of information technologies, particularly the impact of masculinity/femininity on behavioural intention to use IT.

TAM is successful in determining the behavioural intention to use the technologies from the point of view of intrinsic perceptions, rather than extrinsic environmental perceptions (Venkatesh and Morris 2000). Based on the TAM school of thought, perceived ease of use will, at the same time, affect both perceived usefulness and attitude towards use. Consequently, perceived usefulness will affect both attitude towards usage and intention to use. Moreover, attitude towards usage will affect behavioural intention to use. Other researchers introduced extrinsic environmental factors such as extra-organisational factors (Igbaria and Zinatelli 1997) and product characteristics (Hong, Thong et al. 2002) to extend the breadth of the TAM model.

TAM postulates that the two most important determinants of user acceptance of technologies are ease of use and usefulness (Davis 1989). The TAM model looks at these two determinants and their relationship to behavioural intention to use. Significant empirical research has shown positive results in using TAM to predict the acceptance and usage behaviour of end users. The TAM model has been examined in a variety of technologies, services, products and environments, including IT technology (Davis 1989), the world-wide web (Atkinson and Kydd 1997; Moon and Kim 2001; Chen, Gillenson et al. 2002; Cheng, Sheen et al. 2006), e-commerce (Chen, Gillenson et al. 2002; Koufaris 2002), online banking (Pikkarainen, Pikkarainen et al. 2004), e-mail systems (Gefen and Straub 1997), online shopping (Gefen 2003), software adoption (Szajna 1994), smart cards (Plouffe, Hulland et al. 2001), building management systems (Lowry 2002), and biometric devices (James, Prim et al. 2006).

As has been shown in previous TAM studies, we anticipate perceived usefulness and perceived ease of use to positively impact upon the intention to use. If an individual believes the technology is useful and easy to use, we assume that he/she is more likely to adopt it. We also expect the perceived ease of use of the technology to impact its perceived usefulness.

With consideration to the technology acceptance behaviour studies, TAM mostly proposes an essential framework to describe the influence of external variables towards behavioural thought (Davis 1989). Among the blooming expansion of TAM's significant researches, the external variables are further and further growing as well (Yu-Lung, Yu-Hui et al. 2007).

In addition to the TAM, there are many theoretical technology acceptance models, such as the Theory of Reasoned Action (TRA), the Motivational Model (MM), the Theory of Planned Behaviour (TPB), a model combining the TAM and the Theory of Planned Behaviour (TPB), the Model of Personal Computer Utilization (PCU), the Innovation Diffusion Theory (IDT), and the Social Cognitive Theory (SCT) (Venkatesh, Morris et al. 2003). Among these models, the TAM is believed to be the most robust, parsimonious, and significant in explaining information system acceptance behaviour (Davis, Bagozzi et al. 1989; Davis 1989; Venkatesh and Davis 2000; Venkatesh, Morris et al. 2003; Wu, Tao et al. 2007; Yu-Lung, Yu-Hui et al. 2007).

Additionally, the TAM has received widespread empirical support through validation, application, and replication for its power to predict usage of IT (Davis, Bagozzi et al. 1989; Davis 1989; Venkatesh and Davis 1996; Venkatesh and Davis 2000; Venkatesh and Morris 2000; Venkatesh, Morris et al. 2003). Nevertheless, the generality of the TAM fails to contribute meaningful information on user attitude in relation to a specific system. In addition, the TAM supposes that usage is volitional, which means there are no obstacles that would prevent the user from using IT.

However, the TAM misses some significant sources of variance, such as cost and time (Mathieson, Peacock et al. 2001). To overcome these limitations some improvements were carried out (Agarwal and Prasad 1997; Horton, Buck et al. 2001). Towards overcoming its limitations, there were many attempts made to develop the TAM model (Agarwal and Prasad 1997; Horton, Buck et al. 2001). Loo (2009) stated that even though the improved TAMs can overcome the limitations of the previous TAMs, researchers are tackled with having to make a choice from a

multitude of models, and "pick and choose" constructs across the models, or pick a "favoured model" and mostly ignore the contributions from other models.

2.4.7 UTAUT Model

To overcome the aforementioned limitations a new model labelled the Unified Theory of Acceptance and Use of Technology (UTAUT) was introduced by Venkatesh et al. (2003). Many researchers have since conducted studies to explore and validate the UTAUT within different backgrounds. For example, Al-Gahtani et al. (2007) conducted an empirical study to validate UTAUT in Saudi Arabia.

Venkatesh et al. (2003) compared eight models in association with core constructs, beliefs and intentions, moderators and percentages of explained variance, including TAM, the Theory of Reasoned Action (TRA), a motivational model (MM), the Theory of Planned Behaviour (TPB), combined TAM and TPB model (C-TAM-TPB), a model of PC utilization (MPCU), the Innovation Diffusion Theory (IDT), and the Social Cognitive Theory (SCT). They found that the eight models described between 17% and 53% of the variance in user intentions to use IT. Furthermore, behaviour intention explained the variance of usage behaviour to be around 39%. Following the evaluation of these models, they invented the UTAUT and tested using the original data used for the eight models, and it was found that the outcome excelled the eight individual models (69% adjusted R^2). UTAUT thus appears to be the best theory to present a constructive tool to measure the likelihood of any new technology acceptance (Venkatesh, Morris et al. 2003).

Moreover, the UTAUT was empirically tested to ensure its validity. Four constructs were identified as direct determinants of user acceptance and usage behaviour: (1) Performance Expectancy (PE), (2) Effort Expectancy (EE), (3) Social Influence (SI),

and (4) Facilitating Conditions (FC). The UTAUT model is shown in Figure 4. The four determinants of user acceptance in UTAUT were moderated by gender, age, experience and voluntariness.
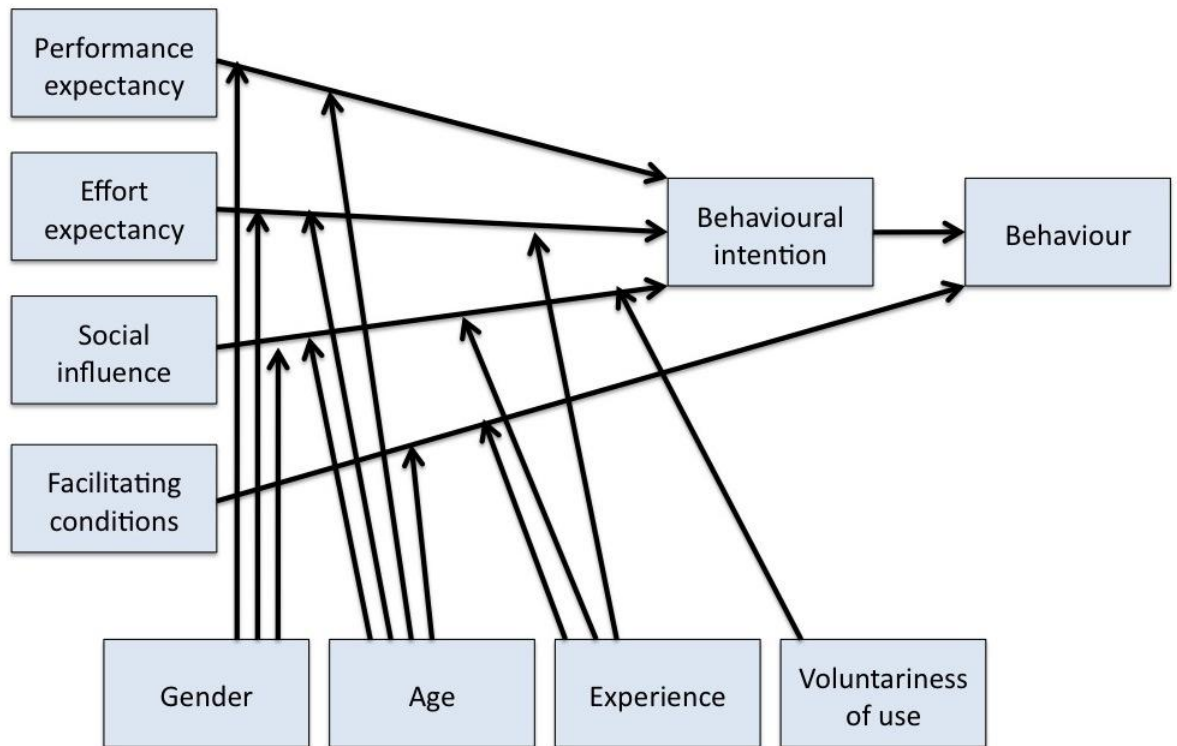
Figure 7: UTAUT model (Venkatesh, Morris et al. 2003)

The enhanced model is then used to explore the factors affecting user acceptance of biometric authentication systems within e-commerce applications. The determinants of the model and the added variables are clarified in the following section.

UTAUT anticipates that gender will moderate the effect of performance expectancy and effort expectancy, as well as the social influence. UTAUT expects males to be likely to rely on performance expectancy while determining acceptance of a technology with their highly task oriented nature (Park, Yang et al. 2007). In contrast, female technology acceptance could be determined mostly by effort expectancy, rather than performance expectancy under cognitions associated with

gender roles. This moderating effect of gender has been replicated in a number of studies in the field of technology acceptance within a variety of technologies like electronic mail (Gefen and Straub 1997), e-learning (Ong and Lai 2006), communication technologies (Ilie, Van Slyke et al. 2005) and online purchasing behaviour (Thomas and Taskov 2007). Venkatesh and Morris (2000) found that "performance expectancy (perceived usefulness on TAM) influences behavioural intention to use a system more strongly for men than it influences women" (p.118), "effort expectancy (perceived ease of use on TAM) will influence behavioural intention to use a system more strongly for women than it influences men" (p.119), and "subjective norm influences behavioural intention to use a system more strongly for women than it influences men" (p.119). Venkatesh et al. (2003) reported reliable findings.

2.4.7.1 Performance Expectancy

Venkatesh et al. (2003) defined performance expectancy as the degree to which an individual believes that using the system will help him or her to attain gains in job performance. In the same research, they found that performance expectancy was a strong predictor of a user's intention to use a new technology in the workplace. Ong et al. (2004) provided empirical support for the relationship between perceived usefulness and behavioural intention in the context of web applications. Moon and Kim's (2001) research showed that perceived usefulness, which is performance expectancy in this study, has a positive impact on the intention to use any Internet application. As biometric authentication systems are mainly web systems, it can consequently be assumed that the same opinion will apply. In the present context, performance expectancy refers to the perception that using a biometric authentication system will help and benefit e-commerce users to secure their transactions.

Based on Al-Gahtani et al. (2007), there are rigid boundaries in social roles and expectations for women compared to men in Saudi Arabia, hence, there are far fewer women in qualified knowledge worker roles. Therefore, it is believed that women in Saudi Arabia will be less inclined than men to anticipate that the use of new a biometrics system would improve their e-transaction.

2.4.7.2 Effort Expectancy

Effort expectancy is defined as the degree of ease associated with the use of the system. In fact, the concept of effort expectancy was captured by three constructs: perceived ease of use, complexity, and ease of use, from these models TAM, Model of Personal Computer Usage (MPCU), and Innovation Diffusion Theory (IDT0. Together these constructs define effort expectancy as the perceived ease of use which refers to the usability of the computerised interface in transaction based applications (Dillon and Morris 1996).

Ong et al. (2004) indicated that perceived ease of use was positively associated with perceived usefulness and behavioural intention in the context of web-based applications.

2.4.7.3 Social Influence

Social influence is defined as the degree to which an individual perceives the importance of the beliefs of others that he or she should use the new system (Venkatesh, Morris et al. 2003). Venkatesh et al. (2000) validate the fact that social influence plays a significant role in determining the acceptance and usage behaviour of new technology. Users may have unfavourable or encouraging awareness towards using a new technology because of the perceptions of family members, associates or peer influence. Davis et al. (1989) believe that, within some situations, individuals

might use technology to comply with others' mandates, rather than their beliefs. Social influences play a primary role in determining the behaviour use towards new technology (Yogesh and Malhotra 1999).

In Arabic cultures, employees are expected to exhibit a stronger association between social influence variables and behavioural intentions. Additionally, younger individuals are likely to occupy lower roles in behavioural intentions to use the IT technology(Al-Gahtani, Hubona et al. 2007).

2.4.7.4 Facilitating Conditions

Factors and resources that an individual believes exist to support his or her activities are termed facilitating conditions. Venkatesh et al. (2003) defined facilitating conditions as the degree to which an individual believes that an organisational and technical infrastructure exists to support the use of the system. In the current context, facilitating conditions refer to the objective factors in the environment that make an act of use easy to achieve. In our research, both technical and non-technical support was integrated. Triandis (1980) stated that behaviour could not occur if objective, facilitating conditions prevented it. Al-Gahtani et al. (2007) stated that there is a direct relationship between facilitating conditions and behaviour intentions to use within Saudi Arabian culture. Moreover, in the same study, they found that age and experience/education level can negatively interact with the influence of facilitating conditions on IT usage. Particularly, they considered that increasing levels of age and experience/education level would mute the dependence on a facilitating infrastructure to use IT.

2.4.7.5 Anxiety

Anxiety is an important direct determinant of intention to use the technology. It is defined as the evoking of anxious or emotional reactions regarding behaviour (Campueau and Higgins 1995) such as using a biometric authentication system. Nevertheless, the UTAUT model does not incorporate anxiety as a direct determinant. This is because anxiety is affected by perceived ease of use. Thus, it is an indirect determinant of intention to use (Venkatesh 2000).

2.4.7.6 Self-Efficacy

Monsuwe´ et al. (2004) defined self-efficacy as an individual's self-confidence in his or her ability to perform tasks across multiple computer application domains. Wang et al. (2003) found computer self-efficacy and perceived ease-of-use to be related. Several studies have found positive relationships between perceptions of convenience and the use of e-commerce applications (Wang, Wang et al. 2003; Lassar, Manolis et al. 2005). Based on the theoretical and empirical support from the literature, it can be concluded that, the stronger a person's self-efficacy beliefs, the more likely he or she is to attempt to attain the required outcome (Al-Somali, Gholami et al. 2008). Users who have low computer self-efficacy are less likely to use web-based applications. Gong et al. (2004) found that computer self-efficacy had a direct positive effect on intention to use web-based applications.

2.4.7.7 System Characteristics

System characteristics have been hypothesised to directly influence user beliefs (Davis 1993). Consequent research has validated the role of system characteristics in technology acceptance in other perspectives (Davis 1993; Venkatesh and Davis 1996; Igbaria and Zinatelli 1997). A multiplicity of common information technology system characteristics have been anticipated and examined. Organisations frequently

make an effort to develop their systems by providing more features to enhance the functionality of their system. It is significant to examine the impact of these features on users' opinions (Mukherjee and Hoyer 2001). Many studies have exposed the fact that providing familiar features to the system generally improves the system acceptance (Nowlis and Simonson 1996). However, other studies showed that providing familiar features may not at all times have a positive outcome (Broniarczyk and Gershoff 1997). The introduction of system characteristics to the research model aims to reveal the ambiguity presently related with biometric authentication systems.

2.4.8 Consideration of Moderators in the Literature

The original TAM did not incorporate any moderating effects, and some studies such as (Venkatesh, Morris et al. 2003) recommended incorporating these moderators to include gender, age, and experience or education level, in order to build better predictions associated with user behaviour for a particular technology. UTAUT is an example which incorporated moderating effects.

2.4.8.1 Gender

Gender was described by Schlegel (Igbaria and Chakrabarti 1990) as "the way members of the two sexes are perceived, evaluated, and expected to behave." Gender is a significant variable in explaining differential outcomes in consumer behaviour research (Qualls 1987; Forsythe and Chun 2000). There has been a limited amount of gender-based study in information technology research (Gefen and Straub 1997; Forsythe and Chun 2000; Venkatesh and Morris 2000; Thomas and Taskov 2007). However, the differences between men and women have been studied in various contexts such as electronic mail (Gefen and Straub 1997), information retrieval

(Venkatesh and Morris 2000), e-learning (Ong and Lai 2006), communication technologies (Ilie, Van Slyke et al. 2005) and online purchasing behaviour (Thomas and Taskov 2007).

The majority of the studies appear more favourable towards men than women. Anandarajan et al. (2000) stated that men were more likely to access work pages than women. Nevertheless, gender was not linked with individual factors such as ease-of-use, frequency of use and time usage(Anandarajan, Simmers et al. 2000).

Morris et al. (2005) found that as age increased, men were increasingly influenced by attitudes toward the use of technology compared to women. In contrast, as age increased, women were more influenced by perceived behavioural control compared to men. Gefen et al. (1997) found that the perceptions of men and women vary. The perceived social usefulness of email was found to be lower with men than women. Conversely, men perceived ease-of-use to be higher than women. Nonetheless, the actual use of email did not vary across gender. Venkatesh et al. (2000) proposed that gender would affect the association between perceived usefulness, perceived ease-of-use, and subjective norms on intention to use the technology. These factors were more important for men than women (Thomas and Taskov 2007). The behaviour of online users with new IT might be conditioned by their gender (Yi, Jackson et al. 2006). Internet addiction was argued to be more likely a male addiction (Griffiths 1999; Anderson 2001; Niemz, Griffiths et al. 2005; Mythily, Qiu et al. 2008). Typically females showed higher levels of computer anxiety (Igbaria and Chakrabarti 1990; Venkatesh and Morris 2000)**,** as well as lower levels of self-efficacy towards using computers in general, and the Internet and e-commerce in particular (Broos 2005). It has been taken into account that females feel less confident than males in using IT, which implies that self-efficacy has less influence

on usefulness and ease-of-use (Shashaani 1994; Hernández-Ortega, Jiménez-Martínez et al. 2008).

2.4.8.2 Age

Age was found to affect the influence of attitude, social influence, and perceived behaviour control. An attitude was more salient for younger workers while perceived behavioural control was more salient for older workers. Social influence was more salient to older women (Venkatesh and Morris 2000). Moreover, age was found to affect the influence of the determinants toward behaviour. For instance, the effects of performance expectancy, effort expectancy, and social influence were moderated by gender and age based on the findings of Venkatesh et al. (Venkatesh, Morris et al. 2003).

2.4.8.3 Education Level

The level of education has been used as a moderator, but not in the study related with technology acceptance. For instance, it has been found that parental education moderated the environmental contributions to variation in verbal IQ (Rowe and Jacobson 1999). Moreover, educational level has been examined as a factor in the research associated with factors that influence the acceptance and use of IT. For illustration, Zakaria (2001) showed that only the highest educational level was a significant predictor to the variance of IT implementation.

While education level was not applied as a moderator in technology acceptance, it was instead examined as a factor to determine technology acceptance. However, education level appeared to have an impact on the influence of determinants toward new technology acceptance in some approach or other in this research. It is expected that users who have different levels of education may have different views relating to

the acceptance of the use of biometric authentication systems. Hence, education level will be examined as a moderator, and it is expected to impact the influence of determinants toward behavioural intentions to use the system.

2.4.9 Cultural Aspects

As Myers et al. (2002) stated, culture can have an impact on a user's decision to accept and use a particular system. For example, gender, which is a fundamental aspect of culture, was found to influence the IT acceptance process (Gefen and Straub 1997; Venkatesh and Davis 2000). TAM and UTAUT may not predict technology acceptance among all cultures in the world (Gefen and Straub 1997; Napaporn 2007). Moreover, culture is essential to explore the impact of these moderators on the influence of the determinants towards behavioural intentions to use the biometrics system, to generate a model that best describes behavioural intention and acceptance to use the system.

2.4.10 Critique of Relevant Literature in Users' Acceptance of Technology

There is concrete evidence that social and cultural influences, behaviours and attitudes towards usage of technology have an influence on the acceptance and use of new technology (Al-Gahtani, Hubona et al. 2007; Kripanont 2007; Oshlyansky, Cairns et al. 2007; AlAwadhi and Morris 2008; Al-Qeisi 2009). In addition, the TAM and UTAUT have a great power in examining the acceptance of technology in this field. However, other issues that rise in developing e-commerce and e-government systems remain important to review in order to achieve a greater understanding of how scholars have applied these issues in the world of e-transactions.

2. 5 Summary

The present study differs from earlier studies in many aspects, for example, this research considers new issues, such as motivating factors for biometric technology acceptance in the Middle East, which none of the prior studies did. Also, the current research considers factors that existed in the literature review and which focus on technological and organisational aspects with regard to e-commerce and e-government in a new study context: Saudi Arabia. Finally, the development of a comprehensive framework is one of the main intentions of the current research project through an empirical study in the context of Saudi Arabia. Based on the literature review, we concluded the following gaps in knowledge which should be tackled:

- It is worth noting that the majority of biometric authentication user acceptance studies have focused on research surveys (Laux, Tao et al. 2007). To our knowledge, this is the first systematic study relating to this issue carried out by academic and non-biased researchers in Saudi Arabia. Therefore, given this gap in the literature, the current research aims to test the influence of culture on the acceptance and use of a new technology and system. While studying this technology use cross-culturally, we propose to shed light on the effect of the cultural context on usage behaviours, therefore, extending TAM to cross-cultural settings.

- This work also aims to investigate technology acceptance models in non-western cultures, in particular, in this era of advanced technology, to overcome the gap among the different cultures. The current study is located in Saudi Arabia as an example of a non-western culture.

- In spite of its increasing importance, academic study in this area is particularly lacking in Saudi Arabia. Biometrics technology within e-commerce, in the context of Saudi Arabia, is still at an early stage of development and little is known about user behaviour toward acceptance of this new technology and factors that influence their behaviours and attitudes towards it.

- A valuable approach for new technology integration should include developing an understanding of: 1) the user behaviour and attitudes to using the technology, and 2) a realistic expectation of how this technology could meet user needs and how rapidly this technology will reach acceptance and adoption. Large gaps in knowledge of these areas can result in wasting time and money on integrating inappropriate technologies.

In summary, the purpose of the literature review was: to build a strong theoretical background for the research by applying relevant theories in this context; to identify the issues in relation to the acceptance of biometric authentication systems; and to identify the gaps that should be addressed in this research in relation to these issues.

The next chapter, therefore, examines the feasibility of using biometric authentication based on initial experiments that aims to explore whether Saudis practically and culturally are willing to accept biometric authentication technology.

Chapter 3. The Feasibility of Using Biometric Authentication: The Initial Experiment

3. 1 Introduction

The literature review in Chapter 2 discussed many well-known theories and models which are, in one way or another, practical for the theoretical background of this research. Moreover, it identified the gaps that should be addressed in relation to the acceptance of biometric authentication systems in the context of Saudi Arabia in order to overcome the gap among the different clusters of investigative biometrics technology acceptance in non-western cultures.

This chapter focuses on the feasibility of biometric authentication systems in online services and their user acceptance in Saudi Arabia as an initial experiment. Additionally, it will explore whether Saudis practically and culturally are willing to accept biometric authentication technology. For this work, three hundred and four Saudi participants, consisting of men and women between the ages of 18 and 55, took part in a survey that was developed to investigate the level of user acceptance for biometric authentication systems.

3. 2 The Objectives

The objectives of this survey were to:

- Give an indication of the current familiarity with the concept of biometrics in Saudi Arabia.

- Find an answer for a very important question – whether Saudis will accept and be encouraged to use biometric authentication systems.

- Examine which biometric authentication method is most suitable for Saudis.

3. 3 Hypotheses

The related hypotheses for this study are:

Hypothesis 1: In general, Saudi users are not very familiar with the concept of biometrics.

Hypothesis 2: Saudi users will rapidly accept biometric authentication systems.

Hypothesis 3: As a result of some religious and cultural aspects, the fingerprint will be the most suitable method for authentication purposes.

3. 4 Method

The survey was designed according to the methods established by Churchill (1999), who distinguishes between three types of research design methods depending on the research's questions and aims: descriptive research ,causal research and exploratory research which is the method used in this study.
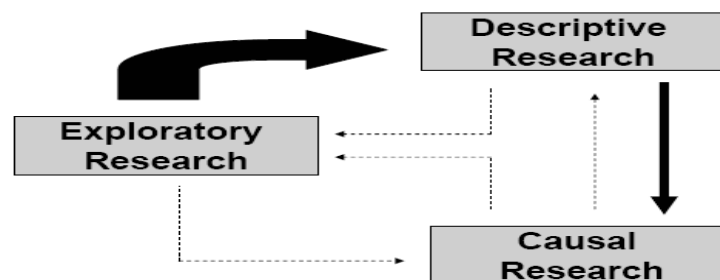
Figure 8: Relation of research designs (Churchill 1999)

According to Sekaran (2003), the methods are part of the design; therefore, she agrees with Bryman et al. (2007) that methods are aggregate to explain data collection. Also, based on Sekaran's definition of research design, this experiment is conducted for the intention of testing the hypotheses derived from the theoretical

framework presented. It is believed that studies employing hypotheses testing purpose generally tend to clarify the nature of certain relationships, or establish the differences along with groups or the independence of two factors or more in a circumstance. Hypotheses testing offer an improved perceptive of the relationships that exist with variables. Churchill (1999) explains this type of research, in terms of its purpose and aims, as follows:

3.4.1 Purpose

1) To formulate a base for more precise investigation and for developing hypotheses. 2) To establish precedence for further research. 3) To gather information about the practical problems of carrying out research on particular conjectural statements. 4) To clarify concepts. 5) To develop provisional explanations, not demonstrating the feasibility of a given explanation.

3.4.2 Aims

1) To generate hypotheses for quantitative/qualitative tests. 2) To generate information to structure questionnaires. 3) To provide overall background information. 4) To secure impressions on new product concepts.

3. 5 Survey Instruments

Stevens (1946) proposed a hierarchy of levels for measuring data, which consisted of four separate strata:

- **Nominal Measurement**: labels or names. If any two labels have the same identification, they belong to the same category. Matching or non-matching can be the only analysis, and mode or dispersion the only measures.

- **Ordinal Measurement**: numbers or labels representing a scale of a ranked list of objects. This measurement can be used for determining the mode, median, percentage, percentile rank and chi square.

- **Interval Measurement**: a scale of ordinal measurements separated by the same interval, where differences between pairs of numbers can be compared. Mode, mean, standard deviation, F-test and correlation can be used for this measurement (Leedy and Omrod 2001) .

- **Ratio Measurement**: a series of equal interval numbers having meaningful ratios. Most physical attributes are measured on ratio scales: for example, weight, length, and temperature relative to absolute zero. Mode and mean (arithmetic and geometric) can be used for this measurement (Stevens 1946) .

The variables measured in this survey were ordinal. An example of an ordinal scale, which is commonly used in measuring attitudes, can be seen in the Likert scale (Likert 1932). This scale helps to facilitate a more efficient collation and summarisation of data, to aid in extracting meaningful information about the data and supporting the performance of statistical operations to augment that data's validity.

3. 6 Sample Size

For all experiments in this research, the target populations of this study were customers, providers, and regulators of Saudi Arabian financial services. This population consisted of the end customers of e-commerce services, managerial, employees and technical personnel of e-commerce service providers. The people selected to take part in a questionnaire were critical to the success of the experiment. The group of participants is called a sample, which is a smaller group that is supposed to represent the larger population.

The study group was specifically selected to represent a group of e-commerce and online banking users, in main cities of Saudi Arabia, which have the highest attentiveness of Internet users. Moreover, it has a high concentration of residential Saudis and has the best-developed Internet infrastructure across the country. Thus the contributors were selected with care because they were considered to be the most likely users of e-commerce and online banking, with access to technology and significant familiarity and experience with online applications.

The sampling frame targeted equal division of the genders. For this reason, there is a strong evidence to propose that the sample and applicability of findings examined in this research will be a reasonable and representative reflection of the country at large. Although only main cities have been considered in the study, the cosmopolitan nature of attendees used in the study revealed the diversity of attendees all over the country. The selected sample size was derived using statistical sample size calculations. The equation below is used to determine the minimum sample size[14]:

$$Minimum\ Sample\ Size(n) = \frac{t^2 \times p \times (1-p)}{m^2}$$

Where:

n = minimum sample size

t = Confidence level at 95% (standard value of 1.96)

p = Estimated fractional population of subgroup (Almogbil 2005)

m = Margin of error at 5% (standard value of 0.05)

The sample size was calculated based upon these factors:

Population of Saudi Arabia 100%[15] = 22,673,538

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[14] Retrieved Feb 12, 2008, from http://www.surveysystem.com/ssformu.htm.
[15] Retrieved Feb 12, 2008, from http://www.citc.gov.sa/NR/rdonlyres/722D574C-F670-48D1-A9FD-4FF6C53AAF91/0/ATLASCensus1425H.pdf.

Banking customers: 45% est. (Almogbil 2005) = 10,203,029

Online banking users: 20% (SAMA statistics 2008) = 2,040,606

p = 2,040,606/10,203,029= 0.20

Minimum customer sample size *(n)* = 246**.**

3. 7 The Survey Design

The initial investigation was a cross-section survey. In a cross-sectional survey, data are gathered just once, perhaps over a period of days or weeks or months (Sekaran 2003). The purpose was to investigate a small number of people in a chosen population, and then draw conclusions from the results and apply these to the larger population. The advantages of examining a sample are reduced costs, time efficiency, and ease of testing. The method used in this survey integrated the use of electronic mails. E-mail was used for its low cost and reduced transfer time. A survey was developed to investigate the level of user acceptance of biometric authentication systems. During the investigation, it was possible for the participants to post questions via e-mail if they did not understand. The questionnaire was planned to take about ten minutes.

The primary aim was to make the questions as neutral as possible. One of the problems faced when making the survey was to know how to ask questions that would provide appropriate answers, while in addition, ensure the survey did not become too lengthy. Before the actual survey, two respondents were asked to help in a pre-test of the questionnaire. They commented that the language used had to be suitable for the population tested, and this resulted in a challenge to make the questions understandable and answerable. The complete questionnaire questions,

originally produced in English, were translated to Arabic by several bilingual professionals in an iterative process to ensure that both versions converged.

The questionnaire consisted of three parts:

- A personal profile of the participant.

- Identification of the respondent's attitude and views regarding the use of the Internet and e-services.

- A series of five-point scale questions to examine the respondent's familiarity and perceptions of the concept of biometrics. This third part was the most difficult of the questionnaire.

3. 8 Overview of Participants

As with all experimental studies in this research, prior knowledge of the background of those sampled presented obvious support of the broad base of findings observed. While online users are commonly younger and more highly educated than conventional users, these samples are close to the online user population and thus are representative of online banking (Gefen and Straub 2004).

The actual study population consisted of three hundred and four participants, of whom 165 (54.27%) were male and 139 (45.72%) were female. Their ages ranged from 18 to over 50 years, with 94 (30.2%) being between 26 and 35; 91 (29.93%) aged between 18 and 25; 80 (26.31%) aged between 36 and 50; 39 (12.82%) being over 50; and none being under 18.

Eighty-nine (27.98%) of the respondents had postgraduate degrees, 99 (32.57%) undergraduate degrees, and the remaining 107 (35.2%) had a secondary-school education. The survey found that the male respondents were more likely to use online banking, e-commerce, and online shopping. This was expected due to cultural

factors. For example, the management and organisation of family budgets is often the responsibility of men in Saudi culture.

3. 9 Findings and Discussion

A statistical analysis website[16] called 'Survey Methods' was used to analyse the respondents' answers. A variety of statistical methods based on the Statistical Package for the Social Sciences (SPSS) were used to analyse the data this study collected. Prior to analysis, research instrument items were examined, through SPSS, for accuracy of data entry, missing values, outliers and normality. Routine pre-analysis screening procedures for assessment of multivariate assumptions were carried out. Below is a more detailed discussion of the findings.

3.9.1 Results Regarding the First Objective

Surprisingly, 69.2% of the men and 57.1% of the women claimed to be familiar with the concept of biometrics, which contradicts the first hypothesis.

Since the selected sample did not consist only of those with high levels of competence in information technology, due to diversity being a consideration during participant selection, the first result is an encouraging indication that the adoption of biometric authentication methods in Saudi Arabia may be well-received. The following figure shows familiarity with biometrics by gender.

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[16] www.surveymethods.com
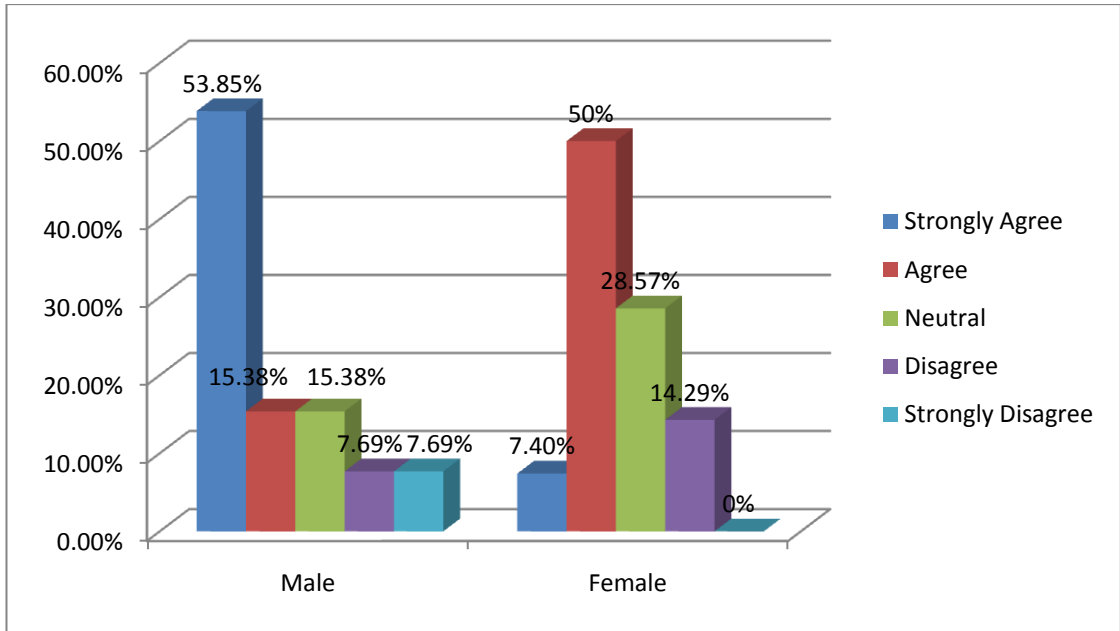
Figure 9: Familiarity with biometrics by gender

Based on an American study by Elliott et al. (2007), who conducted a survey of the perceptions of 391 individuals to biometrics authentication technology, 75.4% of the respondents were familiar with biometrics technology, while the remainder of (24.6%) were not which was in line with our findings.

In a more recent study, designed by Chris et al. (2009) to investigate how biometrics are perceived in other cultures, data from India, South Africa and the United Kingdom were collected via online survey and compared. Cross-cultural attitudinal differences were seen. While the results from India and South Africa were in line with our findings, respondents from the UK were the least likely to have a positive attitude towards biometric technology which was in contrast to Saudi respondents. However, a Canadian survey of 1,200 participants conducted by Citizenship and Immigration Canada (2003) showed that respondents had a positive familiarity of biometrics (54%).

3.9.2 Results Regarding the Second Objective

Acceptance of the use of biometric authentication methods was particularly high (65%) among participants who did not object to the registration of biometric data for authentication in Saudi Arabia. Moreover this acceptance was higher with females, as 54.89% of those who thought biometric methods would be acceptable were women, the following figure shows acceptance of biometric method use by gender.
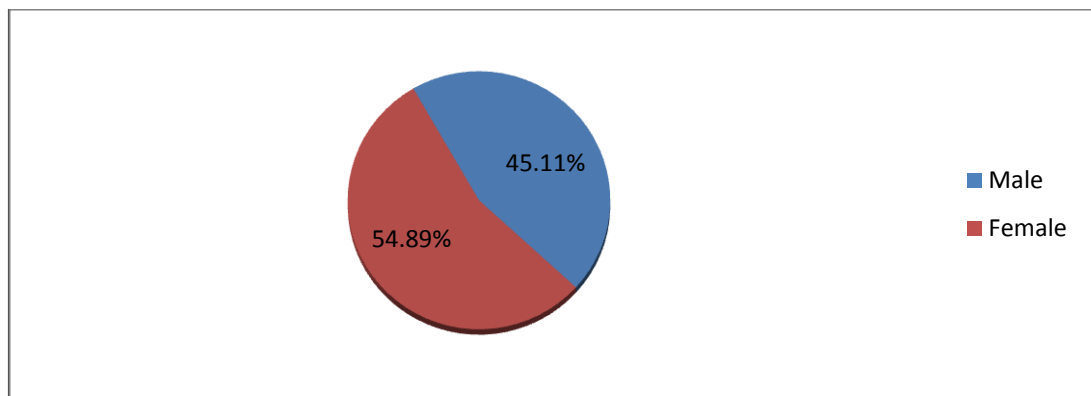
Figure 10: Acceptance of biometric use by gender

Furthermore, 78.4% of the female respondents and 69.2% of the male respondents said that they would be comfortable registering their biometric data for use. In terms of enthusiasm to use biometric authentication methods, 78.4% of the respondents were eager to try the new technology. 87.6% said that they believed that such methods would be easy to use compared to traditional authentication methods, and the same percentage also believed it would be more secure. In addition, 93.3% of those enthusiastic respondents agreed that biometric authentication methods would improve e-commerce security. Additionally, 83.6% of the same respondents were willing to buy a biometric device in case such a biometric system was implemented. All of these findings support the second hypothesis and strongly indicate the likelihood of the acceptance of biometric authentication systems in Saudi society.

3.9.3 Results Regarding the Third Objective

The third hypothesis stated that the use of fingerprinting would be the most suitable method for authentication. The results match what was suggested in this hypothesis, as 91.2% of the respondents said they would prefer the use of a fingerprint authentication method. 51.7% were female. Additionally, 63.4% of those who would prefer to a use fingerprint authentication method held a postgraduate diploma. This result is in line with a study by Elliott et al. (2007) which stated that the most acceptable form of biometrics in the USA was found to be the use of fingerprints.

Finally, in respect to these issues, the respondents were asked a final question concerning their readiness to embrace biometric authentication. This was, 'Do you think the Saudi society is ready to embrace biometric authentication?' In general, less than 3% of the respondents believed that their society was unready to embrace biometric authentication, while more than two-thirds said that they did believe that their society was capable of using biometric authentication and was prepared to implement the technology.

On the other hand, the findings shed some light upon some other important issues related to the major obstacles and barriers facing the adoption of biometric authentication in Saudi Arabia. Overall, the respondents perceived a lack of appropriate legislation and regulation, the lagging behind of security and privacy reservations, and cultural influences to be the three greatest obstacles facing Saudi consumers in implementing biometric authentication. Table 5 provides further details on these and other types of barriers, and makes it easier to evaluate their relative strengths.

Obstacles to the adoption of biometric authentication	Score					Total
	Strongly Agree	Agree	Neutral	Dis-agree	Strongly Disagree	
Lack of appropriate legislation and regulation	89 (29.2%)	133 (43.7%)	45 (14.8%)	20 (6.5%)	17 (5.59%)	304
Lagging behind of telecommunications	15 (5%)	73 (24%)	91 (30%)	52 (17%)	73 (24%)	304
Security and privacy reservations	51 (17%)	110 (36%)	100 (33%)	27 (9%)	16 (5%)	304
Biometric devices and software costs	15 5%)	64 (21%)	61 (20%)	91 (30%)	73 (24%)	304
Cultural influence	73 (24%)	88 (29%)	52 (17%)	49 (16%)	42 (13%)	304
Low intention to use biometrics and inflexible resistance to change resistance to change	40 (13%)	85 (28%)	121 (40%)	37 (12%)	21 (7%)	304

Table 5: Obstacles to the adoption of biometric authentication in Saudi Arabia

Moreover, compared to a study by Chris et al. (2009), the security and privacy reservations of using biometrics technology was a significant concern for the people of Saudi Arabia and UK, with more than half of the respondents indicating that security and privacy reservations are the one of greatest obstacles facing the adoption of biometrics technology. Chris et al. (2009) identified many obstacles to the acceptance of biometric technology, such as data security and health and safety fears.

Another important survey question involved the perceived benefits and advantages of adopting biometric authentication in Saudi Arabia. It presented the respondents with four significant benefits for rating. The question was phrased: 'In the case of the implementation of biometric authentication, how beneficial would it be for you and for Saudi society?' The majority of the respondents considered that the four benefits would be obtained if biometric authentication was to be implemented. They had the same opinions about most of the benefits, although the intensity of their agreement differed somewhat.

3.9 Summary and Conclusion

The findings, with regard to the motivations surrounding the acceptance of biometric authentication in online services, clearly indicate that security, convenience, ease of use, and greater privacy act as strong motivators when present. However, this initial experiment does have some limitations that need to be acknowledged and addressed in future studies. First, although its sample provided a good understanding of the likelihood of user acceptance in biometric authentication by highly educated people and those who are familiar with the Internet, they do not provide insight into consumers who are not regular Internet users, but who sometimes use online services.

The overall conclusion from this experiment is that there is a willingness to use biometrics for specific applications. Compared to the Elliott et al. (2007) and Chris et al. (2009) studies, there were no cross-cultural differences in this investigation in terms of the familiarity and fingerprint preference among Saudi Arabian, American, Indian and South African users, while the UK respondents were less willing to use biometrics technology (Chris, Kathy et al. 2009).

In a manner similar to the studies of (Elliott, Massie et al. 2007; Chris, Kathy et al. 2009), our study suggested that many individuals have complex somewhat dichotomous, attitudes towards biometrics technology. Nevertheless, the studies described above show that many individuals have concerns regarding the way biometric systems might be used. Additionally, a number of issues with biometrics technology have been identified. This study helped to identify some of the factors affecting user acceptance of the biometrics authentication technology such as

familiarity, data security, willingness and ease to use. It can be concluded that cultural differences have an impact on the way biometric authentication technology will be used and it can be argued that these aspects have to be taken into consideration when developing biometrics authentication technology.

In fact, because this investigation aimed to discover and clarify the feasibility of biometric authentication in online services and the acceptance of this new method by Saudi society, it forms the base for another large investigation, which will be explained in the next chapter, with over 300 participants and will also consist of an exploratory research design.

Furthermore, the experimental findings concern the users' and do not address how well a biometric authentication system would actually meet consumer needs. It is important to investigate the user acceptance in a particular mode. For this work, we created a laboratory experiment that actively tested a biometric authentication system in combination with a survey which was then used to measure the likelihood of the user's acceptance of this technology. Therefore, the next chapter describes the first phase of this experimental study which adopted the Technology Acceptance Model (TAM) based on Davis (1989), as the theoretical basis on which to develop the research framework, and which was extended to study the intention to use biometric authentication systems in e-commerce applications across Saudi Arabia.

Chapter 4. User Acceptance: Using an Extension of TAM – Experimental Phase I

4. 1 Introduction

The previous experiment, reported in Chapter 3, successfully determined the importance of authentication on the web, the feasibility of biometric authentication systems and their user acceptance in Saudi Arabia, through conducting an online survey. In this chapter, an experiment to examine user acceptance of a biometric authentication system in e-commerce within the Saudi society was conducted. It examined whether Saudis are practically and culturally willing to accept biometric authentication technology. The experiment included the development of a fingerprint authentication system. This study is different. A laboratory experiment was created that actively tested a biometric authentication system in combination with a survey which was then used to measure the likelihood of a user accepting this technology. This technique aims to overcome the limitations of using a questionnaire technique exclusively to measure user acceptance in biometrics technology.

The Technology Acceptance Model (TAM) based on Davis (1989) was adopted as the theoretical basis on which to develop the research framework and was extended to study the intention to use biometric authentication systems in e-commerce applications across Saudi Arabia. The model has proven its efficiency as a good predictor for the biometrics system. The relevant research hypotheses were examined by capturing the users' experiences of using an online biometric system which was created for this purpose.

The rest of the chapter is organised as follows: section 4.2 presents the aim of this chapter, followed by the research model and hypothesis development in section 4.3, the exponential approach and the details of biometrics authentication system in sections 4.4 and 4.5, and this is followed by the sample size in section 4.6. The evaluation of the hypothesised model is detailed in section 4.7, while the measurement development is explained in section 4.8. The data analysis and results are presented in section 4.9, followed by a discussion in section 4.10. Some conclusions are drawn in section 4.11.

4. 2 Aim

The main purpose of this chapter is to examine whether Saudis are practically and culturally enthusiastic to accept biometric authentication technology.

4. 3 Research Model and Hypothesis Development

The research framework and the relevant hypotheses for user acceptance of biometric authentication in e-commerce were mainly developed based on the intrinsic features of the TAM model. We have modified the model to meet the goals of our research by adding other intrinsic factors, new product attributes and social influences. The introduction of new product attributes to the model aims to reflect the uncertainty currently associated with the e-commerce environment (Yogesh and Malhotra 1999; Paul 2003; Cheng, Sheen et al. 2006). Social influence is introduced to the model and is represented as a subjective norm in many theories (Venkatesh, Morris et al. 2003). It acts as one of the determinants of behavioural intentions and usage behaviour. The proposed model is illustrated in Figure 10, and the related hypotheses are showed in table 7.
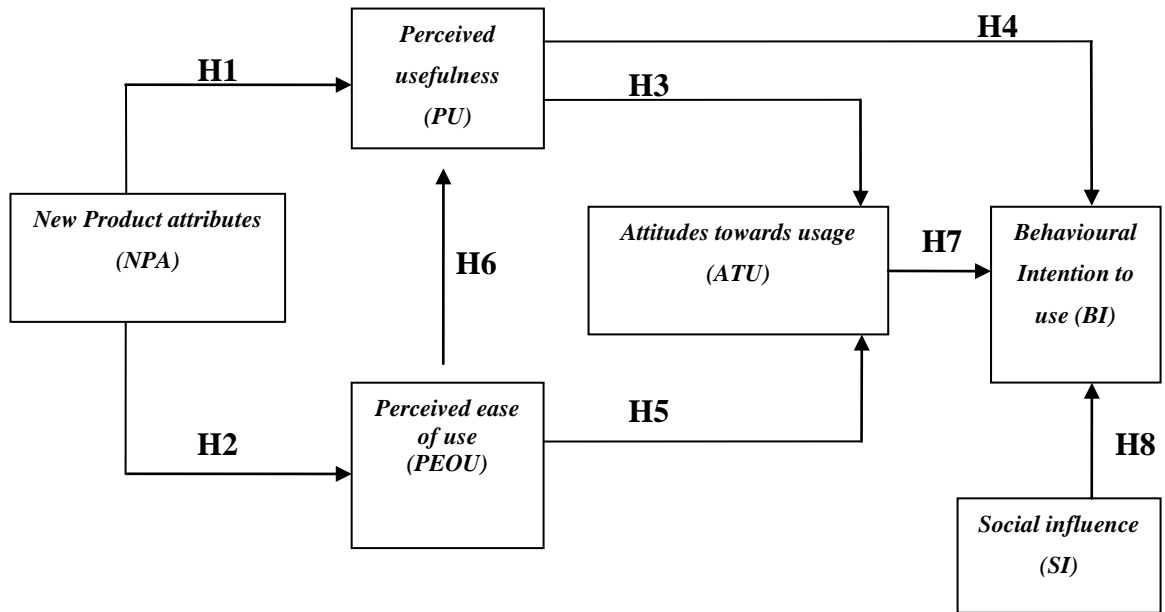
Figure 11: Proposed research model - the extended TAM

Hypotheses
H1 The new product attributes of the biometric authentication system in e-commerce have a positive relationship with perceived usefulness.
H2: The new product attributes of the biometric authentication system in e-commerce have a positive relationship with perceived ease of use.
H3: The perceived usefulness of using the biometric authentication system in e-commerce will positively influence the attitudes towards using the technology.
H4: The perceived usefulness of using the biometric authentication system in e-commerce will have a positive impact on an individual's behavioural intention to use the technology.
H5: The perceived ease of use of the biometric authentication system in e-commerce will positively influence the attitudes towards using the technology.
H6: The perceived ease of use of the biometric authentication system in e-commerce will positively influence the perceived usefulness of using the technology.
H7: Perceived attitudes towards using the biometric authentication system in e-commerce will have a positive impact an individual's behavioural intention to use this technology.
H8: Social influence will positively influence the individual's behavioural intention to use the biometric authentication system in e-commerce.

Table 6: Experimental phase I hypotheses

Therefore, this study proposes the following relationships. The relationships are represented in the following functions (Lin and Lu 2000):

- *Function 1: Behavioural Intention to use (BI) = f (Perceived usefulness (PU), Attitudes towards usage (ATU), Social influence (SI)).*

- ***Function 2:*** *Attitudes towards usage (ATU) = f (Perceived usefulness (PU), Perceived ease of use (PEOU)).*

- ***Function 3:*** *Perceived usefulness (PU) = f (Perceived ease of use (PEOU), New product attributes (NPA)).*

- ***Function 4:*** *Perceived ease of use (PEOU)) = f (New product attributes (NPA)).*

4. 4 Experimental Design

To explore the biometric authentication system in e-commerce, we designed an experiment which used two experimental phases, as described in this chapter and the following chapter, and which included the development of a fingerprint log in an authentication system. The experiment also involved a survey instrument to measure the likelihood of individual adoption of such technology. The method used to collect the data was a "self-administered questionnaire" which explained the purpose of the survey, and via a laboratory experiment, after which the respondents were asked to complete the questionnaire. We used this method in order to ensure a high response rate, accurate sampling and minimum interviewer bias (Oppenheim 1992).

As mentioned in section 3.6, the study group was specifically selected to represent a group of e-commerce and online banking users, from the main cities in Saudi Arabia, which have the highest proportion of Internet users. Moreover, they have a high concentration of residential Saudis and has the best-developed Internet infrastructure across the country.

The stakeholders in our project were the e-commerce industry (e.g., e-commerce, e-government, online banking, etc.) and the customers using these services. About 306

Saudis participated in the experiment, which was held between June and September 2008. Three laptops with a fingerprint reader were made available. The "participant" was asked to verify his or her identity with a fingerprint reader and enrol in the system. After completing the experiment, every participant was asked to complete a 43-question survey to measure the user acceptance of using the biometric authentication system.

Both experimental tasks (phase I & phase II) during this study were performed in a computer laboratory. The research instrument to evaluate the constructs of interest was developed by adapting existing measures from the literature to the current research context. All items were scored on a five-point Likert-type scale ranging from (1) strongly disagree to (5) strongly agree. As the experiment was conducted within an Arabic speaking country, the questionnaire, initially written in English, was translated into Arabic by a bilingual person whose native language is Arabic. The Arabic questionnaire was then translated back into English by another bilingual person. This English version was then compared with the original version and no items were found to deviate considerably in terms of language. This procedure was conducted not only because it can avoid any distortions in meaning across cultures, but also because it can improve the translation quality.

The questionnaire opened by asking for demographic data. These questions covered factors such as age, gender, education level, region, familiarity with computers, frequency of use of computers for work purposes, and frequency of use of online banking, e-transactions or online shopping. The participants were also asked to specify their preferred websites and the online service vendors they trust. These questions looked for individual thoughts from the participants, and made an effort to reveal participant reflections and feelings about the internet and e-commerce

activities. The researcher chose a sample from the population, deciding that 306 participants should be sufficient for the laboratory experiments based on the method and statistical equation illustrated previously in Section 3.6 to determine the sample size. To avoid any sort of sampling bias, the author ensured that people with various backgrounds and different experiences and ages took part in this experiment. However, the chosen sample may not accurately represent the population. Sometimes, even when we use random sampling, we may encounter a sampling bias. To decrease this risk, we should use an appropriate sampling technique with a large enough sample (Cohen 1988).

A survey was developed to investigate the level of user acceptance for biometric authentication systems. The experiment and survey would last approximately 20 minutes.

Five respondents were asked to help in pre-testing the experiment tasks and the questionnaire before starting the actual experiment. They commented that the questions had to be presented in a more readable and less technical manner. All questions were re-phrased to take this point into account.

4. 5 Overview of Participants

One hundred and thirty five (44.1%) of the participants were female and 171 (55.9%) were male. Subject ages ranged from 18 to over 55 years. More than a third of the participants were between 26 and 35 (35.3%).

Slightly more than half of the participants (168) were from the central region of Saudi Arabia, and more than half of participants (178) were studying at the undergraduate level, with only 7.8% at the postgraduate level.

Table 8 shows the demographic information for the sample used. The majority (71.2%) had been using the Internet for about 20 hours weekly, whereas less than 12% had been using it for less than 5 hours a week. Around half (48.2%) of all participants connect to the Internet with DSL/1MB or higher. Over two thirds (75.6%) of participants used the Internet for e-transaction services such online banking and online shopping fewer than five times monthly.

Respondents characteristics	Number of respondents (n=306)	Percentage (%)
Gender		
Male	171	55.9%
Female	135	44.1%
Age		
Under 18	26	8.5%
18-25	63	20.6%
26-35	108	35.3%
36-50	93	30.4%
Over 50	16	5.2%
Education level		
Pre Secondary	32	10.50%
Secondary	72	23.50%
Undergraduate	178	58.2%
Postgraduate	24	7.8%
Region		
Central region	168	54.9%
West region	58	19.0%
East region	27	8.8%
North region	15	4.9%
South region	38	12.4%

Table 7: The profile of survey sample

4. 6 The Biometric Authentication System

Based on the results of our research on the usage of this technology around the world, we found that many financial institutions use biometric methods to secure

their services, such as the United Banker's Bank (UBB)[17] (and others mentioned in Chapter 2, section 2.2.5.2). Hence, we tested the main hypotheses of this research in both experimental phases, based on a similar authentication method used by UBB. Figure 11 illustrated the process of the biometrics system which was proposed by UBB and DigitalPersona Company[18]. The UBB has developed strengths in biometrics, with the deployment of fingerprint readers for some 2,500 employees and UBB clients to securely log into online resources locally and over the Internet, and they do not have to remember multiple passwords – just which finger to press onto the small USB-connected scanner.
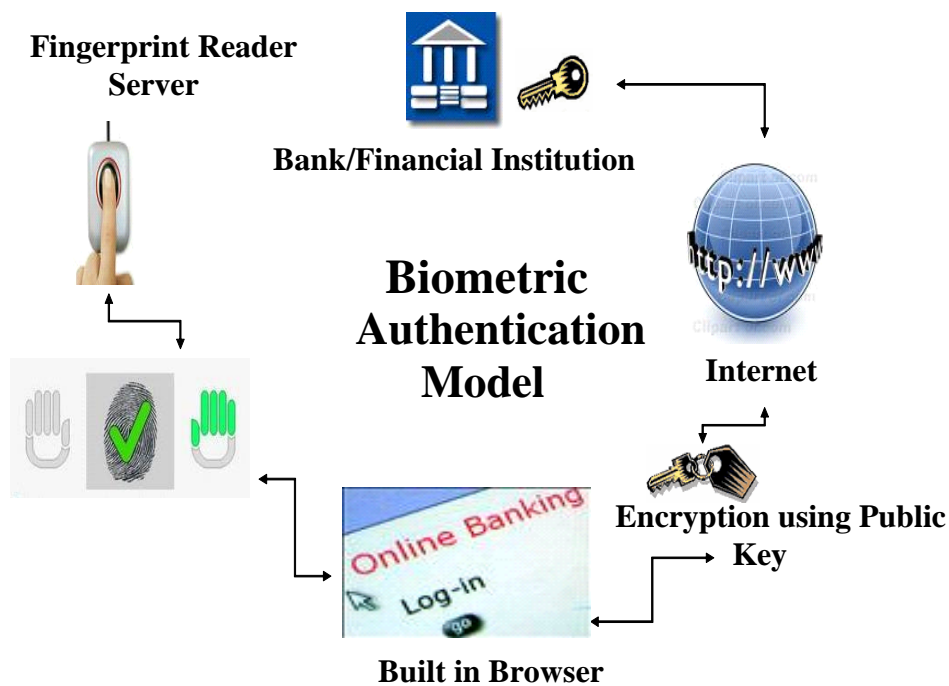
Figure 12: The model of biometric authentication system

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[17] http://www.ubb.com/
[18] http://www.ubb.com/operations/online-banking.aspx

The system used in the experiment is quite simple. It consists of a fingerprint sensor, fingerprint authentication software, and a computer. In this case the Digitalpersona U.are.U® 4000 Sensor, which uses a USB connection, was chosen as a sensor, and the Griaule Fingerprint SDK Software from Griaule was chosen as software. Two HP Pavilion dv3000 and Sony Vaio VGN-C2S personal laptops running Windows XP were chosen to run the experiments. The laptops were set up with the following specifications: Intel® Core® 2 Duo processor and 1 GB RAM. This application was developed using C# .NET 2005 under the Windows XP platform. The Griaule fingerprint SDK was chosen to integrate the sensor with this application, and the programming code to integrate the sensor with the system was modified from Wei-Meng Lee (2007).

In particular, we built a biometric authentication system whereby users can register and enrol into their accounts with their fingerprints. Once a user is registered, the next time he/she logs in to the system, the user can simply scan his/her fingerprint and the system will grant access. The whole process of scanning and identifying the fingerprint takes about 10 seconds.

4. 7 Experimental Procedure

An interactive interface for an online fingerprint login system was developed using PHP. The system would simulate account creation and allow users to login using a fingerprint sensor instead of a user ID and password. At the beginning of any experiment session, preliminary questions were asked to determine the participants' familiarity with biometrics and their comfort level in performing the experiment. The participants were then asked to complete the following three tasks:

- **Task 1:** Start by creating your own account, which will include your personal data.

- **Task 2:** Place the index fingerprint on the fingerprint sensor to register it for the first time.

- **Task 3:** After the registration process is completed, login to your account by placing the registered fingerprint on the sensor again.

Upon completion of the above tasks, the participants were asked to answer a list of questions about their perspective of the fingerprint system, in terms of its perceived usefulness and perceived ease of use, their attitudes towards its usage, new product attributes. Moreover, questions regards social influence should be answered based on their previous experience with IT technology and their behavioural intention to use the biometric systems.

4. 8 Measurement Development

The reason for carrying out the questionnaire was to examine the hypotheses. The complete questionnaire items, originally produced in English, were translated to Arabic by several bilingual professionals in an iterative process to ensure that both versions converged. Table 9 shows the items used to estimate the Saudi predictor latent constructs.

Perceived Usefulness	
PU1	*Using the system in my job would enable me to accomplish tasks more quickly.*
PU2	*Using the system would enhance my effectiveness on the job.*
PU3	*Using the system would make it easier to do my job.*
PU4	*I would find the system useful in my job.*
PU5	*If I use the system, I will spend less time on routine job tasks.*
Perceived Ease of Use	
PEOU1	*Learning to operate the system is easy for me.*
PEOU2	*My interaction with the system would be clear and understandable.*

PEOU3	I would find the system flexible to interact with.
PEOU4	It would be easy for me to become skilful at using the system.
PEOU5	I would find the system easy to use.
PEOU6	Using the system takes too much time from my normal duties.
PEOU7	Overall, I believe that the system is easy to use.

Attitude toward usage	
ATU1	Using the system is a bad idea.
ATU2	The system makes work more interesting.
ATU3	Working with the system is fun.
ATU4	I like working with the system.
ATU5	This service feature is a great idea.
ATU6	The service feature would be fun to use.
ATU7	This is the best way to improve the quality of service.
ATU8	This service feature is here to stay.
ATU9	Many people will use this service feature.
ATU10	This service feature fills a real need for me.
ATU11	This service feature is a big improvement over existing login methods.
ATU12	This service feature can provide real value to me.
ATU13	This service feature is just another gimmick.
ATU14	This system fills a need for many people.
ATU15	Many people will believe that this system is worth the cost.

New Product Attributes	
NPA1	It is likely that this new feature will offer advantages to the users.
NPA2	The new feature is likely to perform well.
NPA3	It is likely that the new feature will add value to the online banking industry.

Behavioural Intention to Use	
BI1	Assuming that I have access to this service feature, I intend to use it.
BI2	I will definitely try this service feature.
BI3	It is very likely that I will use this service feature.
BI4	I intend to use the system in the next 12 months.
BI5	I predict I will use the system on a regular basis.
BI6	I plan to use the system in the next 12 months.

Social influence	
SI1	People who influence my behaviour think that I should use the system.
SI2	People who are important to me think that I should use the system.
SI3	In general, my organisation has supported the use of the system.

Table 8: The items used to estimate the Saudi predictor latent constructs

4. 9 Data Analysis and Results

A variety of statistical methods based on the Statistical Package for the Social Sciences (SPSS) was used to analyse the collected data from our experiment.

4.9.1 Reliability and Validation of the Measurement Scale

A variety of statistical methods based on the Statistical Package for the Social Sciences (SPSS) were used to analyse the collected data. Two separate reliability measures were used to illustrate the reliability of data. Veal (2005) defines reliability as the degree to which research findings would be the same if the research were to be repeated with a different sample or at a later date. In other words, the reliability of a measure indicates the extent to which the measure is without bias and hence offers consistent measurement across time and across the various items in the instrument (Kripanont 2007). It helps to assess the integrity of measures (Sekaran 2003).

4.9.1.1 Cronbach's Coefficient Alpha

For this work, we have used the most popular test of inter-item consistency, which is the Cronbach's coefficient alpha (Cronbach 1951; Nunnally 1979; Peter 1979; Sekaran 2000; Pallant 2005). Cronbach's coefficient alpha tests the consistency of participant responses to all the measurement items. To the degree that the items are independent measures of the similar concept, they will be correlated with one another (Sekaran 2000; Kripanont 2007).

In the first round, the Cronbach's alpha values for PU, PEOU, ATU, NPA, BI and SI were found to be 0.887, 0.758, 0.831, 0.625, 0.885 and 0.760, respectively. Based on (Sekaran 2000), reliabilities lower than 0.6 are considered to be poor, those in the 0.7 range are acceptable, and those over 0.8 are good. The closer to 1.0 the better the reliability coefficient is. It is generally agreed that the minimum acceptable value of Cronbach's alpha is 0.70 (Peter 1979; Pallant 2005), but this could be reduced to 0.6 for exploratory research (Robinson, Shaver et al. 1991a).

Reliability tests suggested that screening the data along Churchill's (1979) recommendations would improve reliability levels (Aladwani and Palvia 2002). We screened the collected data by discarding items that showed very low corrected item-total correlations, i.e., <0.40. After the screening process, 4 items were discarded from our pool of items, namely PEOU6, ATU9, ATU12, and NPA3. The reliability levels then came out as 0.887, 0.894, 0.914, 0.741, 0.885 and 0.760 for PU, PEOU, ATU, NPA, BI and SI, respectively. The Cronbach's alpha coefficients, before and after the deleted items, are illustrated in Table 10.

4.9.1.2 *Item-to-Total Correlation*

In addition to the Cronbach's alpha, a second measure to assess internal consistency was applied. This measure is the item-to-total correlation, which measures the correlation of the item to the total scale and the inter-item correlation (i.e., the correlation among items) (Hair, Black et al. 2006). It is recommended that the item-to-total correlations should exceed 0.50 and the inter-item correlation should exceed 0.30 (Robinson, Shaver et al. 1991a). As suggested by Cohen (1988), correlation (r) = 0.10 to 0.29 implies a small correlation (both positive and negative correlation), (r) = 0.30 to 0.49 implies a medium correlation, and (r) = 0.50 to 1.0 implies a strong correlation. Table 11 shows that all item-total correlation values exceeded 0.5, except some items in social influence (SI), and all inter-item correlation values exceeded 0.3, except a few items in attitude toward usage (ATU), almost all of which exceeded 0.30, with only a few below 0.30 .

The questionnaire proved to be reliable according to the Cronbach's Alpha coefficient. The bi-variate relationships indicate that all variables were significantly correlated with each other. This suggests that the correlations are positive between the behavioural intention to use and its independent variables, i.e., attitude toward

usage, perceived usefulness, perceived ease of use, new product attributes and social influence, and they are significant at 0.01% level. Table 12 presents the first-order correlation coefficients among the variables.

Measurement items (interval scale)	Items	Cronbach's alpha	Cronbach's alpha after items deleted	Reliability results
Perceived usefulness (PU)	5	0.887	0.887	Good
Perceived ease of use (PEOU)	7	0.758	0.894	Good
Attitude toward usage (ATU)	15	0.831	0.914	Good
New product attributes (NPA)	3	0.625	0.741	Acceptable
Behavioural intention to use (BI)	6	0.885	0.885	Good
Social influence (SI)	3	0.760	0.760	Acceptable

Table 9: The Cronbach's alpha coefficients

Measurement Items (Interval Scale)	Items	Inter-Item Correlation	Item- total correlation
Perceived usefulness (PU)	5	0.487-0.723	0.625-0.797
Perceived ease of use (PEOU)	7	0.428-0.749	0.581-0.810
Attitude toward usage (ATU)	15	0.245-0.674	0.547-0.753
New product attributes (NPA)	3	0.594-0.594	0.594-0.594
Behavioural intention to use (BI)	6	0.599-0.594	0.661-0.728
Social influence (SI)	3	0.390-0.747	0.437-0.694

Table 10: Inter-item/item-total correlation

		BI	ATU	PU	PEOU	NPA	SI
BI	Pearson Correlation	1	.718**	.594**	.519**	.595**	.350**
	Sig. (2-tailed)		.000	.000	.000	.000	.000
	N	306	306	306	306	306	306
ATU	Pearson Correlation	.718**	1	.674**	.502**	.762**	.404**
	Sig. (2-tailed)	.000		.000	.000	.000	.000
	N	306	306	306	306	306	306
PU	Pearson Correlation	.594**	.674**	1	.493**	.587**	.391**
	Sig. (2-tailed)	.000	.000		.000	.000	.000
	N	306	306	306	306	306	306
PEOU	Pearson Correlation	.519**	.502**	.493**	1	.435**	.386**
	Sig. (2-tailed)	.000	.000	.000		.000	.000
	N	306	306	306	306	306	306
NPA	Pearson Correlation	.595**	.762**	.587**	.435**	1	.419**
	Sig. (2-tailed)	.000	.000	.000	.000		.000
	N	306	306	306	306	306	306
SI	Pearson Correlation	.350**	.404**	.391**	.386**	.419**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	
	N	306	306	306	306	306	306

**. Correlation is significant at the 0.01 level (2-tailed).

Table 11: Correlation coefficients among the variables

4.9.1.3 Discriminate Validity of Constructs

In addition, as suggested by Fornell et al.(1981) the average variance extracted (AVE) which is the equals the total of all squared multiple correlations of a

construct's item divided by the number of items had been calculated according to the following formula:

$$AVE = \frac{\sum_{i=1}^{n} \lambda^{2i}}{n}$$

Where λ represents the squared multiple correlations and n represents the number of items (Hair et al., 2006).

The average variance extracted (AVE) for each measure consistently exceeded 0.50, as shown on Table 13. Table 14 illustrates the results of testing the discriminate validity of constructs. All indicators weigh more highly on their own constructs than on other constructs which is supporting the discriminate validity of the constructs.

Variable constructs	Average variance extracted
Perceived usefulness (PU)	0.51
Perceived ease of use (PEOU)	0.54
Attitude toward usage (ATU)	0.53
New product attributes (NPA)	0.52
Behavioural intention to use (BI)	0.61
Social influence (SI)	0.59

Table 12: Average variance extracted (AVE)

Latent variable	1	2	3	4	5	6
Social influence (SI)	**.769**					
New product attributes (NPA)	.290	**.719**				
Perceived ease of use (PEOU)	.245	.250	**.735**			
Perceived usefulness (PU)	.276	.391	.305	**.717**		
Attitude toward usage (ATU)	.228	.394	.241	.375	**.731**	
Behavioural intention to use (BI)	.256	.387	.314	.416	.390	**.784**

Table 13: Discriminant validity (intercorrelations) of variable constructs

4.9.2 Analytic Strategy for Assessing the Model

Path analyses (Land 1969; Li 1975; Kenny 1979) were used to analyse the data. Path analysis is a multivariate analytical method of empirically examining sets of

relationships in the form of linear causal models (Li 1975; Duncan 1986; Lin and Lu 2000). Path analysis has been applied to many disciplines, including sociology (Duncan 1986; Ingram, Patchin et al. 2007), psychology (Werts and Linn 1960; Friedman and Wall 2005), management (Anderson, Helriegel et al. 1977; Lu and Yeh 1998; Parolia, Goodman et al. 2007) and the Internet (Lin and Lu 2000; Paul and Mark 2001; Montgomery, Shibo et al. 2004).

The initial step in path analysis is to identify a path diagram. The hypothetical causal relationships are indicated by unidirectional arrows linking two variables together. The research model describes the path diagram in this study. According to the research model, new product attributes (NPA) are posited to exert simultaneous, direct, and linear influences on both perceived usefulness and perceived ease of using the biometric authentication system in e-commerce. The user's beliefs further influence his/her attitude towards using the system, as well as the behavioural intention to use the system.

The significance of the path coefficient related with each path represents the strength of each linear influence. While the path coefficients can be estimated in several ways (Kenny 1979), multiple regression analyses have been used by most empirical applications of this methodology. Li (1975) stated that the path coefficient has been revealed to be identical to the standardised regression coefficients. These coefficients are comparable among variables because they are normalised into the same unit (Lin and Lu 2000).

We conducted path analysis with a series of multiple regression analyses to test our research model. Notice that the variable (BI) has paths to it only from the variables (ATU, PU, and SI). To obtain the coefficients for those paths we simply conducted a

multiple regression to predict behavioural intention to use (BI) from attitude toward usage (ATU), perceived usefulness (PU) and social influence (SI). The beta weights are the path coefficients leading to BI: 0.568 from ATU, 0.189 from PU and 0.057 from SI.

In the model, ATU has paths to it from PEOU and PU, therefore we predicted ATU from PEOU and PU. The path coefficients leading to ATU are: 0.564 from PU, and 0.225 from PEOU. The following output shows the path coefficients leading to PU: 0.293 from PEOU, 0.459 from NPA. In the model PU has paths to it from PEOU and NPA.

Finally, the beta weights are the path coefficients leading to PEOU: 0.435 from NPA. Based on the model PEOU has paths to it just from NPA, hence we predict PEOU from NPA.

4.9.3 Evaluating the Hypothesised Model

In terms of goodness-of-fit indicators, the model accounts for 54% of the variance in the behavioural intention to use the biometric authentication system. In addition, usefulness and ease of use account for 49% of the variance in attributes towards use the system. New product attributes account for 41% and 18% of the variance in perceived usefulness and perceived ease of use of the biometric system, respectively. Figure 12 presents the path analysis of the model.
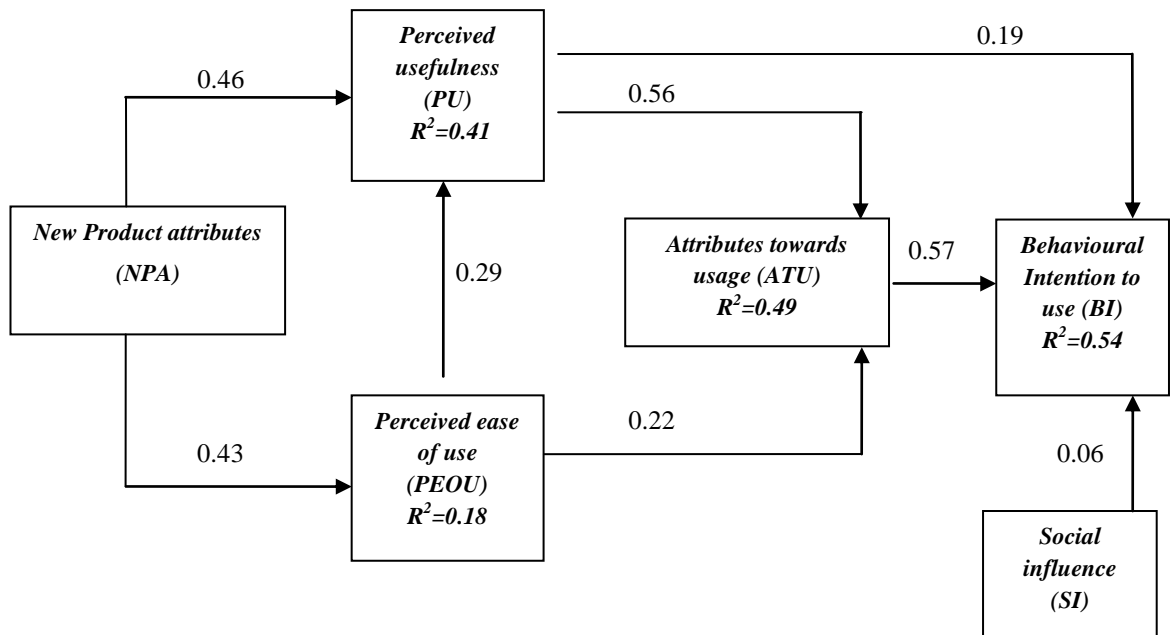
Figure 13: Research model: path analysis

The above results can be summarised as follows:

Function 1: In the multiple regression equation predicting the users' behavioural intentions, the effect of attributes towards usage is fairly strong, as indicated by the path coefficient of 0.57 ($p < 0.001$). The other path coefficients for the perceived usefulness and social influence of using the system, which are 0.19 and 0.06 ($p < 0.001$) respectively, are less statistically significant. All three paths account for approximately 54% of the observed variance in the behavioural intention to use the system. Notably, hypotheses 4, 7 and 8 are supported at the 0.05 level of significance.

Function 2: Attitudes towards usage are statistically significantly related to both the perceived usefulness and the perceived ease of use of the biometric authentication system. The effect of perceived usefulness on attitudes is strong, as indicated by the path coefficient of 0.56 ($p < 0.001$). The other path coefficient, perceived ease of use (0.22) is statistically significant at $p < 0.001$. Forty-nine percent (49%) of the

observed variance in attitude towards using the system can be explained from these two paths. Accordingly, hypotheses 3 and 4 are confirmed at the 0.05 level of significance.

Function 3: The perceived usefulness of the biometric authentication system is statistically significantly predicted by two paths, from the perceived ease of use and new product attributes. The path coefficients from the above paths are 0.29 ($p < 0.001$) and 0.46 ($p < 0.001$), respectively. These two paths together explain approximately 41% of the observed variance in perceived usefulness. Thus, hypotheses 1 and 6 are supported at the 0.05 level of significance.

Function 4: The perceived ease of use the biometric system can be statistically significantly predicted by the path from new product attributes. The path coefficient from the above is 0.43 ($p < 0.001$). The path accounts for 18% of the observed variance in perceived ease of use for the biometric system. Again, hypothesis 2 is confirmed at the 0.05 level of significance.

4. 10 Discussion

This study examines the modified TAM model for the biometric authentication system in the e-commerce environment by adding new product attributes and social influence as external variables. The introduction of new product attributes to the model is intended to reflect the uncertainty currently associated with the e-commerce environment (Yogesh and Malhotra 1999; Paul 2003; Cheng, Sheen et al. 2006). Social influence is introduced to the model and is represented as a subjective norm in many theories (Venkatesh, Morris et al. 2003). It acts as one of the determinants of behavioural intentions and usage behaviour.

The findings of this study show that the behavioural intention to use the biometric authentication system in the e-commerce environment can be predicted by using TAM (R^2=0.54).

The perceived usefulness and the perceived ease of use had significant effects on the attitudes towards using the system ($\beta = 0.56$; $\beta = 0.22$), supporting hypotheses 3 and 5. The implication here is that if the participants believe that the biometric authentication system is useful in a particular situation, then they will be more likely to use the technology. Moreover, participants might be more likely to use the system if they feel that it is easy to use. The perceived ease of use of the system was found to have a significant impact on the perceived usefulness ($\beta = 0.29$), supporting hypothesis 6. A participant's perception of how easy the system is to use may represent a large determining aspect of its perceived usefulness. This implies that the usage complexity of the biometric system will significantly impact its perceived usefulness.

Based on this study, one finding is the relative strength of the relationship between perceived usefulness and intention of using the biometric system compared to the relationship between ease of use and intention of using the system. In fact, the regression analysis explains that the usefulness-intention relationship remains large, while the ease of use-intention relationship is reduced. Based on previous findings (Davis 1989; Gefen and Straub 1997; Lin and Lu 2000; Chen, Fan et al. 2007), there is a more significant link between usefulness and the intention to use than ease of use, whereas, ease of use exerts a significant effect on usefulness.

Furthermore, the significant correlation between the ease of use-intention and ease of use-attitude relationships may be attributed to the possible causal chains (shown in Figure 11):

i) Ease of use $\rightarrow$ usefulness $\rightarrow$ intention

ii) Ease of use $\rightarrow$ usefulness $\rightarrow$ attitudes

For that reason, perception of ease of use can facilitate in perceiving usefulness as well as developing attitudes towards using the system. Perceived ease of use, hence, exerts an indirect impact on the user's intention to use the biometric system.

In Chris et al. (2009) regression analysis was carried out to establish which variables had the biggest effect on respondents' acceptance of the use of biometrics technology across cultures. Based on that study, perceived ease of use of biometrics technology was considered a significant predictor within the UK, India and South Africa (β = 0.10, β = 0.13, β = 0.16), which is similar to our findings among Saudi cultures (β = 0.18).

This study has provided some valuable global impact insights into user acceptance of a biometric authentication system from the perspective of the e-commerce industry. In addition, it tested the descriptive validity of TAM in the domain of e-commerce. Based on the results obtained here, several inferences can be made.

Although the finding from the path analysis shows that the path from social influence to behaviour intention to use is less statistically significant than other paths, we can accept that social influence still has direct determinants of intention to use the system. As a result, it can be concluded that if other people, in the user's social environment, use a technological innovation the user will be more likely to decide to use it.

4. 11 Summary and Conclusion

The research model developed in this chapter is revealed to be a good predictor for the intention to use biometric authentication systems within the Saudi culture. The experiment developed for this study could be used as an indicator for the success of the acceptance of biometric technologies in e-commerce services for both individuals and organisations. Gaining an idea of adoption success could be valuable in avoiding unsuccessful efforts to develop biometric authentication technology, which could prevent major financial losses.

Based on this study, the user acceptance of using biometric technology shows that the technology has the potential to be applied in the e-commerce industry. The data collected and analysed by this experiment indicated that participants believed in the benefits and the potential of this technology. The results of the regression analysis supported the model, and all of the eight proposed hypotheses were confirmed.

The findings outline two main areas associated with the acceptance of biometric authentication systems. First, the careful consideration of the specific biometric technology to be implemented is important, as the new product has attributes that may lead to unwanted adoption behaviour. In addition, this might affect the perceived ease of use of the biometric system in an unpredictable way, possibly requiring extensive training on the biometric technology or the use of different approaches for acceptance procedures. Second, both individuals and organisations have to secure their online services; security plays an important role in the intention to use the biometric authentication system. Hence, acceptance procedures that highlight the advantages of the technology will possibly give support to improving the implementation procedure.

Contrary to what was predicted by Hofstede's cultural dimensions regarding the acceptance of the technology (Erumban and Jong 2006; Elliott, Massie et al. 2007; Chris, Kathy et al. 2009), the construct of individualism was negatively related to participants' attitudes towards biometric technology. Saudi Arabia and India are a collectivist society and the USA and UK are at the individualist end of the scale. Though Saudi Arabia and India were the most positive towards biometrics technology; this was followed by South Africa, UK, and USA as the least positive.

Similarly, power distance scores were positively related to user acceptance of biometrics technology, although the literature suggests that technology would be perceived more positively in individualistic societies. Masculinity, often thought to be negatively linked with technology distribution was found to be positively associated with participant viewpoints towards acceptance of biometric technology.

Based on our findings, the construct of uncertainty avoidance did not have an obvious relationship with perception towards acceptance of biometric technology; these findings are consistent with many studies (Elliott, Massie et al. 2007; Chris, Kathy et al. 2009). Similar to (Chris, Kathy et al. 2009), our findings suggest that Hofstede's cultural dimensions cannot be used to describe the cross-cultural differences seen here. The assertions of Al-Gahtani et al. (2007) and Erumban et al. (2006), about the relationship between culture and attitude towards new technology, were not supported by the findings of this study.

The strength of this research lies in its derivation of its own factors from prior theoretical and empirical research. The applied measures utilised in this research were developed through an extensive review of the literature. Moreover, the study variables, which have been used in many previous technology and authentication

systems within e-commerce adoption researches, were found to have adequate reliability and validity.

In addition to cultural dimensions, it is important to address other factors that may affect the level of acceptance of the technology. Therefore, the next chapter describes the second phase of this experimental study that adapted the UTAUT model to investigate further factors, in addition to the moderated factors such gender, age and education level. The second experimental phase evaluates user acceptance under the same laboratory experiment conditions.

Chapter 5. User Acceptance: Applying the UTAUT –

Experimental Phase II

5. 1 Introduction

This chapter presents recent findings from an ongoing cross-cultural study exploring the acceptance of new security methods, based on biometric authentication systems to be applied to an e-commerce application, within the context of Saudi culture.

In Chapter 4, a study based on Davis' (1986) Technology Acceptance Model (TAM) was performed to examine this subject. Based on the outcomes of Chapter 4, user acceptance of biometric technology reveals that the technology has the potential to be implemented in the e-commerce industry. However, it was realised that other factors may also play an important role in user intentions to accept and use the biometric system, such as facilitating conditions, anxiety, self-efficacy and system characteristics. Moreover, the TAM missed the significant sources of variance such social/cultural influence and the characteristics of new product/system; and moderator factors, such as gender, age and education level.

To overcome these limitations, a study based on Venkatesh et al. (2003), which involved the use of the Unified Theory of Acceptance and Use of Technology (UTAUT), was conducted to examine the acceptance of using biometric systems to secure e-commerce systems and which included all the above factors.

Hence, the major UTAUT constructs were considered in determining acceptance intention and behaviour performance expectancy, effort expectancy, social influence, and facilitating conditions. The research model was tailored to meet the aims of the

study while adding other intrinsic factors such as anxiety, self efficiency and biometric system characteristics.

The rest of the chapter is organised as follows: section 5.2 presents the aim of this chapter, followed by the research model and hypothesis development in section 5.3, while measurement development is explained in section 5.4. The data analysis and results are presented in section5. 5, while analytic strategy for assessing the model is detailed in section 5.6. Evaluation of the hypothesised model is in section 5.7, and this is followed by a discussion in section 5.8. Some conclusions and managerial implications are drawn in section 5.9.

5. 2 Aim

The aim of the chapter is to explore factors affecting users' acceptance of biometric authentication systems within Saudi culture. As mentioned in the previous chapter, an experiment of 306 Saudis was conducted using a fingerprint-based login system to examine whether Saudis are practically and culturally willing to accept biometric authentication technology. The results were then examined using a proposed conceptual framework based on the Unified Theory of Acceptance and Use of Technology (UTAUT) with moderating variables such age, gender and education level.

5. 3 Research Model and Hypothesis Development

The present study developed a research framework based on the UTAUT model with three variables added: computer self-efficacy, anxiety and biometric system characteristics. The research model replaced experience with education level and voluntariness was discarded to suit the requirements of the context being studied. This is justified by the fact that the study focuses on end users in underdeveloped

cultures and the issue of education level is of great significance in both cases (Oshlyansky, Cairns et al. 2007).

The enhanced model was then used to explore the factors affecting user acceptance of using biometric authentication systems within e-commerce applications. The determinants of the model and the added variables are clarified in the following section. The study framework and the relevant hypotheses for the acceptance of biometric authentication systems within e-commerce systems were primarily developed based on the fundamental features of the UTAUT model. For this work, the model was tailored to meet the objectives of the study by adding other intrinsic factors; the research model is shown in Figure 13.
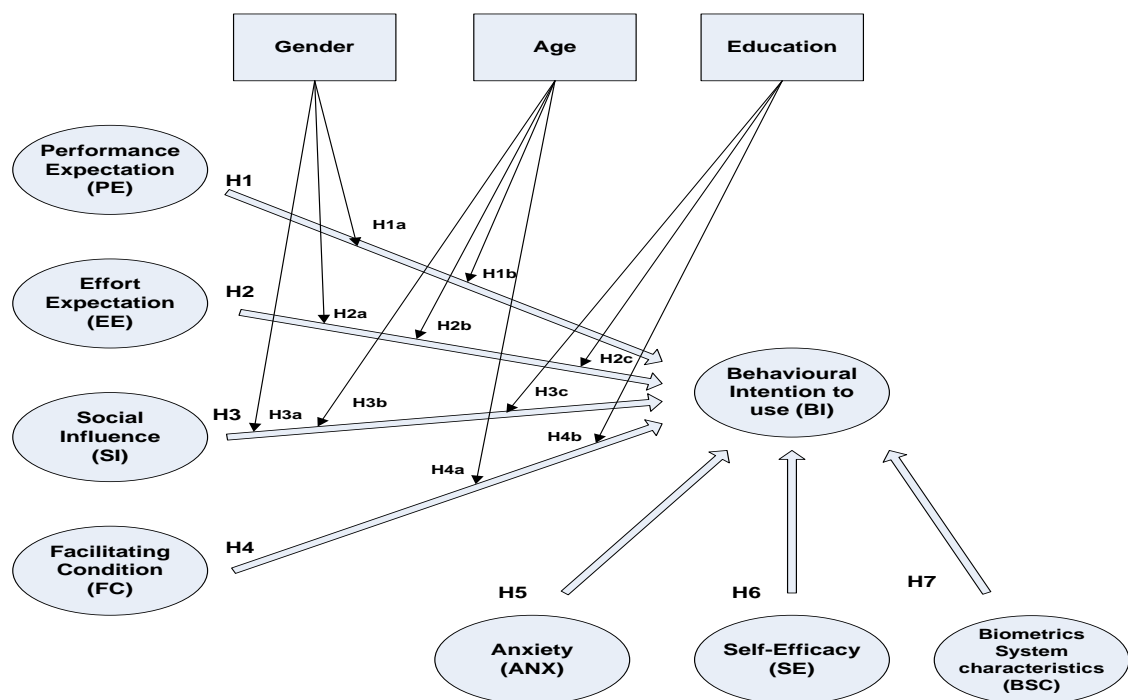
Figure 14: UTAUT research model

Several hypotheses were constructed, as illustrated in Table 15. The sources of these hypotheses are also shown in this table.

Hypotheses	Source
H1: Performance expectancy will have a positive influence on behavioural intentions to use the system.	(Venkatesh, Morris et al. 2003)
H1a: Gender will positively moderate the influence of performance expectancy on behavioural intentions to use that system for men.	
H1b: Age will not moderate the influence of performance expectancy on behavioural intentions to use that system.	(Venkatesh, Morris et al. 2003)
H2: Effort expectancy will have a positive influence on behavioural intentions to use the biometric authentication system.	
H2a: Gender will positively moderate the influence of effort expectancy on behavioural intentions to use that system for men.	
H2b: Age will not moderate the influence of effort expectancy on behavioural intentions to use that system.	
H2c: Education level will negatively moderate the influence of effort expectancy on behavioural intentions to use that system for men.	
H3: Social influence will have a positive influence on behavioural intentions to use the system.	(Venkatesh, Morris et al. 2003)
H3a: Gender will positively moderate the influence of social influence on behavioural intentions to use that system for men.	
H3b: Age will negatively moderate the influence of social influence on behavioural intentions to use that system.	
H3c: Education level will negatively moderate the influence of social influence on behavioural intentions to use that system.	
H4: Facilitating conditions will have a positive influence on behavioural intention to use that system.	(Venkatesh, Morris et al. 2003)
H4a: Age will negatively moderate the influence of facilitating conditions on behaviour intention to use that system.	
H4b: Education level will negatively moderate the influence of facilitating conditions on behaviour intention to use that system.	
H5: Anxiety will have a negative influence on behavioural intentions to use the system.	(Campueau and Higgins 1995) (Venkatesh, Morris et al. 2003)
H6: Self-efficacy is positively related to behavioural intention to use the system.	(Campueau and Higgins 1995)
H7: The system characteristics have a positive relationship with behavioural intention to use the system.	(Davis, F. D. 1993)

Table 14 : Experimental phase II hypotheses

5. 4 Measurement Development

Measurement items used in this study were adapted from earlier validated measures (Venkatesh, Morris et al. 2003; Al-Gahtani, Hubona et al. 2007; Oshlyansky, Cairns et al. 2007; AlAwadhi and Morris 2008), or were developed on the base of a theoretical background and literature review. A five-point Likert scale ranging from (1) 'strongly agree' to (5) 'strongly disagree' was used to measure responses. A pilot experiment was conducted on a representative sample of five individuals randomly selected and questionnaire statements were tailored based on the results of this initial experiment. The measurement items used to assess each item are presented in Table 16.

Constructs		Measures
Performance expectancy	PE1	Using the system in my job would enable me to accomplish tasks more quickly.
	PE2	Using the system would enhance my effectiveness on the job.
	PE3	Using the system would make it easier to do my job.
	PE4	I would find the system useful in my job.
	PE5	If I use the system, I will spend less time on routine job tasks.
Effort expectancy	EE1	Learning to operate the system is easy for me.
	EE2	My interaction with the system would be clear and understandable.
	EE3	I would find the system flexible to interact with.
	EE4	It would be easy for me to become skilful at using the system.
	EE5	I would find the system easy to use.
	EE6	Using the system takes too much time from my normal duties.
	EE7	Overall, I believe that the system is easy to use.
Facilitating conditions	FC1	I have the resources necessary to use the system.
	FC2	I have the knowledge necessary to use the system.
	FC3	A specific person (or group) is available for assistance with system difficulties.
Self-efficacy	SE1	I could complete a job or task using the system if there was no one around to tell me what to do as I go.
	SE2	I could complete a job or task using the system if I could call someone for help if I got stuck.
	SE3	I could complete a job or task using the system if I had a lot of time to complete the job for which the system was provided.

	SE4	I could complete a job or task using the system if I had just the built-in help facility for assistance.
Behavioural intention	BI1	Assuming that I have access to this service feature, I intend to use it.
	BI2	I will definitely try this service feature.
	BI3	It is very likely that I will use this service feature.
	BI4	I intend to use the system in the next 12 months.
	BI5	I predict I will use the system on a regular basis.
	BI6	I plan to use the system in the next 12 months.
Social influence	SI1	People who influence my behaviour think that I should use the system.
	SI2	People who are important to me think that I should use the system.
	SI3	In general, my organisation has supported the use of the system.
Anxiety	ANX1	I feel apprehensive about using the system.
	ANX2	It scares me to think that I could lose a lot of information.
	ANX3	Using the system by hitting the wrong key.
	ANX4	I hesitate to use the system for fear of making mistakes I cannot correct.
Biometrics system characteristics	BSC1	It is likely that this system will offer advantages to the consumer.
	BSC2	The system is likely to perform well.
	BSC3	It is likely that the system will add value to the e-commerce application.

Table 15 : Summary of measurements items

5. 5 Data Analysis and Results

The software packages used to perform the assessment of the research model were SPSS version 16 and AMOS version 17 as a Structural Equation Model analysis; the following subsections present the reliability and validation of the entire scales.

5.5.1 Reliability and Validation of the Measurement Scale

As suggested by Anderson et al. (1988), to appraise the reliability and validity of the measures, two-phase processes were employed to analyse the data. The first phase consists of the analysis of the measurement model, where the second phase is concerned with the assessment of the structural relationships along with latent

constructs. The assessment of the measurement model involves the estimation of internal consistency reliability, in addition to the convergent and discriminate validity of the study instruments, which shows the strength measures used to assess the anticipated model (Fronell 1987).

For reliability, all scales used were above the minimum recommended values level of 0.70, as illustrated in Table 17, which can provide an indication of adequate internal consistency (Nunnally 1978).

In addition, the constructs showed satisfactory convergent and discriminate validity. Fornell et al.(1981) suggested the convergent validity is adequate when constructs have an average variance extracted (AVE) of at least 0.5. To examine convergent validity all item loadings should be above 0.5 (Hair, Anderson et al. 1992). To examine the satisfactory discriminate validity, as suggested by Chin (1998), the AVE from the construct should be greater than the variance shared among a particular construct and other constructs in the research model.

Table 18 illustrates that all indicators load more highly on their own constructs than on other constructs. All findings indicate the convergent and discriminate validity of this study's instrument items.

Variable constructs	Items	Loading	t-Value	Composite reliability	Cronbachs alpha(a)	Average variance extracted
Performance expectancy (PE)	PE1	0.833	52.583	0.954	0.887	0.512
	PE2	0.871	61.166			
	PE3	0.843	54.118			
	PE4	0.821	46.832			
	PE5	0.869	48.921			
Effort expectancy (EE)	EE1	0.797	53.794	0.937	0.758	0.543
	EE2	0.865	59.352			
	EE3	0.845	51.654			
	EE4	0.821	48.945			
	EE5	0.875	49.840			
	EE6	0.868	52.943			
	EE7	0.895	51.985			

Facilitating conditions (FC)	FC1	0.784	52.237	0.934	0.871	0.689
	FC2	0.876	49.766			
	FC3	0.893	47.876			
Social influence (SI)	SI1	0.779	51.239	0.892	0.760	0.596
	SI2	0.783	48.954			
	SI3	0.864	46.543			
Behavioural intention to use (BI)	BI1	0.817	58.451	0.921	0.885	0.614
	BI2	0.875	52.657			
	BI3	0.827	49.841			
	BI4	0.893	47.942			
	BI5	0.791	51.542			
	BI6	0.867	52.681			
Self-efficacy (SE)	SE1	0.795	39.564	0.887	0.844	0.633
	SE2	0.834	38.871			
	SE3	0.852	40.119			
	SE4	0.898	42.689			
Anxiety (ANX)	ANX1	0.783	39.564	0.812	0.812	0.587
	ANX2	0.791	38.871			
	ANX3	0.829	40.119			
	ANX4	0.824	42.689			
Biometric system characteristics (BSC)	BSC1	0.852	38.561	0.865	0.741	0.523
	BSC2	0.874	37.833			
	BSC3	0.794	41.174			

Table 16: Psychometric properties of the constructers

Latent variables	PE	EE	FC	SI	BI	SE	ANX	BSC
Performance expectancy (PE)	**0.717**							
Effort expectancy (EE)	0.573	**0.735**						
Facilitating conditions (FC)	0.548	0.516	**0.742**					
Social influence (SI)	0.487	0.342	0.311	**0.769**				
Behavioural intention to use (BI)	0.525	0.578	0.514	0.599	**0.784**			
Self-efficacy (SE)	0.478	0.367	0.532	0.477	0.485	**0.783**		
Anxiety (ANX)	0.321	0.376	0.653	0.479	0.532	0.541	**0.703**	
Biometric system characteristics (BSC)	0.474	0.653	0.473	0.290	0.443	0.367	0.575	**0.719**

Table 17 : Discriminant validity of constructs

5.5.2 Analytic Strategy for Assessing the Model

This section discusses the results in association with the structural model and the hypotheses produced for all constructs. The structural model can be examined by investigating the path coefficients beta weight (β) which demonstrates how well-fit the relationships among the variables and the (R^2) value are, which illustrates the amount of variance explained by independent variables (Al-Somali, Gholami et al.

2008). Both, the R^2 and the path coefficients signify how well the model is fitting. R^2 explains the predictive influence of the research model. The values should be interpreted in a similar approach as R^2 in a regression analysis. Additionally, the path coefficients should be significant and reliable with expectations (Chwelos, Benbasat et al. 2001).

5.5.3 Evaluating the Hypothesised Model

The structural model results show that all beta path coefficients are positive and statistically significant (at $p < 0.05$). The beta values of all path coefficients are also shown. Performance expectancy (PE), effort expectancy (EE) and social influence (SI) had a positive influence on behavioural intention to use (BI) (respectively, $\beta = 0.873, 0.746, 0.315, p < 0.001$). The negative influence of facilitating conditions (FC) on behavioural intention to use (BI) ($\beta = -0.065$) was not statistically significant.

Anxiety (ANX), self-efficacy (SE) and biometric system characteristics (BSC) had a positive influence (respectively $\beta = 0.169, 0.298, 0.653, p < 0.001$) on behavioural intention to use (BI). Unexpectedly, gender did not show significant interactions with any predictor latent items. Age had a negative ($\beta = -0.077, p < 0.05$) interacting effect with effort expectancy (EE) along with behavioural intention to use (BI). Moreover age showed a negative ($\beta = -0.065, -0.074, p < 0.05$) interacting effect with social influence (SI) and facilitating conditions (FC), respectively, on behavioural intention to use (BI).

Education illustrated three interacting effects: a positive ($\beta = 0.168, p < 0.001$) interacting effect with effort expectancy (EE) on behavioural intention to use (BI); a positive ($\beta = 0.256, p < 0.05$) interacting effect with social influence (SI) on

behavioural intention (BI); and a strongly positive (β = 0.543, p < 0.001) interacting effect with facilitating conditions (FC) on behavioural intention (BI).
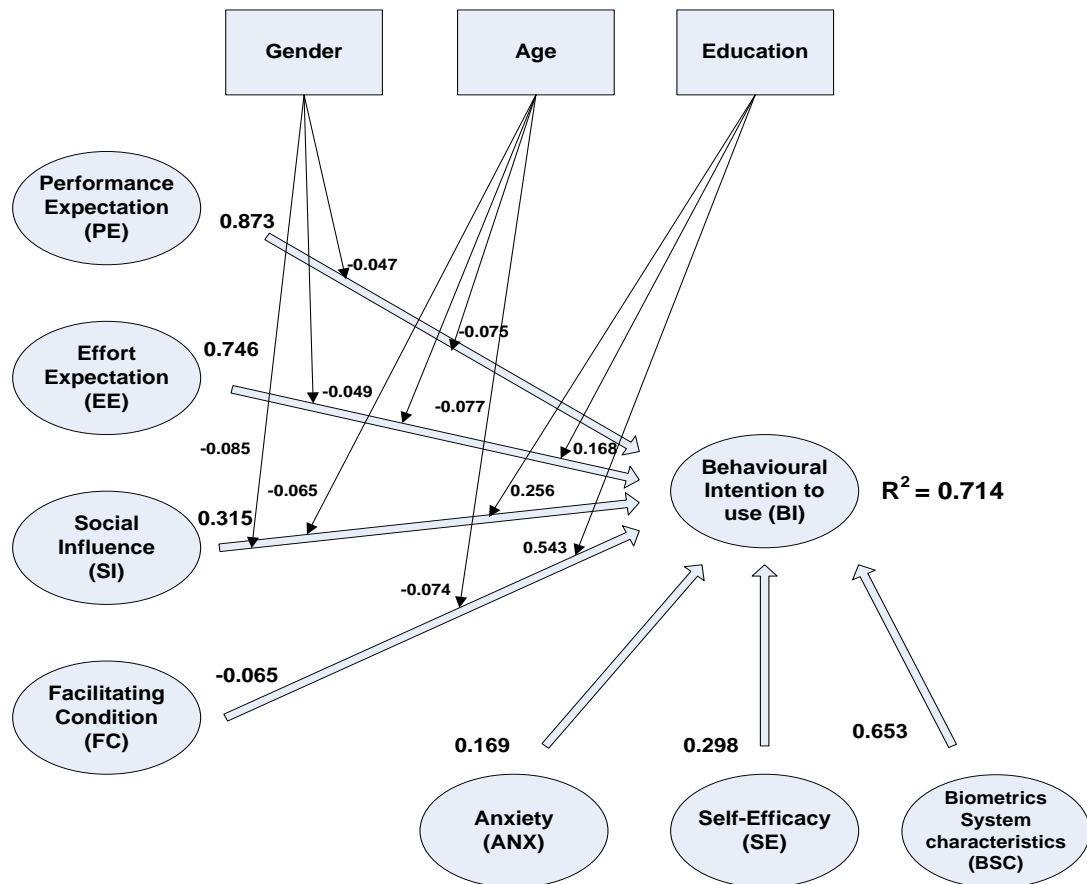
Figure 15: Results of structural model

The effects of the revealed antecedents of behavioural intention (BI) totally explained 71.4% of the variance in behavioural intention to use the biometric authentication system (R^2=0.714). This was an indication of the good explanatory power of the model for behavioural intention (BI), which was much higher compared to other UTAUT based information technology acceptance studies, such as Al–Gahtani et al. (2007), with an R^2 equal to 0.391 for intention to use.

5. 6 Discussion

Table 19 shows the hypotheses and outcomes. Expansion in the use of the Internet has encouraged institutions and companies to promote and trade their goods and services online. Various banks and financial institutions have applied new secure applications through the Internet, such as biometric authentication systems to increase efficiency, to reduce risks and costs, and to improve security. As more and more financial institutions apply biometric authentication systems, it is important for these financial institutions to identify factors that influence their customer behavioural intention to use such systems. This study identifies several important factors influencing customer behavioural intention towards biometric authentication system acceptance, including, performance expectancy, effort expectancy, biometric system characteristics, social influence, anxiety, facilitating conditions, self-efficacy, age, gender and education.

No.	Hypothesis path	R^2	Path coefficient(β)	Supported?
H1	PE→BI	0.713	0.873	Yes
H1a	Gender→PE→BI	0.003	-0.047	No
H1b	Age→PE→BI	0.007	-0.075	No
H2	EE→BI	0.578	0.746	Yes
H2a	Gender→EE→BI	0.002	-0.049	No
H2b	Age→EE→BI	0.004	-0.077	No
H2c	Education →EE→BI	0.027	0.168	Yes
H3	SI→BI	0.087	0.315	Yes
H3a	Gender→SI→BI	0.004	-0.085	No
H3b	Age→SI→BI	0.008	-0.065	No
H3c	Education→SI→BI	0.034	0.256	Yes
H4	FC→BI	0.004	-0.065	No
H4a	Age→FC→BI	0.007	-0.074	No
H4b	Education→FC→BI	0.045	0.543	No
H5	ANX→BI	0.032	0.169	Yes
H6	SE →BI	0.043	0.298	Yes
H7	BSC →BI	0.054	0.653	Yes

Table 18 : Assessment of structural model

Interestingly, the implication of such a finding is that almost all respondents showed Internet usage in a range of situations, suggesting awareness with this medium, and hence, the potential willingness to engage in new secure e-transaction methods.

One finding by this study is that the relative strength of the relationship among performance expectancy (PE) and behavioural intention to use (BI) the biometric system contrasted with the relationship between effort expectancy (EE) and behavioural intention to use the system. In fact, Structured Equation Modelling (SEM) shows that the performance expectancy (PE) towards the behavioural intention (BI) relationship is large, even as the effort expectancy (EE) towards behavioural intention (BI) relationship is reduced.

As suggested by Venkatesh et al. (2003), it was found that performance expectancy (PE) had a positive effect on the behavioural intention (BI) to use the system. However, no interacting effect with performance expectancy (PE) and gender on behavioural intention (BI) to use the biometric system was discovered. Moreover, it was revealed that effort expectancy (EE) had a less significant effect on behavioural intention (BI) in the existence of interactions with moderating variables.

The positive interaction between the effort expectancy (EE) and education level on intention to use the system indicated that, with higher educational levels, effort expectancy becomes more important in predicting Saudi's behavioural intentions.

The results show that, with Saudi users, social influence positively influences behavioural intention, however, as confirmed by Al-Gahtani et al. (2007), this influence is diminished by increasing age and level of education. In contrast, education level was not significantly related to the perception of using biometrics technology within Americans' users (Elliott, Massie et al. 2007).

The findings also coincide with the findings of Al-Gahtani et al. (2007), which found that the negative outcome of facilitating conditions (FC) on behavioural intention (BI) was not considerable in the presence of the negative interacting outcome of increasing age, along with the strong positive interacting outcome of growing education level with facilitating conditions on behavioural intention to use.

Surprisingly, the test of the research model did not reveal any significant gender influence on the relationship between performance expectancy, effort expectancy and social influence and behaviour intention to use a biometric authentication system. These results are not in accordance with the results reported in various other studies, which indicate gender differences in the acceptance of new technology as one aspect of socio-cultural differences between males and females (Venkatesh and Davis 2000; Venkatesh, Morris et al. 2003). Moreover, gender was significantly related to biometrics technology within American users (Elliott, Massie et al. 2007) while older respondents were found to be less likely to use biometrics for online application but more likely to use biometrics technology at ATMs (Elliott, Massie et al. 2007). The absence of gender differences in our study could be attributed to the sample of users, comprising males and females who are receiving similar educational opportunities. Moreover, most of the expected likeness in self-efficacy (SE) is caused through the understanding and the experiences of the sample considered. Many studies revealed that IT experience assists in narrowing the gender differences gap (Wong and Hanafi 2007).

Based on our hypothesised model, the behavioural intention (BI) of using the system can be predicted from the biometric system characteristics (BSC). Hence, the path coefficients from the above paths are 0.653 ($p < 0.001$). As expected self-efficacy (SE) and anxiety (ANX) have minimal effects on behavioural intention (BI).

In order to ensure the continued success of biometric authentication systems, it is critical that the traditional product development process develop into a user-centric model that takes into consideration the essential role users play in the biometric authentication development. By considering the partnership among biometric authentication systems and users, we can begin to have a significant impact on the implementation of these systems, including: enhanced effectiveness and ease-of-use, reduced product/system complexity, enhanced system performance, and increased user satisfaction. When focusing on these features, biometric systems developers can develop the usability of their systems, and thus, may also improve system performance and hence their return on investment, including: improved accuracy and compact errors, reduce time to capture a suitable sample, enhanced efficiency and less attempts required, reduced need for support from desk help or system operators, and reduced support and training costs. Therefore, effectiveness and ease-of-use enhancement not only guide to improved, easier-to-use products/system; they can also guide to considerable cost savings as a result of enhanced biometrics system performance.

In order to increase the acceptance of biometric authentication systems and gather the benefits of improved system performance, it is important to get a holistic approach in which users are a key factor in the development of a biometric authentication system. By considering the users' points of view in the implementation process, wherein users have an essential role in the improvement of a biometric authentication system, we can start to have a considerable impact on a system's effectiveness and ease of use.

5. 7 Summary and Conclusion

The amount of research on the acceptance of new technologies among users is enormous. An important aim of many organisations is to appreciate the factors that enhance the acceptance of new technology and determine which technologies are more feasible for implementation. This research has introduced some of the key perceptions with regards to the users as being the key issues of biometric system adoption:

- Context of use: including user characteristics, and social/cultural aspects.

- User and organisational requirements: including organisations, users and technical requirements.

However, there is a lack of literature on biometric technology acceptance, particularly in Middle Eastern countries. From this perspective, this research attempted to extend the understanding of individual differences when applying the UTAUT as a representative and powerful technology acceptance model to the Saudi users, and to understand the acceptance process in relation to biometric authentication technology with e-commerce systems. The next chapter presents the conclusions of the overall experimental approach, summarises managerial implications, and sheds more light onto further directions for research.

Chapter 6. Conclusions and Recommendations

6. 1 Introduction

Chapters 3, 4 and 5 explained the examination of user acceptance of biometric authentication systems within e-transactions such as e-commerce and e-government applications. Chapter 3 investigated the feasibility of biometric authentication systems in online services and their user acceptance in Saudi Arabia. Chapter 4 extended the work carried out in Chapter 3 by conducting an experiment on the same subject. It measured user acceptance towards the use of biometric authentication technology by applying TAM.

Following this, the second phase of the experiment in Chapter 5 demonstrated aspects related to user acceptance of technology with regard to three moderator variables, age, gender and education level, in order to investigate user acceptance of the experimental stage. This chapter presents the conclusions drawn, along with theoretical, methodological and practical implications. The purpose of this final chapter is to summarise the findings of the study, highlight limitations of the study and provide suggestions for further research.

6. 2 Testing the Overall Hypothesis

In testing and making modifications associated with the proposed research model, two groups of hypotheses were tested:

- Direct path hypotheses.

- Moderating hypotheses.

For direct path hypotheses it was found that:

- All direct path hypotheses in phase (I) were supported (see Table 20).

- Only one hypothesis was not supported in phase (II) (see Table 20).

With the moderating hypotheses only two moderating hypotheses were supported (see Table 20).

Overall Hypothesis	Hypothesis Result	Evidence Reference
Direct path hypotheses		
Phase I		
H1: The new product attributes of the biometric authentication system in e-commerce have a positive relationship with perceived usefulness.	Supported	Section 4.3
H2: The new product attributes of the biometric authentication system in e-commerce have a positive relationship with perceived ease of use.	Supported	Section 4.3
H3: The perceived usefulness of using the biometric authentication system in e-commerce will positively influence the attitudes towards using the technology.	Supported	Section 4.3
H4: The perceived usefulness of using the biometric authentication system in e-commerce will have a positive impact on an individual's behavioural intention to use the technology.	Supported	Section 4.3
H5: The perceived ease of use of the biometric authentication system in e-commerce will positively influence the attitudes towards using the technology.	Supported	Section 4.3
H6: The perceived ease of use of the biometric authentication system in e-commerce will positively influence the perceived usefulness of using the technology.	Supported	Section 4.3
H7: Perceived attitudes towards using the biometric authentication system in e-commerce will have a positive impact on an individual's behavioural intention to use this technology.	Supported	Section 4.3
H8: Social influence will positively influence the individual's behavioural intention to use the biometric authentication system in e-commerce.	Supported	Section 4.3
Phase II		
H1: Performance expectancy will have a positive influence on behavioural intentions to use the system.	Supported	Section 5.3
H2: Effort expectancy will have a positive influence on behavioural intentions to use the biometric authentication system.	Supported	Section 5.3
H3: Social influence will have a positive influence on behavioural intentions to use the system.	Supported	Section 5.3
H4: Facilitating conditions will have a positive influence on	Not supported	Section 5.3

behavioural intention to use that system.

H5: Anxiety will have a negative influence on behavioural intentions to use the system.	Supported	Section 5.3
H6: Self-efficacy is positively related to behavioural intention to use the system.	Supported	Section 5.3
H7: The system characteristics have a positive relationship with behavioural intention to use the system.	Supported	Section 5.3
Moderating hypotheses		
H1a: Gender will positively moderate the influence of performance expectancy on behavioural intentions to use that system for men.	Not supported	Section 5.3
H1b: Age will not moderate the influence of performance expectancy on behavioural intentions to use that system.	Not supported	Section 5.3
H2a: Gender will positively moderate the influence of effort expectancy on behavioural intentions to use that system for men.	Not supported	Section 5.3
H2b: Age will not moderate the influence of effort expectancy on behavioural intentions to use that system.	Not supported	Section 5.3
H2c: Education level will negatively moderate the influence of effort expectancy on behavioural intentions to use that system for men.	Supported	Section 5.3
H3a: Gender will positively moderate the influence of social influence on behavioural intentions to use that system for men.	Not supported	Section 5.3
H3b: Age will negatively moderate the influence of social influence on behavioural intentions to use that system.	Not supported	Section 5.3
H3c: Education level will negatively moderate the influence of social influence on behavioural intentions to use that system.	Supported	Section 5.3
H4a: Age will negatively moderate the influence of facilitating conditions on behaviour intention to use that system	Not supported	Section 5.3
H4b: Education level will negatively moderate the influence of facilitating conditions on behaviour intention to use that system.	Not supported	Section 5.3

Table 19: Review of overall hypothesises

6. 3 General Conclusions

This section states briefly the general conclusions of this research. Before doing so, it is important to consider that this experimental approach was carried out with significant results. With this factor considered, the following main conclusions can be stated:

- It can be concluded that the biometric authentication system was acceptable as a new secure authentic method.

- It can be concluded that usefulness (performance expectancy) is still the most important concern in the behavioural intentions to use the system. To encourage users' acceptance of the system, the organisation should promote the system's usefulness (performance expectancy) more than promoting its ease of use (effort expectancy).

- We consider that specific contextual aspects, unique to each country and dissimilarities in the underlying acceptance of biometric technology present an improved explanation of the differences in attitudes observed across Saudi Arabia and the others countries in addition to Hofstede's cultural dimensions.

6. 4 Research Significant Contribution

The amount of research on the acceptance of new technologies among organisations and users is enormous. An important aim of many organisations is to appreciate the factors that will enhance the acceptance of new technology and decide which technologies are valuable to apply. Despite this, there is a lack of literature on biometric technology acceptance, particularly in Middle Eastern countries. This research contributes to the literature on biometric technology acceptance by utilising a sample of individuals from a Saudi culture, which is currently limited in academic journals.

Biometric technology, in particular within e-commerce applications, is not commonly used in most countries at the moment. However, it is believed that with the worldwide quest for stronger security methods, particularly with regard to financial transactions, biometric technology could be embraced by most institutes in many countries.

Only a few researches have investigated the cultural factors affecting user acceptance of biometric authentication systems (Erumban and Jong 2006; Elliott, Massie et al. 2007; Chris, Kathy et al. 2009; Uzoka and Ndzinge 2009). From this perspective, this research attempted to extend the understanding of individual differences when applying TAM and UTAUT as a representative and powerful technology acceptance model to Saudi users, and to understand the acceptance process in relation to biometric authentication technology for e-commerce systems.

This thesis contributes to the literature of information systems, particularly in the field of e-transaction security. It fills a gap in the knowledge which had recognised the significance of secure biometric authentication methods, especially within the context of e-commerce and e-government, but had not yet addressed it.

The research is unique due to its cultural environment which opens up new directions for further research. This investigation was carried out in a new environment, in addition to measuring one main aspect: user acceptance.

6. 5 Managerial Implications

Based on this study, the user acceptance of using biometric technology shows that the technology has the potential to be applied in the online banking industry. The data collected and analysed by this experiment, indicated that participants believed in the benefits and the potential of this technology. The results of the path regression and SEM analysis supported both models.

The findings outline two main areas associated with the acceptance of biometric authentication systems. First, a consideration of a specific biometric technology to be implemented is important, as the new system has characteristics that may lead to unwanted acceptance behaviour. In addition, this might affect the perceived ease of

use of the biometric system in an unpredictable way, possibly requiring extensive training on the biometric technology or the use of different approaches for acceptance procedures. Second, both individuals and organisations have to secure their online services; security plays an important role in the acceptance of use of the biometric authentication system. Hence, acceptance procedures that highlight such advantages of the technology are likely to give support to improving the implementation procedure.

The strength of this research lies in derivation of its own factors from prior theoretical and empirical research. The applied measures utilised in this research were developed through an extensive review of the literature. Moreover, the study variables, which have been used in many previous technology and authentication systems within e-commerce and e-government acceptance researches, were found to have adequate reliability and validity.

From a practical standpoint, while the whole global economy is keeping its eyes on Saudi Arabia as one of the richest economies in the world, this study may present a better understanding of Saudi users' biometric technology and the factors effects their acceptance. Thus, the findings of this study would be good indicators for other cultural concerns on biometric technology acceptance.

The findings of this study are expected to present practical insights for organisations tackling difficulties in security within e-commerce applications. It is significant to conclude that education level can significantly impact biometric technology acceptance. These results, hence, present a valuable baseline for organisations to build proficient segmentation strategies based on significant individual moderating factors such as age, gender and education level.

The above mentioned results seem to present the following implications:

- The study significantly contributes to fields of information technology and information security. It adds new knowledge in this field and highlights the importance of the perceptions of users regarding biometric security technologies. It helps to determine the factors that affect the acceptance of biometric technology. Moreover, the thesis presents security technology companies and developers of information security products with information to help in the determination of what is significant to their user base when taking into account the introduction of new secure systems and products.

- This research aimed to discover findings on the characteristics, preferences, perceptions, and attitudes of user acceptance of biometric authentication systems within the online environment in Saudi Arabia. These findings will be of great relevance for e-commerce and e-government organisations targeting Saudi users or users within similar cultural background.

- The thesis provides an overall picture of relevant aspects of e-commerce and e-government, and with regard to Saudi Arabia in particular. A clear description and understanding of models and theories of technology acceptance have been synthesised from theoretical and practical viewpoints. It is hoped that the study will contribute to a wider understanding of authentication methods to secure online applications, including the usage behaviour and intention to use the biometric authentication system in the future. In addition, this study demonstrates the effects of some cultural aspects as moderators, along with other moderators, on the influence of key determinants toward behaviour intention.

- The findings of this study will assist financial and government organisations to develop strategic plans in order to enhance security and the acceptance of new secure login methods, along with biometric technology.

- Usefulness (performance expectancy) is still the most important concern in the acceptance of using the system.

- Ease of using (effort expectancy) the system, nevertheless, has an indirect effect on the development of behavioural intentions to use. That is, the easier the biometric system is to use, the more useful it is perceived to be.

- To encourage user acceptance of the system, the organisation should promote the system's usefulness more than promoting its ease of use. Focusing only on the ease of using the system would not enhance user acceptance of the system.

- With higher educational level, effort expectancy becomes more important in predicting behavioural intentions to use the system. It shows that much work needs to be done in terms of education users regarding the potential of biometrics technology.

- It has been found that social influence factor has less significantly influence on behaviour intention, although some researchers have argued for the incorporation of social influence in models of acceptance and use of new technology (Taylor and Todd 1995; Kripanont 2007). For this study, social influence had no significant influence on behaviour intention to use the system. This might be because the selected sample already had familiarity with the Internet and online banking or because most of them were educated

and were already IT literate. Based on the empirical evidence, which recommended that experience and education level moderated the relationship between social influence and behaviour intention to use, social influence becomes less important with increasing levels of education (Karahanna 1999; Kripanont 2007).

- Moreover, it has been found that facilitating conditions have no significant effect on behaviour intentions to use the system. This finding was not consistent with the study of Venkatesh et al. (2003), who recommended that facilitating conditions have a significant effect on behaviour intention. The study of Taylor et al. (1995b) showed that the presence of facilitating conditions do not necessarily persuade usage. It has been implied that the absence of facilitating resources may represent a barrier to usage and, hence, prevent the creation of intention to use. Nevertheless, our research could not find a considerable positive impact of facilitating conditions on usage behaviour. This is probably due to the fact that clients who hold an online banking account are used to similar technological applications and did not find the presence, or not, of facilitating conditions significant.

- Although gender has received great attention as a key moderating influence in many findings, such as those of Venkatesh et al. (2003), the current study results are not in accordance with the results reported in various other studies, which indicate gender differences in the acceptance of new technology as one aspect of socio-cultural differences between males and females (Venkatesh and Davis 2000; Venkatesh, Morris et al. 2003). The absence of gender differences in this study can be attributed to the fact that males and females studied tended to have received similar educational opportunities. Moreover,

similarities in self-efficacy (SE) are caused through likenesses in the understanding and the experiences of the sample considered. In support of this finding, many studies revealed that IT experience assists in narrowing the gender differences gap (Wong and Hanafi 2007).

- The findings did not reveal any significant age influence among behaviour intention to use the system.

- Self-efficacy and anxiety of using the system had minimal effects on behavioural intention to use, which is inconsistent with many previous studies, such as Ramayah and Aafaqi (2004) and Kripanont (2007). The implications for the Organizations and managers is that, as many countries applying the biometrics technology for issuing passport/visa and users travel more and are increasingly exposed to biometric technology recognition in the airports and borders, they will appear to expect the organizations and financial institutions to also utilize more secure methods to confirm identity and validate vulnerable financial and illegal transactions.

- Organisations need to think about cultural differences prior to implementing biometric authentication systems. Biometrics technology is expected to be most appropriate where there is a need for new secure authentication methods. Biometrics technology has proven to be a controversial and emotional technology, and finally, the success of biometrics technology depends on the perceptions of those individuals who will use it.

- Nevertheless, biometric authentication systems should be implemented in a way that is based on user perceptions, e.g. users could be presented with it as

a better, more convenient and better controlled option, rather than forcing them to accept this technology.

- Other information security related studies reveals the benefits that service-oriented organisations and companies might gains when using biometric technology, specifically in terms of improving operational effectiveness or security, it is the end user that is considered here, and his preference and requirements for particular processes and devices that may guide to the successful acceptance of this technology.

- Users seek convenience and seek to avoid password clutter (e.g. people write them down, they forget them, they make up easy-to-hack passwords), particularly among old and less-educated people. The IT manager might, hence, anticipate the incorporation of biometric authentication systems when obtaining a new technology.

- Adopting a biometric authentication system will also strengthen the organisation's overall level of IT security and provided means for biometric technology usage to become ingrained in the corporate culture. It has expectantly reduced password sharing, forgetting and hacking.

- Moreover, as e-payment fraud and individual security threats continue to rise, and more than ever before biometric recognition is obligatory in travel/visa requirements within many countries, it may propel more widespread implementation, in particular for those who look for perfect e-transactions. To profit from these situations, organisations and managers should seek to discover from their users the features (e.g. usefulness, security, speed of transaction, ease of use and convenience) and biometric methods (e.g.

fingerprint, face and iris recognition) that they prefer. The users may even be willing to pay additional charges to benefit from these features.

- We consider that specific contextual aspects are unique to each country and dissimilarities in the underlying acceptance of biometric technology present an improved explanation of the attitudinal differences observed across Saudi Arabia and others countries further to Hofstede's cultural dimensions.

- Within the majority of technological systems there will be specific contextual or significant concerns that influence the way they are perceived in a certain culture or society. In the same context, we do not consider biometric authentication systems to be unique. There will likely be similar contextual concerns that influence the way other systems are perceived.

- Decision making for the development or design of any technological system such as games, e-learning and e-commerce, based only on advanced models of culture are unlikely to be adequate. An evaluation of the culture and context of use is required to make sure that the system is successful when released across many markets. Organisations would do well to consider cultural differences before applying any systems.

- It was strongly suggested by Fornell et al. (1981) that the data collected from the survey should not only be tested for reliability, but also tested for construct validity. In particular, discriminant validity, which is one of the tests for construct validity, should be tested by using SEM analysis this was completed for this study.

6. 6 Lessons Learned

The aim of this section is to present final thoughts and explain lessons learned during this research.

6.6.1 The Generation of Ideas

The early thoughts of any research begin with a personal interest in the field. With more understanding, the arguments anticipated in the literature generate novel ideas and insights. This research started with initial thoughts about overall information security within e-commerce and e-government, which was driven by personal interest. This was followed by the motivation to investigate further the role of biometric authentication, due to its recognised potential as one solution to tackle security issues among e-commerce and e-government applications.

Due to gaps in the knowledge field, initial ideas of experiments emerged. At some stages in the initial experiment, author thoughts were driven by the findings achieved from the initial experiments. Consequently, it is believed that the generation of ideas begins with interest, which is formulated by argument and driven by outcomes.

6.6.2 Prior to the Experiment

Once the biometric authentication system was ready to be appraised, it was significant to consider several issues, for example, compilations, testing and experiment processes. The system had to be free from compilation errors to avoid any intrusion through the experiment. Moreover it was important to present the experimental tasks in order to complete the experiment. This provided the chance to look at the experimental process from the user's point of view. Additionally, it was helpful to carry out a trial prior to the experiment in order to recognise any possible

enhancement opportunities. Trials are useful, as they save time and effort, since the cost of trial failure is by far less than that of a main experiment (Alotaibi 2009).

Participants required a short training session based on the nature of the experiment. As the participants were involved in the training, the researcher could setup the experiment by organising the material and setting up the biometric authentication system.

6.6.3 Coding with Fingerprint Device

It was a rich experience to program and integrate an application with a fingerprint device. It is worth mentioning that not all fingerprint devices are compatible with the Griaule SDK. This can cause some problems in relation to initialisation and capturing of the fingerprint. The problem presented is in the form of rejection problems. This is called "false rejection" and occurs with any technology. This problem rarely happens (less than 0.1% of the cases), but it was important to keep this possibility in mind during the implementation stage, thus we could plan how to act if that happened. However, many false rejections occur because of an error in the registration stage, with the capture of a fingerprint. Accurate registration is the best way of avoiding false rejection.

6. 7 Limitations and Directions for Future Research

Although these results can be considered to be statistically significant, the research has some limitations that affect the reliability and validity of the findings. First, the experiment is not representative of the whole of Saudi Arabia. This study was conducted only in the main cities. To generalise the findings, we need to study the acceptance of use of biometric systems in other parts of Saudi Arabia, particularly in

rural areas (about 20% of the whole population)[19]; rural areas might have lower education levels and are served less by telecommunications and IT services than urban areas. Future comparative studies could target these areas to achieve comparative national results. The research could even be extended to include other countries operating under similar conditions to observe whether comparable results are attained and to study the impact of culture, if any, on these findings.

It is important to realise that other factors may also play an important role in user acceptance of biometric systems. Examples of such factors include trust, risk and privacy.

This thesis dealt with intentions to use the system, not actual online e-commerce behaviour. In fact, there is a general consensus between researchers that the level to which users express their intentions to use an e-commerce website is a reasonable predictor of the actual user's behaviour (Ajzen 1985; Ajzen 2005; Ajzen, Albarracín et al. 2007). Consequently, by not investigating actual e-commerce use, this potentially considerable effect remains unclear (Pavlou and Chai 2002).

6. 8 Epilogue

This thesis has confirmed a direct link with the use of biometric authentication systems and user acceptance aspects of e-commerce. The experience gained from this research recommended that the usefulness is more important than ease of use in the acceptance. Moreover, with higher education levels, effort expectancy becomes more important in predicting behavioural intentions to use the biometric system.

The research models developed in this thesis were revealed to be good predictors for the acceptance to use a biometric authentication system. The experiments developed

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[19] http://www.unicef.org/infobycountry/saudiarabia_statistics.html

for this study could be used as an indicator for the success of the acceptance of biometric technologies within e-commerce and e-government applications for both individuals and organisations. Gaining an idea of the acceptance success could be valuable in avoiding unsuccessful efforts to develop biometric authentication technology, which could prevent major financial losses.

Appendices

Appendices relate to relevant work, surveys and experimental results are included on attached CD.

REFERENCES

Agarwal, R., & Prasad, J. (1997). The role of innovation characteristics and perceived voluntariness in the acceptance of information technologies. *Decision Sciences, 28*(3), 557-582.

Ajzen, I. (1985). *From intentions to actions: A theory of planned behavior*: Heidelberg, Germany: Springer.

Ajzen, I. (2005). *Attitudes, personality, and behavior:* Milton-Keynes, England, Open University Press/McGraw- Hill.

Ajzen, I., Albarracín, D., & Hornik, R. (2007). *Prediction and change of health behavior: Applying the reasoned action approach:*Mahwah, NJ,   Lawrence Erlbaum Associates.

Ajzen, I. & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior:* Englewood Cliffs, NJ, Prentice-Hall.

Al-Diri, K. (2008). *The Effect of Visual Media Cues on Initial Trust in Business to Consumer Electronic Commerce Websites in Saudi Arabia.*School of Informatics. University of Bradford.

Al-Diri, K., Hobbs, D. & Qahawji, R. (2008). The Human Face of e-Business: Engendering Consumer Initial Trust Through the use of Images of Sales Personnel on e-Commerce Websites. *International Journal of E-Business Research, Idea Group Inc, 4*(4), 58-78.

Al-Farsy, F. (2003). *Modernity and traditional: The Saudi equation*. Beccles, Suffolk: Willing Clowes.

Al-Gahtani, S. (2001). The applicability of TAM outside North America: An empirical test in the United Kingdom. *Information Resource Management Journal, 14*(3), 37-46.

Al-Gahtani, S., Hubona, G., & Wang, J. (2007). Information technology (IT) in Saudi Arabia: Culture and the acceptance and use of IT. *Information & Management, 44*, 681-691.

Al-Harby, F., Qahwaji, R., & Kamala, M. (2008). The feasibility of biometrics authentication in e-commerce: User acceptance. *Paper presented at the IADIS International Conference WWW/Internet*, Freiburg, Germany.

Al-Saggaf, Y. (2004). The effect of online community on offline community in Saudi Arabia. *The Electronic Journal of Information Systems in Developing Countries, 16*(2), 1-16.

Al-Shehry, A., Rogerson, S., Fairweather, N., & Prior, M. (2006). The motivations for change towards e-government adoption: Case studies from Saudi Arabia. *Paper presented at the eGovernment Workshop*.

Al-Shehry, A. M. (2008). *Transformation towards E-government in The Kingdom of Saudi Arabia: Technological and Organisational Perspectives.* De Montfort University.

Al-Somali, S. A., Gholami, R., & Clegg, B. (2008). An investigation into the acceptance of online banking in Saudi Arabia. *Technovation, In Press, Corrected Proof.*

Al-Sudairy, T. (1994). *A strategic approach to developing iInformation systems in the Kingdom of Saudi Arabia.* University of London, London.

Aladwani, A., & Palvia, P. (2002). Developing and validating an instrument for measuring user-perceived web quality. *Information & Management, 39*(6), 467-476.

Alawadhi, S., & Morris, A. (2008). The use of the UTAUT model in the adoption of e-government services in Kuwait. *Paper presented at the 41st Hawaii International Conference on System Sciences*.

Alexander, D. (2008). *Learning, Thinking, Buying, Using: Contextual Effects on Consumers' Adoption of Really New Products.*Department of Business Administration, Duke University.

Alotaibi, M. (2009). *Electronic Customer Knowledge Management Systems: a multimodal interaction approach.* University of Bradford, Bradford, UK.

Almogbil, A. (2005). *Security, perceptions and practices: Challenges facing adoption of online banking in Saudi Arabia.* The George Washington University, Washington D.C.

Alsajjan, B. (2008). Internet banking acceptance model across cultures: The case of England and Saudi Arabia. *Paper presented at the PhD Symposium, 21-22 May 2008*. Brunel Business School, Brunel University, UK.

Anandarajan, M., Simmers, C., & Igbaria, M. (2000). An exploratory investigation of the antecedent and impact of internet usage: an individual perspective. *Behaviour & information technology 19*(1), 69-85.

Anderson, C. R., Helriegel, D., & Slocum, J. W. (1977). Managerial response to environmentally induced stress. *Academy of Management Journal, 20*(2), 260-272.

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin, 103*, 423-441.

Anderson, K. (2001). Internet use among college students: An exploratory study. *J Am Coll Health 50*, 21-26.

Antonella De, A. & Leantros, K. (2006). Globalisation vs. localisation in e-commerce: cultural-aware interaction design. *Proceedings of the working conference on Advanced visual interfaces.* Venezia, Italy.

Aziz, M., Riley, C. & Johnson, G. (2008). Usability challenges in emerging markets. *The international conference on enterprise and information systems.* Barcelona, Spain.

Ashbourn, J. (2000). *Biometrics: Advanced identity verification: The complete guide*. London: Springer.

Atkinson, M., & Kydd, C. (1997). Individual characteristics associated with world wide web use: An empirical study of playfulness and motivation. *The Data Base for Advances in Information Systems 28*(2).

Bandura, A. (1977a). Self-efficacy: Towards a unifying theory of behavioral change. *Psychological Review, 84*, 191-215.

Barua, A. C., & Whinston, A. B. (1996). Creating a collaboratory in cyberspace: Theoretical foundation and an implementation. *Journal of Organizational Computing, 5*(4), 417-442.

Benyon, D., Turner, P. & Turner, S. (2005). *Designing Interactive Systems:* Harlow, England Addison-Wesley.

Broniarczyk, S., & Gershoff, A. (1997). Meaningless differentiation revisited. *Advances in Consumer Research, 24*, 223-228.

Broos, A. (2005). Gender and information and communication technologies (IT) anxiety: male self assurance and female hesitation. *CyberPsychology and Behaviour, 8*(1), 21-31.

Campueau, D., & Higgins, C. (1995). Computer self efficacy: Development of a measure and initial Test. *MIS Quarterly, 19*(2), 189-211.

Chen, C., Fan, Y.-W., & Farn, C.-K. (2007). Predicting electronic toll collection service adoption: An integration of the technology acceptance model and the theory of planned behavior. *Transportation Research Part C: Emerging Technologies, 15*(5), 300-311.

Chen, L., Gillenson, M., & Sherrell, D. (2002). Enticing online consumers: An extended technology acceptance perspective. *Information and Management, 39*, 705-719.

Cheng, J. M.-S., Sheen, G.-J., & Lou, G.-C. (2006). Consumer acceptance of the internet as a channel of distribution in Taiwan – A channel function perspective. *Technovation, 26*(7), 856-864.

Chin, W. (1998). Issues and opinion on structural equation modeling. *MIS Quarterly, 22*(1), 7-16.

Chowdhury, M. and R. Islam (2003). Critical Factor in Consumer Perceptions: A Cognitive Approach. *Journal of Business Research 5*,1-18.

Chris, R., Kathy, B., Graham, J., Benyon, D. (2009). Culture & biometrics: regional differences in the perception of biometric authentication technologies. *AI Soc. 24*(3), 295-306.

Churchill, A. G. J. (1999). *Marketing Research: Methodological Foundation* (7th Ed.). Hinsdale, IL: The Dryden Press.

Churchill, G. (1979). A paradigm for developing better measures of marketing constructs. *Journal of Marketing Research 16*(1), 64-73.

Chwelos, P., Benbasat, I., & Dexter, A. (2001). Research report: empirical test of an EDI adoption model. *Information System Research, 12*(3), 304-321.

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences:* Hillsdale, NJ, Erlbaum.

Coventry, L., De Angeli, A., & Johnson, G. (2003). Honest it's me! self service verification. *Paper presented at the CHI Workshop on Human-Computer Interaction, Adoption Study and Security Systems*.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika, 31*.

Davis, F. (1986). *Technology acceptance model for empirically testing new end-user information systems: Theory and results.* Massachusetts Institute of Technology.

Davis, F. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly, 13*(3), 319-340.

Davis, F. (1993). User acceptance of information technology: system characteristics, user perceptions and behavioral impacts. *International Journal of Man–Machine Studies, 38*, 475-487.

Davis, F., Bagozzi, R., & Warshaw, P. (1989). Extrinsic and intrinsic motivation to use computers in the workplace. *Journal of Applied Social Psychology 22*(13), 1111-1132.

Davis, F., Bagozzi, R., & Warshaw, P. (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science, 35*(8), 982-1003.

Didero, M., & Gareis, K. (2008). Differences in Innovation Culture Across Europe. Transformative Use of ICT in EU Regions. Transform, Germany.

Dillon, A., & Morris, M. (1996). *User acceptance of new information technology: Theories and models* (Eds. Vol. 31). Medford NJ: Information Today.

Duncan, O. D. (1986). Path analysis: Sociological example. *The American Journal of Sociology, 72*(1), 1-16.

Elliott, S., Massie, S. & Mathias, S. (2007). The perception of biometrics technology: A survey. *IEEE Workshop on Automatic Identification Advanced Technologies,* Alghero.

Erumban, A. & S. Jong (2006). Cross-country differences in ICT adoption: A consequence of Culture?. *Journal of World Business 41,* 302-314.

Everdingen, Y. & E. Waarts (2003). The effect of national culture on the   adoption of innovations. *Marketing Letter 14*(3), 217-232.

Fishbein, M. & Ajzen, I. (2010). *Predicting and changing behavior: The reasoned action approach.* New York, Psychology Press (Taylor & Francis).

Fogg, B. J. (2002). Stanford Guidelines for Web Credibility A Research Summary from the Stanford Persuasive Technology Lab. Retrieved from http://www.webcredibility.org/guidelines, April 3, 2008.

Fornell, C., & Larcker, D. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*, 39-50.

Forsythe, S., & Chun, L. (2000). Exploring Gender Differences in Online Behavior. *Paper presented at the International Textile and Apparel Association (ITAA).*

Fox, R. (2002). News track. *Commun. ACM, 45*(10), 9-10.

Friedman, L., & Wall, M. (2005). Graphical views of suppression and multicollinearity in multiple linear regression. *The American Statistician, 59*(2), 127-136.

Fronell, C. R. (1987). *A second generation of multivariate analysis: classification of methods and implications for marketing research.* Chicago, IL: American Marketing Association.

Furnell, S., Dowland, P., Illingworth, H., & Reynolds, P. (2000). Authentication and supervision: A survey of user attitudes. *Computers & Security, 19*, 529-539.

Furnell, S., & Evangelatos, K. (2007). Public awareness and perceptions of biometrics. *Computer Fraud and Security, 1*, 8-13.

Gefen, D. (2003). TAM or just plain habit: A look at experienced online shoppers. *Journal of End User Computing 15*(3), 1-13.

Gefen, D., & Straub, D. (1997). Gender differences in the perception and use of e-mail: An extension to the Technology Acceptance Model. *MIS Quarterly, 21*(4), 389-400.

Gefen, D. & Straub, D. (2004). Consumer trust in B2C e-Commerce and the importance of social presence: experiments in e-Products and e-Services. *Omega 32*(6), 407-424.

Giesing, I. (2003). *User perceptions related to identification through biometrics within electronic business.* University of Pretoria.

Gong, M., Xu, Y., & Yu, Y. (2004). An enhanced technology acceptance model for Web-based learning. *Journal of Information Systems Education, 15*(4), 365-373.

Griffiths, M. (1999). Internet addiction: fact or fiction. *The Psychologist, 12*(5), 247-250.

Hair, J., Black, W., Babin, B., Anderson, R., & Tatham, R. (2006). *Multivariate data analysis* (6th Ed.). Upper Saddle River, New Jersey: Pearson Education, Inc.

Hair, J. R., Anderson, R. E., Tatham, R. L., & Black, W. C. (1992). *Multi-Variate Data Analysis with Readings*. New York: Macmillan.

Herman, A. (2002). Major bank signs up for digital signature verification technology. *Biometric Technology Today, 10*, January, 2002.

Hernández-Ortega, B., Jiménez-Martínez, J., & José Martín-De Hoyos, M. (2008). B2C e-commerce acceptance: The moderating effect of gender. *Communications of the IBIMA, 6*(16), 104-112.

Hoeffler, S. (2003). Measuring Preferences for Really New Products. *Journal of Marketing Research 40,* 406-420.

Hoeffler, S., Page Moreau, P. (2006). *Building Evolutionary Bridges for Revolutionary Products.* Nashville, Tennessee.

Hofstede, G. (1980). *Culture's consequences: International differences in work-related values*. Beverly Hills, CA: Sage.

Hofstede, G. (1990). *Cultures and organizations: Software of the mind.* New York, McGraw-Hill.

Hofstede, G. (2001). *Culture's consequences: Comparing values, behaviors. Institutions and organizations across nations* (2nd Ed.). London: Sage.

Hong, W., Thong, J. Y. L., Wong, W. M., & Tam, K. Y. (2002). Determinants of user acceptance of digital libraries: An empirical examination of individual differences and system characteristics. *Journal of Management Information Systems, 18*(3), 97-124.

Horton, R. P., Buck, T., Waterson, P. E., & Clegg, C. W. (2001). Explaining intranet use with the technology acceptance model. *J Inf Technol, 16*(4), 237-249.

Hossain, E. (2007). An Evaluation of Brands Image, Product Attributes and Perceived Quality of a Selected Consumer Non-durable Product. *Administration and Management Review 19*(2), 47-63.

Igbaria, M., & Chakrabarti, A. (1990). Computer Anxiety and Attitudes Towards Microcomputer Use. *Behavior and Information Technology, 9*(3), 229-241.

Igbaria, M., & Zinatelli, N. (1997). Personal computing acceptance factors in small firms: A structural equation model. *MIS Quarterly, 21*(3), 279-305.

Ilie, V., Van Slyke, C., Green, G., & Lou, H. (2005). Gender Differences in Perceptions and Use of Communication Technologies: A Diffusion of Innovation Approach. *Information Resources Management Journal, 18*(3), 13-31.

Ingram, J., Patchin, J., Huebner, B., McCluskey, J., & Bynum, T. (2007). Family life, peer associations, and serious delinquency: A path analysis. *Criminal Justice Review, 32*(4), 380-400.

Jain, A. (2004). Biometric recognition: How do I know who you are? *Paper presented at the Signal Processing and Communications Applications Conference Proceedings of the 12th IEEE.*

Jain, A., Hong, L., & Pankanti, S. (2000). Biometric identification. *Communications of the ACM, 43*(2), 91-98.

James, T., Prim, T., Boswell, K., Reithel, B., & Barkhi, R. (2006). Determining the intention to use biometric devices: An application and extension of the Technology Acceptance Model. *Journal of Organizational and End-User Computing, 18*(3), 1-24.

Kamppuri, M., Bednarik, R. & Tukiainen, M. (2006). The expanding focus of HCI: Case culture. *Proceedings of NordiCHI.* Oslo, Norway.

Karahanna, E., Straub, D. W., & Chervany, N. L. (1999). Information technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs. *MIS Quarterly, 23*(2), 183-213.

Kenny, D. A. (1979). *Correlation and Causality*. New York: Wiley.

Koufaris, M. (2002). Applying the technology acceptance model and flow theory to online consumer behavior. *Information Systems Research, 13*(2), 205-223.

Kripanont, N. (2007). *Examining a Technology Acceptance Model of Internet Usage by Academics within Thai Business Schools*. Victoria University, Melbourne, Australia.

Land, K. C. (1969). *Principles of path analysis*. San Francisco: Jossey-Bass.

Lassar, W. M., Manolis, C., & Lassar, S. S. (2005). The relationship between consumer innovativeness, personal characteristics, and online banking adoption. *International Journal of Bank Marketing, 23*(2), 176-199.

Laurie, A. J., Annie, I. A., & Julia, B. E. (2007). Towards understanding user perceptions of authentication technologies. *Paper presented at the Proceedings of the 2007 ACM Workshop on Privacy in Electronic Society*.

Laux, D., Tao, L. & Triplett, J. (2007). Customer acceptance of biometric technology in the hotel industry.

Leedy, P. D., & Omrod, J. E. (2001). *Practical Research, Planning and Design* (7th Ed.). New Jersey: Prentice-Hall, Inc.

Lehmann, D. (1999). Consumer behavior and Y2K. *Journal of Marketing Channels, 63*(5), 14-18.

Li, C. C. (1975). *Path analysis: A primer*. Pacific Grove, CA: The Boxwood Press.

Liao, S., Shao, Y., Wang, H., & Chen, A. (1999). The adoption of virtual banking: An empirical study. *International Journal of Information Management 19*, 63-74.

Likert, R. (1932). A Technique for the Measurement of Attitudes. *Archives of Psychology, 140*, 1-55.

Lin, J. C. C., & Lu, H. P. (2000). Towards an understanding of the behavioural intention to use a web site. *International Journal of Information Management 20*, 197-208.

Liu, S., & Silverman, M. (2001). A practical guide to biometric security technology. *IT Professional Archive, 3*(1), January, 2001.

Loo, W. H., Yeow, P. H. P., & Chong, S. C. (2009). User acceptance of Malaysian government multipurpose smartcard applications. *Government Information Quarterly, 26*(2), 358-367.

Lowry, G. (2002). Modeling user acceptance of building management systems. *Automation in Construction, 11*, 695-705.

Lu, H. P., & Yeh, D. C. (1998). Enterprise's perceptions on business process re-engineering: A path analytic model. *OMEGA International Journal of Management Science, 26*(1), 17-27.

Mao, E. and P. Palvia (2006). Testing an Extended Model of IT Acceptance in the Chinese Cultural Context. *ACM SIGMIS Database The DATA BASE for Advances in Information Systems 37*(2), 20-32.

Malhotra. Y., & Galletta, D. F. (1999). Extending the Technology Acceptance Model to account for social influence. Theoretical Bases and Empirical Validation. *Hawaii International Conference on Systems Sciences,* 6-14.

Malhotra. Y., & Galletta, D. F. (2004). Building systems that users want to use. *Communications of the ACM, 47*, 88-94.

Mathieson, K., Peacock, E., & Chin, W. (2001). Extending the technology acceptance model: The influence of perceived user resources. *The Data Base for Advances in Information Systems, 32*, 86-112.

McCoy, S., Galletta, D., King, W. (2007). Applying TAM across cultures: the need for caution. *European Journal of Information Systems 16*(1), 81-90.

Meyers-Levy, J., & Tybout, A. (1989). Schema congruity as a basis for product evaluation. *The Journal of Consumer Research, 16*(1), 39-54.

Mohammad, M. & Oorschot, P. (2008). Security and usability: the gap in real-world online banking. *Proceedings of the 2007 Workshop on New Security Paradigms*. New Hampshire, ACM.

Monsuwe´, T. P., Perea, T., Dellaert, B. G., & Ruyter, K. D. (2004). What drives consumers to shop online? A literature review. *International Journal of Service Industry Management, 15*(1), 102-121.

Montgomery, A., Shibo, L., Kannan, S., & John, C. L. (2004). Modeling online browsing and path analysis using clickstream data. *Marketing Science, 4*(4), 579-595.

Moon, J., & Kim, Y. (2001). Extending the TAM for a world-wide-web context. *Information & Management 38*, 217-230.

Mordini, E., & Petrini, C. (2007). Ethical and social implications of biometric identification technology. *Ann Ist Super Sanità, 43*(1), 5-11.

Morris, M. G., Venkatesh, V., & Ackermann, P. L. (2005). Gender and age differences in employee decisions about new technology: an extension to the theory of planned behavior. *IEEE Transactions on Engineering Management, 52*(1), 69-84.

Mukherjee, A., & Hoyer, W. (2001). The effect of novel attributes on product evaluation. *The Journal of Consumer Research, 28*(3), 462-472.

Myers, M., & Tan, F. (2002). Beyond Models of National Culture in Information Systems Research. *Journal of Global Information Management, 10*(1), 24-32.

Mythily, S., Qiu, S. & Winslow, M. (2008). Prevalence and correlates of excessive Internet use among youth in Singapore. *Ann Acad Med Singapore 37*(1), 9-14.

Napaporn, K. (2007). *Examining a Technology Acceptance Model of Internet Usage by Academics within Thai Business Schools.* Victoria University, Melbourne, Australia.

Naumann, E., Jackson, J. (2001). How to implement a customer satisfaction program. *Bus Horiz 44*(1), 37.

Nielsen, J. (2001). *Designing for Web Usability*. Indianapolis, New Riders Publications.

Niemz, K., Griffiths, M. & Banyard, P. (2005). Prevalence of pathological Internet use among university students and correlations with self-esteem, The General Health Questionnaire (GHQ), and disinhibition. *Cyberpsychol Behav 8*(6), 562-570.

Nowlis, S., & Simonson, I. (1996). The effect of new product features on brand choice. *Journal of Marketing Research, 32*, 36-46.

Nunnally, J. (1978). *Psychometric theory* (2nd ed.). New York: McGraw-Hill.

O'Gorman, L. (2003). Comparing passwords, tokens, and biometrics for user authentication. *Paper presented at the Proceedings of the IEEE.*

Ong, C.-S., & Lai, J.-Y. (2006). Gender differences in perceptions and relationships among dominants of e-learning acceptance. *Computers in Human Behavior, 22*(5), 816-829.

Ong, C.-S., Lai, J.-Y., & Wang, Y.-S. (2004). Factors affecting engineers' acceptance of asynchronous e-learning systems in high-tech companies. *Information & Management, 41*(6), 795-804.

Oppenheim, A. (1992). *Questionnaire design, interviewing and attitude measurement.* London, Pinter Publishers.

Oshlyansky, L., Cairns, P., & Thimbleby, H. (2007). Validating the Unified Theory of Acceptance and Use of Technology (UTAUT) tool cross-culturally. *Paper presented at the HCI 2007 the 21st British HCI Group Annual Conference.*

Pallant, J. (2005). *SPSS Survival Manual.* United Kingdom: Open University Press.

Park, J., Yang, S., & Xinran, L. (2007). Adoption of mobile technologies for Chinese consumers. *Journal of Electronic Commerce Research, 31*(3), 196-206.

Parolia, N., Goodman, S., Li, Y., & Jiang, J. J. (2007). Mediators between coordination and IS project performance. *Information & Management, 44*(7), 635-645.

Paul, A. P. (2003). Consumer acceptance of electronic commerce: Integrating trust and risk with the Technology Acceptance Model. *International Journal of Electronic Commerce, 7*, 101-134. M. E. Sharpe, Inc.

Paul, B., & Mark, C. (2001). Critical path analysis of TCP transactions. *IEEE Press, 9*, 238-248.

Pavlou, P. A., & Chai, L. (2002). What drives electronic commerce across cultures? A cross-cultural empirical investigation of the theory of planned behavior. *Journal of Electronic Commerce Research, 3*(4), 240-253.

Peter, J. P. (1979). Reliability: A review of psychometric basics and recent marketing practices. *Journal of Marketing Research, 16*, 6-7.

Pikkarainen, T., Pikkarainen, K., Karjaluoto, H., & Pahnila, S. (2004). Consumer acceptance of online banking: An extension of the technology acceptance model. *Internet Research, 14*(3), 224-235.

Plouffe, C. R., Hulland, J. S., & Vandenbosch, M. (2001). Research report: Richness versus parsimony in modelling technology adoption decisions-understanding merchant adoption of a smart card-based payment system. *Information Systems Research, 12*(2), 208-222.

Png, I., Tan, B., & Wee, K. (2001). Dimensions of national culture and corporate adoption of IT infrastructure. *IEEE Transactions on Engineering Management, 48*.

Prabhakar, S., S. Pankanti, S., & Jain, A. K. (2003). Biometrics recognition: Security and privacy concerns. *IEEE Security & Privacy, 1*(2), 33-42.

Prakash, K. (2009). Deploying Systems Approach to Manage Employee Resistance to Change in Library and Information Centres. *International Conference on Academic Libraries (ICAL-2009)* Delhi, INDIA.

Qualls, W. (1987). Household decision behavior: The impact of husbands' and wives sex role orientation. *Journal of Consumer Research, 14*, 264-279.

Ramayah, T., & Aafaqi, B. (2004). Role of self-efficacy in e-library usage among students of a public university in Malaysia. *Malaysian Journal of Library & Information Science, 19*(1), 39-57.

Ravi, P., Richard, H., & John, H. (2007). The relationship between individual differences, culture, anxiety, computer self-efficacy and user performance. *Int. J. Inf. Syst. Chang. Manage. 2*(2),125-138.

Reid, P., & Magnuson, G. (2005). EDS Canada: Privacy & Identity Management Survey. *www.eds.com.* Retrieved 5 October 2007.

Robinson, P., Shaver, R., & Wrightsman, S. (1991a). Criteria for scale selection and evaluation. *Paper presented at the Measures of personality and social psychological attitudes, Academic Press*, New York.

Rowe, D. C., & Jacobson, K. C. (1999). Genetic and Environmental Influences on Vocabulary IQ: Parental Education Level as Moderator. *Child Development, 70*(5), 1151.

Sadiq, M., Sait, K., Al-Tawil, K., & Syed, H. (2004). E-commerce in Saudi Arabia: Adoption and perspectives. *Australian Journal of Information Systems (AJIS), 12*(1).

Schmidt, M., Das, D., Kumar, V., & Bekkering, E. (2008). *A Proposed Study and Analysis of User Perceptions of Biometric Acceptance* Paper presented at the Proceedings of the 39th Annual Meeting of the Decision Sciences Institute.

Sekaran, U. (2000). *Research methods for business: A skill-building approach* (3rd Ed.). New York: John Wiley and Sons.

Sekaran, U. (2003). *Research methods for business: A skill-building approach* (4th Ed.). new York: John Wiley & Sons, Inc.

Shashaani, L. (1994). Gender differences in computer experience and its influence on computer attitudes. *Journal of Educational Computing Research, 11*(4), 347-367.

Simon, J. (2001). The impact of culture and gender on web sites: an empirical study. *The Data Base for Advances in Information Systems 32*(1), 18-37.

Snelders, D. & Schoormans, J. (2000). Are Abstract Product Qualifications More Subjective? A test of the Relation between Abstraction Level and Opposite Naming. *Advances in Consumer Research 26,*584-587.

Songmei, H. (2006). Effects of alphanumerical display formatting on search time among Chinese and American users. *CHI '06 extended abstracts on Human factors in computing systems.* Montréal, Québec, Canada.

Stanton, N., Salmon, P., Baber, G. & Jenkins, D. (2005). Human Factors Methods; A Practical Guide For Engineering and Design. Aldershot, Hampshire, Ashgate Publishing Limited.

Stevens, S. S. (1946). On the Theory of Scales of Measurement. *Science, 103*, 677-680.

Stewart, O. T. & Chakraborty, J. (2008). Did Hofstede Get it Right? Enculturating Automatic Speech Recognition Systems. *Proceedings of International Conference on Intelligent User Interfaces.* Canary Islands, Spain.

Straub, D., Keil, M., & Brenner, W. (1998). Testing the technology acceptance model across cultures: A three country study. *Information & Management, 33*(1), 1-11.

Straughn, R., & Albers-Miller, N. (2001). An international investigation of cultural and demographic effects of domestic retail loyalty. *International Marketing Review, 18*(5), 521-541.

Strickland, L. S., & Hunt, L. E. (2005). Technology, Security, and individual privacy: New tools, New threats, and new public perceptions. *Journal of the American Society for Information Science and Technology, 56*, 221-234.

Sun, H. (2002). Exploring Cultural Usability. *IEEE International Professional Communication Conference.* Portland, OR.

Supriya, S. (2006). The social dimensions of the security of Internet banking. *J. Theor. Appl. Electron. Commer. Res. 1(2), 72-78.*

Szajna, B. (1994). Software evaluation and choice: Predictive evaluation of the technology acceptance instrument. *MIS Quarterly, 18*(3), 319-324.

Tamilia, R. D., Senecal, S., & Corriveau, G. (2002). Conventional channels of distribution and electronic intermediaries: A functional analysis. *Journal of Marketing Channels, 9*(3,4), 27-35.

Taylor, S., & Todd, P. A. (1995). Understanding information technology usage: a test of competing models. *Information Systems Research, 6*(2), 144-176.

Thomas, P., & Taskov, K. (2007). Extending gender differences and technology acceptance to a database environment. *Paper presented at the Proceedings of the 6th Annual ISOnEworld Conference*, Las Vegas, Nevada.

Triandis, H. C. (1977). *Interpersonal behavior.* Monterey, CA, Brooks/Cole.

Triandis, H. C. (1980). Values, attitudes, and interpersonal behavior. In H. E. Howe & M. M. Page (Eds.), *Nebraska Symposium on Motivation 1979* (195-259). Lincoln, Nebraska: University of Nebraska Press.

Triplett, J., Laux, D., Luse, D., Tao, L.S. (2009). Customer acceptance of biometric technology in the hotel industry. *Proceedings of the 4th MWAIS Conference, Paper 27.*

Uzoka, F.-M. E., & Ndzinge, T. (2009). Empirical analysis of biometric technology adoption and acceptance in Botswana. *Journal of Systems and Software, 82*(9), 1550-1564.

Vassiliev, A. (2000). *The history of Saudi Arabia.* New York: New York University Press.

Veal, A. J. (2005). *Business research methods: A managerial approach* (2nd Ed.). Australia: Pearson Education Australia.

Venkatesh, V. (2000). Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model. *Information Systems Research, 11*(4), 342-365.

Venkatesh, V., & Davis, F. D. (1996). A model of the antecedents of perceived ease of use: Development and test. *Decision Sciences, 27*(3), 181-451.

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the Technology Acceptance Model: Four longitudinal field studies. *Management Science, 46*(2), 186-204.

Venkatesh, V., & Morris, M. (2000). Why don't men ever stop to ask for directions? Gender, social influence, and their role in technology acceptance and usage behaviour. *MIS Quarterly, 24*(1), 115-139.

Venkatesh, V., Morris, M., Davis, G., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly, 27*(3), 425-478.

Vrontis, D., Thrassou, A. & Melanthiou, Y. (2007). A contemporary higher education student-choice model for developed countries. *Journal of Business Research 60*(9), 979-989.

Wang, Y., Wang, Y., Lin, H., & Tang, T. (2003). Determinants of user acceptance of internet banking: An empirical study. *International Journal of Service Industry Management, 14*(5), 501-519.

Wayman, J. L., & Alyea, L. (2000). *Picking the best biometric for your applications. National biometric test center collected works.* San Jose: National Biometric Test Centre.

Werts, C. E., & Linn, R. L. (1960). Path analysis: Psychological examples. *Psychological Bulletin, 74*(2), 194-212.

Wheeler, D., (2004). The Internet in the Arab World: Digital Divides and Cultural Connections, Royal Institute for Inter-Faith Studies (BRIIFS). Retreived from

<http://www.riifs.org/guest/lecture_text/Internet_n_arabworld_all_txt.htm, March 14, 2010.

Wong, S., & Hanafi, A. (2007). Gender differences in attitudes towards information technology among Malaysian student teachers. *Educational Technology and Society, 10*(2), 158-169.

Woodward, J. D., Webb, K. W., Newton, E. M., Bradley, M., & Rubenson, D. (2001). *Army biometric applications*: RAND Corporation.

Yi, M. Y., Jackson, J. D., Park, J. S., & Probst, J. (2006). Understanding information technology acceptance by individual professionals: toward an integrative view. *Information and Management, 43*(3), 350-363.

Yu-Lung, W., Yu-Hui, T., & Pei-Chi, Y. (2007). Using UTAUT to explore the behavior of 3G mobile communication users. *Paper presented at the 2007 IEEE International Conference on Industrial Engineering and Engineering Management.*

Zakaria, Z. (2001). *Factors related to information technology implementation in the Malaysian Ministry of Education Polytechnic.* Virginia Polytechnic Institute and State University, VA, USA.

Zakour, A. (2009). Information Technology Acceptance across Cultures. In C. S. Ang and P. Zaphiris (Eds.) *Human Computer Interaction: Concepts, Methodologies, Tools, and Applications.* PA, USA, IGI Global. *1,*132-153.

Zanna, M. P., & Rempel, J. K. (1988). *Attitudes: A new look at an old concept.* New York: Cambridge University Press.

Zhang, D. (2000). *Automated Biometrics: Technologies and Systems* Norwell, MA: Kluwer Academic Publishers.