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Privacy in the context of Smart Home Environments

Based upon a survey of experts

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Master's Thesis

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Abstract

Smart environments, particularly smart homes have become an increasingly popular topic for research and real world implementations. Despite the popularity of this topic, there is a lack of tools to enable inhabitants of smart environments to perceive which kind of data smart devices generate and to make inhabitants aware of who is accessing their personal information and the purpose for accessing this information. These issues have caused privacy concerns among inhabitants of smart environments – who would like to ensure their personal information is only utilized for their benefits, rather than being used for malicious purposes. Therefore, smart home environments motivate the need for privacy awareness tools to help inhabitants to better understand the privacy implications when their personal information is misused. To address this problem, this thesis suggests guidelines for the design of privacy awareness tools.

A literature review evaluated instruments to conduct research about privacy concerns. The Internet Users' Information Privacy Concerns (IUIPC) framework from Malhotra, Kim, and Agarwal was selected for the empirical part of this thesis project because it is one of the most reliable models developed to measure privacy concerns at the individual level. Quantitative data was gathered through a survey based on this framework. Data collected from 30 experts in the field of study was analyzed using linear regression analysis techniques and principal component analysis.

These survey results lead to a set of guidelines that could guide designers and service providers as to what aspects of privacy concerns they should consider and what they should concentrate on when designing privacy awareness tools for ubiquitous computing systems, such as a smart home.

Keywords

Privacy, Smart environments, Smart Homes, Ubiquitous Computing, Users' Privacy Concerns, IUIPC Model

Sammanfattning

Intelligenta omgivningar och framförallt smarta hem har kommit att bli ett popular forskning samt impementationsområde. Trots ämnets popularitet är det en brist på verktyg som låter personer i dessa intelligenta omgivningar att förstå vilken typ av data som genereras av de smarta apparaterna, att de förstår vem som får tillgång till deras privatinformation och syftet till att informationen används. Dessa problem leder till påverkar användarintegriteten för personerna i de intelligenta omgivningarna. Personerna vill försäkra sig om att deras privatinformation används till deras fördel och inte missbrukas. Det finns ett behov av integretetsverktyg som kan hjälpa personerna att få en bättre förståelse över hur deras integritet påverkas när deras privatinformation missbrukas. Den här rapporten syftar till att behandla detta problem genom att ta fram riktlinjer baserade på användarnas oro kring deras integritet.

En litteraturstudie genomfördes för att utvärderade metoder för att genomföra forskning på användarintegritet. Ramverket Internet Users' Information Privacy Concerns (IUIPC) från Malhotra, Kim, och Agarwal valdes eftersom det var den en av de mest pålitliga modellen för att mäta den individuella oron kring integriteten hos användarna. Kvantitativ data samlades in genom ett formulär baserat på IUIPC ramverket. Datan samlades in under den empiriska fasen utav 30 experter inom forskningsområdet. Linjär regression och principalkomponentanalys användes för att analysera datan från undersökningen.

Resultatet från undersökningen diskuterades med målet att tillhandahålla riktlinjer till utvecklare och tjänsteleverantörer, om vilka integritets aspecter vilket bör övervägas samt focusera på vid utveckling av integretetsverktyg för ubika datasystem.

Nyckelord

Integritet, Intelligenta omgivningar, Smart hem, Ubika datasystem,
Användarintegretet, IUIPC ramverket.

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List of acronyms and abbreviations

6LoWPAN	IPv6 over Low power Wireless Personal Area Networks.
ACM	Association for Computing Machinery
AdLoc	Advertising Location
AI	Artificial Intelligence
AS	Autonomous System
Auto-ID	Automatic identification
AW	Awareness
CFIP	Concerns for Information Privacy
CL	Control
DASH7	Developers' Alliance for Standards Harmonization of ISO 18000-7
DB	Database
DMA	Direct Marketing Association
DTI	Department of Trade and Industry (U.K.)
ESM	Experience Sampling Method
FIPPs	Fair Information Practice Principles
GDP	Gross Domestic Product
GPS	Global Positioning System
HA	Home Automation
HCI	Human Computer Interaction
HG	Home Gateway
HGI	Home Gateway Initiative
HW	Hardware
ICT	Information and Communication Technology
IEEE	Institute of Electrical and Electronics Engineers
iHCI	Implicit Human Computer Interaction
INT	Intrusion
IPTV	Internet Protocol Television
IT	Information Technology
ITE	Intention
IUIPC	Internet Users' Information Privacy Concerns
JSTOR	Journal Storage
KMO	Kaiser-Meyer-Olki Measure of Sampling Adequacy
KNX	Technology proposed by KNX Association
LBS	Location Base Services
LISREL	Linear Structural Relation
M2M	Machine to Machine
MSA	Measure of Sampling Adequacy
SPSS	Statistical Package for the Social Sciences
OCR	Optical Character Recognition
Paws	Privacy Awareness System
PC	Personal Computer
PCA	Principal Component Analysis
PLS	Partial Least Square
QoS	Quality of Services
RFID	Radio Frequency Identification

RI	Risk
SC	Social Contract Theory
SEM	Structural Equation Modeling
SICS	Swedish Institute of Computer Sciences
SUR	Surveillance
SW	Software
TAM	Technology acceptance model
TR	Trust
TRA	Theory of Reasoned Action
Ubicomp	Ubiquitous Computing
UN	Unauthorized Second Use
US	Usefulness
USD	United States Dollar
VoIP	Voice over IP
WAN	Wide Area Network
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability Microwave Access
WWW	World Wide Web

1 Introduction

This master's thesis concerns privacy and autonomy in the context of ubiquitous computing, particularly in smart home environments. This chapter clearly states the problem and gives a conceptual overview of smart home environments, privacy, and users' privacy concerns. Chapter 2 provides detailed background information. Users' privacy concerns in smart home environments were evaluated through a survey based on the Internet Users' Information Privacy Concerns (IUIPC) framework[*]. This survey served as the basis for a set of proposed guidelines whose purpose is to help designers or services providers create better tools and services that ease inhabitant's privacy concerns, as well as to help inhabitants of smart home environments to improve their understanding of their privacy and autonomy. The thesis concludes with a presentation of conclusions and suggestions for future work.

1.1 General introduction to the area

Increasingly, physical objects have gained the ability to emit data about their environment. With the increasing adoption of sensors, intelligent devices, and wireless networks, houses are becoming smart home environments. In these environments highly specialized, intelligent devices collaborate, process, share, and make deductions from the data captured about the state of the house and the activities of its residents (and visitors) [1]. Cook, et al. [2, 3] believe that by living in a smart home environment its residents can increase the quality of their lives. Although on the surface this development appears to be a good thing, it could also reduce the individuals' security and privacy due to the risks of sensitive personal information being collected and spread.

1.2 Problem definition

In today's smart home environments there is a lack of mechanisms to enable inhabitants to perceive and control the data generated by smart devices in their home [4]. Intelligent devices may acquire a vast amount of sensitive personal data. The collection and processing of this data raises privacy concerns about how the individuals living in such a smart home environment can ensure that this data is shared only for their own good, rather than be collected, shared, used, or maliciously disclosed for purposes that would violate their autonomy and privacy. Moreover, these intelligent devices are expected to collectively generate very large amounts of data – usually *without* the users' consent or their complete awareness of the implications of using such devices [5]. In current smart home environments, individuals are unaware that they are surrounded by a system with sensing capabilities and they are unable to monitor what personal information or other data has been collected nor are they able to effectively control this data.

The invisibility of smart devices also represents another issue, because these devices generally have limited or no user interfaces to inform users of the amount of data collected and how it is used [4]. Even when user interfaces are available,

[*] See Section 3.7 for details of the IUIPC framework.

they present the information to the user in a format that the user is unlikely to understand – typically raw datasets. Moreover, we believe that the currently available tools that have been designed to provide privacy awareness are not designed taking into account users' privacy concerns. Therefore, the smart home inhabitants' privacy and autonomy might be compromised.

1.3 Goals

In order to develop a solution for the problem stated in previous section we explore the nature of users' concerns about information privacy within smart home environments and discussed the results to serve as a set of guidelines. The rationale behind these guidelines is to contribute to the creation of suitable privacy awareness systems for smart home environments that address inhabitants' privacy concerns by fostering the creation of appealing privacy applications.

To gain a deeper understanding of the nature of users' privacy concerns, we investigated relationships among the inhabitants' perceived trust and beliefs in smart home service providers, inhabitants' perceived risk-thresholds related to provide personal information to smart home service providers, the intention of the inhabitants to allow the disclosure of their personal information (behavioral-intention), and inhabitants' perceived-usefulness that smart home environments would enhance the quality of their live.

Moreover, this work aims to give a better understanding of the privacy attitude of users within a smart home environment and the relationship between smart home technology and privacy and autonomy by reflecting on the boundaries and tradeoffs that exist between them. This is a very timely aim as we are currently entering a new era as smart home technology is shifting from research laboratories (where subjects have given their informed consent to being monitored) to commercial introduction of smart home technology. However, this new set of users have not been informed about what information is collected, how this information might be used (for and against them), and how they might or might not be able to control the smart devices and the information that these devices collect.

1.4 Structure of the thesis

Chapter 1 has introduced this master's thesis project by stating the research problem and outlining the goals of this study. Chapter 2 presents relevant background information about the field of ubiquitous computing and smart home environment technology. The chapter also describes the technologies and their most important characteristics. After this the chapter discusses privacy aspects and users' privacy concerns with regard to these technologies. Chapter 3 describes and justifies the selected methodology as well as the steps followed to accomplish our research, including the data collection, survey process, and measurements. Chapter 4 presents and discusses the data collected from the survey. Chapter 5 concludes the thesis by stating the suggested guidelines. Additionally, this final chapter presents recommendations for future work and describes the limitations of the current work.

2 Background

This chapter provides basic background information about ubiquitous computing, smart homes, privacy, and privacy legislation. Additionally, this chapter describes privacy in the context of a smart home environment and users' concerns about privacy. The chapter also describes related work illustrating state of art of smart home environments.

2.1 Ubiquitous Computing

In the beginning of the 1990's Mark Weiser introduced the term "*ubiquitous computing*" and its contraction "*ubicomp*" to explain his vision that computers and computing capacity will be available everywhere, anytime, via any apparatus. His vision also highlighted that computers will vanish into the background becoming transparent to the users. By vanishing into the background and becoming transparent Weiser implied that computers will be so small and inexpensive that users will not think of them as computers. As a result, computers would become similar to electricity, where only its absence is noticed [6]. Today we often use electricity without even thinking about it (e.g., when we switch off or on a light switch). The perception that electricity is available everywhere has become so widespread and common that conscious thoughts about the use of electricity has disappeared from our lives.

Mark Weiser's vision also suggested that the computer revolution would pass through three different eras. The *main frame* era in which one computer would be used by many users, to the *personal computer* era in which one computer would be used by one user, and the *ubiquitous computing* era in which one user uses many computers [5, 6].

Today's world is moving closer to Weiser's vision. Today our home and office environments contain an increasing number of networked computing devices, in the form of chips with all kind of sensors. These devices can be mobile, stationary, or embedded – almost everywhere – in watches, in home appliances, in automobiles, clothes, and so on. Moreover, to an increasing extent these devices communicate to each other in order to seamlessly work together to process and distribute the values sensed (which might include highly personal information) over high-speed wired and wireless networks. These systems assist us in everything we do. Examples of this technology include clocks that automatically set themselves to the correct time after an electric failure, walls that are able to damp certain sounds, and sensors that are able to notify us about intruders [7].

In 1997, Weiser and Brown highlighted that personal computers (PCs), laptops, and tablets could not be considered ubicomp, even though they are Internet-enabled portable devices, as they typically do not seek to understand the context of their environment in order to react appropriately [7]. However, today this is rapidly changing as many of these devices now are incorporating increasing numbers of sensors in order to dynamically adapting to their environment.

2.1.1 Core Characteristics

There are five core characteristics that distinguish *ubicomp* from other information and communication technology (ICT) systems [8], as shown in Figure 2.1. Table 2.1 summarizes these characteristics.

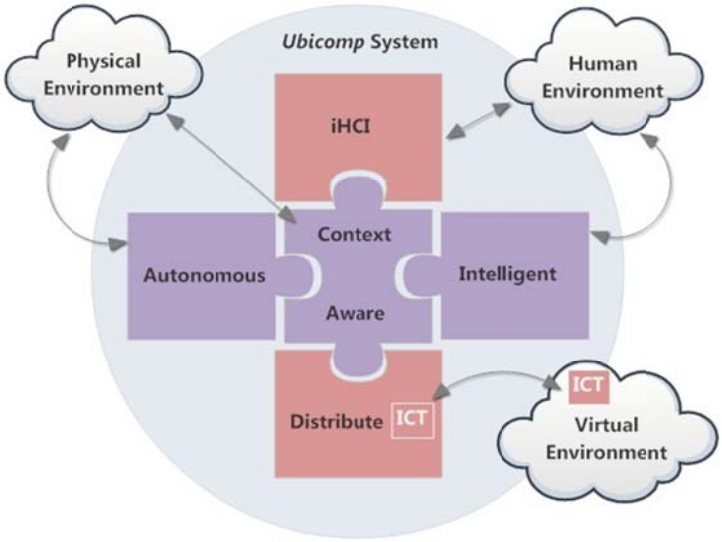

Figure 2.1: *Ubicomp* Core Characteristics (Inspired by Figure 1.2 on page 10 of [8])

Table 2.1: *Ubicomp* characteristics

Characteristics	Description
Distributed ICT	Computers need to be interconnected, distributed, and transparently accessible.
Implicit Human Computer Interaction	Human computer interaction needs to be invisible.
Context Awareness	Computers need to be context aware and able to optimize their operation in their environment.
Autonomy	Computers need to operate autonomously, without human intervention.
Intelligent	Computers need to handle dynamic actions and interactions, governed by intelligent decisions.

2.1.1.1 Distributed ICT

Distributed, interlinked, transparent, and open are common characteristics in ubicomp systems. In this context, distributed implies a collection of computer technologies working and acting as one computer, combining their processing power. When interacting with these distributed ICT systems users perceive it as one system [8].

In ubicomp, network connected intelligent devices offer services that may be accessed locally and/or remotely from anywhere and at any time. A wide range of network technologies can support ubicomp interaction: data networks, wireless data networks, etc. Based on the type of ubicomp services a diverse combination of functions will be required from these networks, such as: minimal jitter, bounded latency, various types of media access control, and so on [8].

Transparency and openness imply that the technology does not intrude into the physical environment or into the activities performed in this environment, but rather that the devices cannot be seen, heard, or consciously touched [9].

Openness implies that these systems are designed to avoid closed implementations. Instead, these systems are designed for interoperability and they can dynamically discover external services. For instance, an ubicomp camera could automatically detect printing services and inform its user about the availability of a printing service. Nevertheless, many systems are still not designed for openness due to the product vendor not being interested in openness, thus vendors may design their products to ignore the presence of competitor's products in order to preserve their market share [8].

2.1.1.2 Implicit Human Computer Interaction

The term human computer interaction (HCI) refers to the interaction between humans and machines. HCI researchers seek to make these interactions more effective, to empower human interaction and to enhance users' interactive experience [8]. The area called implicit HCI (iHCI) is based on the premise that computers or other intelligent devices have some knowledge of the behavior or actions of the users in a given situation. Users perform actions without intending to interact with a computerized system, but an iHCI system can utilize these actions as input. Therefore, the intelligent devices become invisible because some of the interactions are hidden due to the iHCI systems using the users' interactions while doing a task as (implicit) input [10].

Ubicomp devices need to be designed to support iHCI to a great degree in order make computation and digital information access seamless and less obtrusive to the users [8]. To achieve this is important that: (1) the users feel pleasant ceding control to automated systems that – without the users being aware and without the iHCI system intruding into their life; and (2) the system needs to be able to detect users and their context and then adapt accordingly [8].

2.1.1.3 Context Awareness

Everyday communication among humans involves the concept of context. For instance, while speaking with another human being we can perceive odors, environmental conditions, people around us, and so on. In computer science, the concept of context was first used by Schilit, Adams, and Want in 1995 to refer to a system that "*can provide context relevant information and services to users and applications"* and *"adapts itself to the context"* [11]. Context awareness includes detecting, identifying, and locating users' movement, activities, and actions and using this information to provide services that could be beneficial to the user.

Not all ICT systems are context aware. However, in smart environments, the use of sensor technologies facilitates and makes possible the collection of contextual information. The major challenge is selecting what information is *relevant* in a given context and exploiting the adaptability and dynamism of a context aware system to handle the specific context the user is in, as the user may do the same or different activities in the same location or different locations. By properly distinguishing context, *ubicomp* system improve the services provided to users and facilitate the interactions of the users with the system [12].

2.1.1.4 Autonomy

An autonomous system (AS) is a system that is self-governing, able to make its own decisions, and decide upon its most appropriate behavior. In an AS the user simply specifies a high level task and the system will automatically and dynamically control and perform all the low level subtasks. This reduces the complexity seen by the end user. An AS can also re-plan if some of the subtasks have not achieved their goals [8].

2.1.1.5 Intelligent

Intelligent systems are systems – machine or software – which use artificial intelligence (AI). AI is fundamental in ubicomp in order to handle characteristics such as context awareness and autonomy. Intelligent systems are designed to perceive their environment and take actions that maximize their chances of success [13]. Dimensions for classifying these systems are shown in Table 2.2.

Table 2.2: Dimensions for classifying types of intelligent systems [8]

Strong or weak intelligence
Physical (embodied) hardware, e.g. robots or virtual software
Fundamental properties such as autonomous, social, reactive, proactive, etc.
Thinking (cognitive) or acting (behavior)
Human or rational
Complex organisms (explicit, high level, knowledge based action selection) or simple cellular organisms (implicit low level action selection)
Type of design architecture: reactive, model based, goal based, utility based, etc.
Learning or non-learning
Certainty or uncertainty
The environments in which intelligent systems operate: observable, deterministic, sequential, etc.
Individual intelligent entities or as multiple, collective, intelligent entities

2.1.2 Technology

There are four key elements that enable *ubicomp* [14, 15]:

- ***Automatic identification (Auto-ID):*** Auto-ID is a technology used to identify, track, and trace objects, people, and animals. It begins by obtaining data, through the analysis of sounds, electronic signals, images or videos. This data is analyzed by a computer to verify the identity of the object. Typically, Auto-ID systems are barcodes, radio frequency identification (RFID), optical character recognition (OCR), smart cards, and biometrics systems. Every Auto-ID system has two processes: (1) capturing the signal associated with an object and (2) recognition based on computer analysis of that signal. An example of this is capturing the image of a barcode and then decoding the encoded information. Barcodes systems are the most widespread auto-ID technology for object recognition. Barcodes are simply an optical machine-readable mechanism to capture information without the need to enter letters and numbers via a keyboard. Current barcode products can store more than 7,089 characters using a barcode. RFID tags consist of a small chip and antenna. Such a tag can be attached to an object. An RFID reader can read the information stored in a tag if it is within range of the

RFID reader. OCR converts scanned images of handwritten, typewritten, or printed text into machine-encoded text. Using an OCR scanner printed text can be digitalized, stored in a database (DB), and searched. Smart cards are plastic cards, usually the same size of a credit card, with an embedded microchip and some stored data. Smart cards are widely used for electronic "cash" payments, prepaid telephone calls, and so on. Biometrics technology is used to identify humans by their characteristics (such as anatomical – fingerprint, facial, iris recognition – or behavioral – signature characteristics or traits).

- ***Location Based Technology:*** The ability of devices to determine their location enables location based services (LBS). This information can also be used to discovery objects. Location techniques include proximity, lateration, and angulation. If an object is recognized and the position of this object is determined, then the system deduces that the object is in the proximity of the known position. Lateration and angulation, particularly of radio frequency and audio frequency sources, are techniques that utilize timing, distance, or angle measurements between several known points to deduce the position of an object. The global positioning system (GPS) is a widely used location based technology using lateration based upon signals from satellites to provide a global navigation system. A GPS receiver calculates its position by exploiting precise timing signals sent by four or more GPS satellites.
- ***Sensor Technology:*** Sensors are devices that detect and respond to certain types of input from the physical environment and produce an output signal. Sensor technologies are used in a broad range of domains, such as medicine, commerce, industry, and so on. Sensors can monitor temperature, humidity, lightning conditions, pressure, presence or absence of objects, and so on. Wireless sensor systems utilize sensors connected to micro-controllers, memory, batteries, and radios. These sensors platforms can form part of a peer-to-peer or mesh network. These wireless sensors systems are generally self-configuring. Many low cost sensor networks exploit redundancy, so that individual node failures can be tolerated.
- ***Connectivity:*** Wireless connectivity is fundamental for ubiquitous computing. A wide variety of wireless technologies (such as Wi-Fi, WiMAX, cellular telephony, Bluetooth, and IEEE 802.15.4) can be used to provide connectivity between sensor platforms and gateways to other networks or to other sensors and actuators.

2.1.3 Challenges

Despite its proliferation and convenience *ubicomp* has some remaining challenges to overcome [16, 17]:

- The need for *natural interfaces* to support common forms of human expression, in order to allow the user to use more expressive input techniques (such as speech input or handwriting).
- *Context-aware applications* should adapt their behavior based on the information sensed. For instance, the ability to discard useless information and capture only important events (such as an important decision points during a meeting) would be a great aid to users.

- The automation of *capture of live experiences and subsequent access* would be a powerful aid to memory. Most *ubicomp* applications lack an appropriate visualization tool to show the user this captured information in an intuitive and understandable way.
- P*rivacy-enhancing-tools* should show individuals what personal information or data is collected. Individuals are generally not aware that they are surrounded by embedded systems with sensing capabilities and they are *unable* to monitor what data is collected nor deny its collection.
- There is a need for more robust *security* mechanisms in all the components or nodes within an *ubicomp* environment in order to make the system less vulnerable to attacks or malfunctions that could disrupt services or destroy/fake data.

Smart home environments can be considered a sub-domain of ubiquitous computing [18]. Therefore, all of the characteristics, technologies, and challenges mentioned above also apply to smart home environments. The next section will cover some important aspects of smart home environments.

2.2 Smart Homes

There is no generally accepted definition of what a *'smart home'* is. The definition of this term varies based on the technology or the functionality the home provides. Several terms are considered synonymous with this term in different contexts, such as: *'assistive technology', 'e-health', 'digital house', 'smart environments', 'automated house',* and *'intelligent living'* [19]. The more common definitions, among these synonymous terms, are the definitions proposed by Mark Weiser and U.K. Department of Trade and Industry (DTI). Weiser defined a '*smart environment*' as *"a physical world that is richly and invisibly interwoven with sensors, actuators, displays and computational elements, embedded seamlessly in the everyday objects of our lives, and connected through a continuous network"* [6]. The DTI's Smart Home project defined a *'smart home'* as residences that include telecommunications networks that interconnect essential electrical appliances and services, and enables them to be controlled, monitored, or accessed from a distance [20].

Today's homes are evolving into a place for e-health, entertainment, communication, work, commerce, and learning. They are becoming intelligent living environments that provide their residents with proactive services, such as medical care and monitoring of light, temperature, humidity, heating, and energy consumption. This means homes are becoming smart-agents able to perceive the state of the house and its inhabitants through sensor technology. The aim is to increase the comfort, quality of life, productivity of residents, reduce operating costs, and to encourage occupants to use resources more effectively as well as optimize the energy consumption in order to become an environmentally friendly society [2, 3]. Therefore, there are increasing political, social, and commercial interests in the potential of smart homes.

An indication of this interest can be seen in the number of smart homes projects – in academia and business – undertaken around the world. For example, in the United States of America, the *'house_n'* project by MIT is a live-in-laboratory used to investigate, monitor, and record activities and interactions of everyday home life

[21]; and the *'Aware Home Research Initiative'* by Georgia Institute of Technology is a research effort devoted to the technical, social, and design challenges for inhabitants, especially in areas such as health and well-being, digital media and entertainment, and sustainability [22]. In Europe, assisted interactive houses have been developed in The Netherlands, the *'PowerMatchingCity'* project focuses on the development of an integral market model based on ICT that facilitates more efficient energy consumption by householders and effective energy distribution by the distributor system operator [23]. In Sweden, *'The Stockholm Royal Seaport'* project includes a wide variety of projects whose main goal is to use generic ICT infrastructures to help to reduce investment, climate, and environmental costs; while contributing towards a sustainable city [24]. In Asia, the 'Welfare Techno-Houses' project explores the use of an automated monitoring system to allow medical care for elderly and disabled persons from their home in order to improve the quality of their lives [25].

2.3 The technology used by Smart Homes

Advances in ubiquitous computing technologies have allowed the implementation of smart home environments. Hardware (HW) embedded devices such as sensors, actuators, gateways, network devices, radio frequency chips, home appliances, etc. are interconnected and interacting with intelligent software (SW) to cooperatively collect environmental information about the state of the home and the activities and behavior of its inhabitants.

Sensors are a key enabler for smart homes. The rapid proliferation and adoption of sensors has made possible the development of smart environments that can assist people in their daily life. A smart environment exploits distributed and networked technology, but remains transparent to the inhabitants of the home. Based on sensor technology our homes are evolving towards ubiquitous computing, as homes become more and more dependent on computers, especially tiny devices with special purpose-designs to perform dedicated functions. This ubiquitous computing evolution contributes to our increasing dependence on digital information technology [1, 26] and the initiatives developed by industry in the creation of universal frameworks (e.g. The AllJoyn Framework) that enable products, systems, applications and services to simply and transparently share information and interoperate among them, independent of the manufacturer or operating system (OS) [27].

Figure 2.2 illustrates a typical smart home architecture. This architecture includes the elements listed in Table 2.3 [28].

Table 2.3: Smart Home Architecture

Elements	Description
Sensors and meters	Detect, monitor, and measure physical (temperature, humidity, etc.), chemical (carbon dioxide, nitrogen, etc.), electrical, and other properties.
Actuators	Perform actions (For instances, if the temperature is too low then turn on the heating system).
Wireless sensor networks	Consist of small embedded systems with a microprocessor, radio interface, and one or more sensors that communicate

Elements	Description
	using protocols for home automation (HA) such as KNX, Zigbee, Z-Wave, and DASH7 or through network communication protocols such as Wi-Fi, Bluetooth, 6LoWPAN, IEEE 802.15.4, or cellular telephony technology.
Home Gateway (HG)	Located at the border of the home and it is the central point of connectivity from the home to external networks. The HG allows the home owner to control, manage, and monitor the home's appliances and sensors no matter where they are [29]. For instances, the user can control the heating or cooling system. According to Abramowicz [28] there are some characteristics a smart HG should handle, specifically: (1) *connectivity* implies connections between the home's local area network and the Internet – the HG allows the inhabitants to control the home's connectivity with the outside world; (2) *security* functions (e.g. firewall, access control, and monitoring) that enable the home user to feel secure against treats coming from the Internet; (3) *Quality of Services* (QoS) to give preferential treatment to the user's preferred traffic (e.g. for IPTV or VoIP traffic), remote management to enable remote operations and enhance the provisioning of managed services at home; (4) *Software* extendibility in order to deliver service in smart home environments as to integrate home devices into the service infrastructure. Therefore, the software platform running on the HG should be able to install, update, uninstall, and stop and start software modules; and (5) monitoring and diagnostics, the HG must provide monitoring and diagnostic tools.

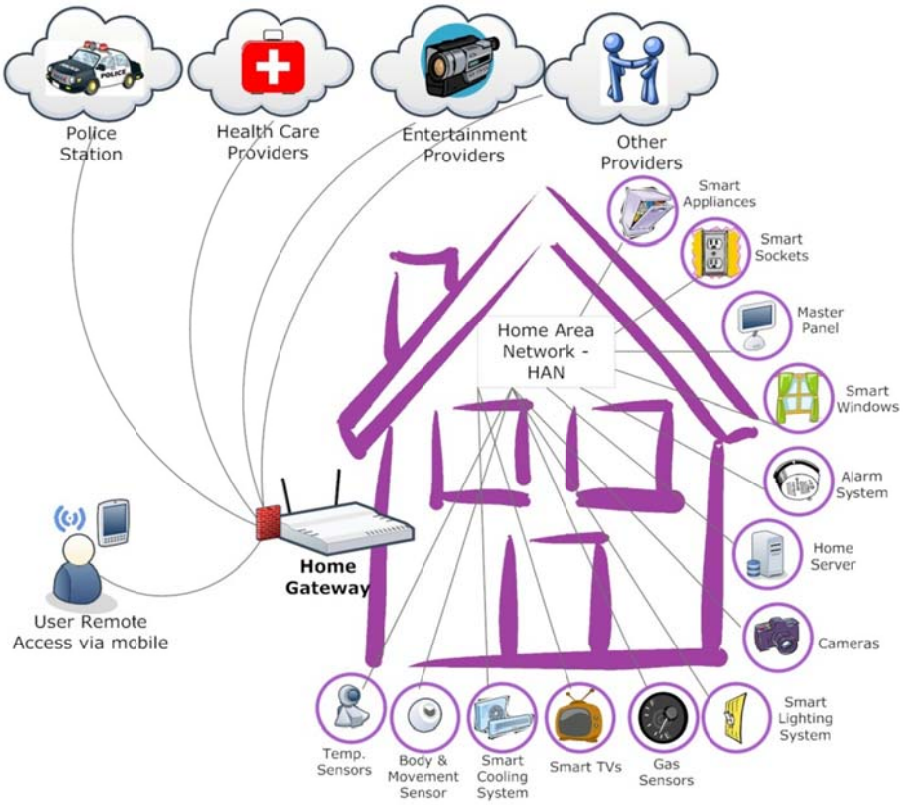

Figure 2.2: Typical Smart Home Environment

2.3.1 Home Automation

The term home automation (HA) refers to systems or technologies that allow interconnectivity and control of devices within the home to achieve the goal of home automation. The interconnection of household devices improves the living, quality of life, and comfort of inhabitants through the provision of services to allow the inhabitants of the home to control various functions of the devices within their house. For instances, controlling heating and air conditioning to maintain the desired temperature and automatically turning off the lights when human or animal presence is not detected [30].

HA is an important factor in a smart home environment, but unfortunately the terms HA and smart home environment are usually seen as synonymous because the objective of both technologies can be understood as the same (increase comfort and quality of life of the inhabitants). However, there are significant differences. For instances, a house with HA will turn on the air conditioning system taking into account the outside environmental factors and whether the inhabitants are at home or not. But HA alone would not be able to intelligently forecast what time the user will come home or adapt to changes in the inhabitants' routines (e.g. inhabitants come home late every Monday), while a smart home environment would adapt [30].

2.3.2 Smart Meters

As stated in previously (Section 2.2) one of the aims of smart home environments is to help to achieve energy efficiency within the home. As a result

smart meter technology has become a fundamental part of smart home environments. Smart meters enable greater energy efficiency because they allow the utility company to learn the home's real-time energy consumption (e.g., measurements of voltage, frequency, and phase angle) at a fine temporal granularity. This allows the utility company to distribute electricity more efficiently [31].

Using a smart meter architecture utility companies are capable of limiting energy consumption or even cutting energy off in order to encourage householders to adapt their energy consumption behavior, during for instance peak hours (by setting a high price). This would promote energy saving and awareness which in the long term might contribute to the reduction of carbon footprint*. Moreover, smart meters would facilitate utility companies providing feedback to the inhabitants about the most cost-efficient manner to use their household devices. By adjusting their behavior inhabitants would be able to reduce their energy costs [33].

In addition to all the benefits the home's occupants gain from living in smart home environments, these environments also cause concerns for the users. Particularly, when the privacy and security of the personal data collect by sensors are unknown (or ignored). In most cases, the inhabitants are not fully aware of what information has been collected nor do they have control over the vast amounts of personal data that not only is being collected but also is increasingly being shared and utilized by third parties without the user's consent. To exemplify, many resident of the municipality of Gävle in Sweden might not be aware that periodic tests for illegal drugs (e.g. cannabis, cocaine, ecstasies) are carried out by the government using the water flushed down toilets that goes in to the municipal wastewater treatment plants. This represents violations to individual's privacy protection since residents expected that when they put their waste out, their privacy will be protected by the government [34].

2.4 Privacy

Debates about privacy are not new topic and violations of privacy did not start with the introduction of ICT. Privacy has been in people's minds since the early 14th century with legal references about privacy being traced back to the "*Justices of the Peace Act in 1361"* in England, which set out sentences for peeping toms and eavesdroppers. Similarly, *"The Castle Doctrine"* in the 17th century was established as an English law by Sir Edward Coke who proclaimed that *"an Englishman's home is his castle"* meaning that a man can do as he pleases in his own house. He goes on to say "*The house may be frail, its roof may shake, the wind may blow through it, the storm may enter, the rain may enter, but the King of England cannot enter, all his force dares not cross the threshold of the ruined tenement"* [17].

During the 19th century Louis Brandeis and Samuel Warren wrote one of the most influential articles that legally frames the term *'privacy'* as *"the right to be let alone"*. Brandeis and Warren were stimulated by the arrival of modern photographic films and the printing press, thus reporters or individuals could take pictures of people without their consent and distribute these pictures to the press

* By knowing our carbon footprint we can understand the impact we cause on the environment [32].

and tabloids. As a result, individuals should be protected from publications that reveal any details of their personal life that they would like to keep confidential [35]. Another influential book was Alan F. Westin's book '*Privacy and Freedom'*. In this book Westin defined *'privacy'* as *"the claim of individuals, groups, or institutions to determine for themselves when, how, and to what extent information about them is communicated to others."* [36]

Despite, the concept of privacy and debates about privacy having been going on for so long, there is still not a general consensus of the definition of the term *'privacy'* nor its implications. Westin states "*no definition [of privacy] is possible, because [those] issues are fundamentally matters of values, interests, and power"* [36].

Notions of privacy seem to come from different perspectives, particularly the sociological and legal. A discussion of privacy from the sociological perspective argues that a definition of privacy is not straightforward or static. It is not straightforward because one person's idea of privacy is prone to be different from the definition of their friends or family members. The term 'privacy' means different things to different people [37]. Such a phenomenon also occurs when policymakers, specialists, practitioners, and scholars, from dissimilar theoretical backgrounds, struggle to define the term, its concerns, and its protection. Additionally, the definition of privacy is not static, because its definition will change over time and the scope will extend due to new social norms, individuals' convictions, philosophical theories, religion, belief and attitudes, or new technologies being introduced [38].

Another approach to privacy in social sciences reflects on how individuals manage and interact with privacy with respect to other individuals by arguing that privacy is not just about establishing rules and imposing its fulfillment, but rather privacy is an ongoing process based on *expectation* in which disclosure and identity are negotiated among people in everyday life. Individuals expect to disclose information among each other, in order to retain or gain something, and they expect that this information is used in a particular way and not in another way [39].

The legal standpoint sees 'privacy' commonly from four aspects: (1) *Territorial privacy* which places limitation on unauthorized invasions into an environment such as a home, workplace, public space, and so on, of another individual. (2) *Bodily privacy* which protects individuals' physical being against invasive procedures, for instance, an unjustified strip search, genetic testing, drug testing, or body cavity search. (3) *Privacy of communications* encompasses protection and security of telephone and mobile conversations, electronic and postal mail, and other means of communication. (4) *Information Privacy* set rules about the handling or the processing of personal data, emphasizing that individuals or organization have the right to decide how, when, and to what extend their personal information is communicated to others. The first three aspects generally have been covered in privacy legislation around the world for a long time, but with the advent of ubiquitous computing those seemingly long-solved privacy issues of territorial, bodily, and communication privacy have once again become highly relevant. Laws covering information have been always around, but with the progress of ICT, particularly the world wide web (WWW), legislation faces new challenges in trying

to include adequate measures to protect the security and personal data of individuals [17, 40].

2.5 Privacy in Ubiquitous Computing

One of the most controversial issues discussed about ubiquitous computing is privacy. For the end user there are several advantages and disadvantages of living in smart environments. On one side, *ubicomp* has the capability of radically changing, in a positive way, the safety, efficiency, and convenience of users (e.g., to help family members, doctors, or nurses to monitor elderly persons). However, *ubicomp* environments also introduce the potential for the misuse of the personal information produced by the system. Users indicate discomfort regarding the possibility for abuse and the absence of control, hence they desire privacy tools in *ubicomp* systems [41].

In *ubicomp* the essence of privacy encapsulates *'not sharing information without the user's consent'* [5]. Moreover, there are some properties of ubiquitous computing technology that create great concern among computer scientists and practitioners regarding privacy (see Table 2.4) [40]. Due to the properties described above and the proliferation of smart and invisible wireless networked computing devices, no single part of our life will escape digitalization. Langheinrich has stated:*"Everything we say, do or even feel, could be digitized, stored and retrieve anytime later"* [40]. Therefore, privacy legislation is necessary.

Table 2.4: Ubiquitous Computing Properties

Property	Description
Ubiquity	The ubiquitous computing environment (consisting of computers, sensing-devices, and infrastructure) will be widespread and present in every aspect of our daily life. Interconnected computers are being embedded in clothes, pets, people, buildings, home, automobiles, work environment, and so on.
Invisibility	The computers, sensing devices, and infrastructure will not only be ubiquitous, but they will also be invisible to humans. As a result, users will unaware of whether they are interacting with computing or communication devices.
Sensing	The miniaturization of computers and the increase in their computing power enables sensors to evolve to be more accurate and to cover a wide range of activities: monitoring environmental conditions – temperature, humidity, heat; physical conditions – heart rates, blood pressure; sensing the location, proximity, and presence of bodies; emotions – stress, excitement, fear; and so on.
Memory Amplification	With the progress in the field of video and speech processing, the low price of memory, and the high capacity of storage systems, it is possible to record every movement we make, thus enabling every aspect of our life to be searched.

2.6 Privacy Legislation

Many governments and standardization bodies have studied the how personal information is handled and collected. As a result, they have regulated these practices to assure that these practices are fair and provide adequate privacy protection to individuals.

The fundamentals of the current laws about privacy can be traced to The Fair Information Practice Principles (FIPPs) [4, 42] which is a broadly accepted framework, followed in the United States, Canada, and Europe, as well as by many international organizations. These principles have been identified as the basis for the European Union directive 95/46/EC and have provided input to legislation in many parts of the word [43]. Table 2.5 summarizes these principles.

Table 2.5: Fair Information Practice Principles (FIPPs) [35]

Principle	Description
Notice/Awareness	Individuals should know what personal information is collected, maintained, and used by specific entities.
Choice and Consent	Individuals should have the option to decide how their personal information is collected, how it may be used, and under what circumstances it may be disclosed to third parties.
Access/Participation	Individuals should have access to the data collected and should have the possibility to correct mistakes.
Integrity/Security	The data collected should be accurate and secure. Entities should restrict or limit access to the data and ensure that this data is not utilized for unauthorized purposes. Entities should also implement mechanisms to prevent a breach of the integrity of this information.
Enforcement/Redress	Each entity should have in place mechanisms to enforce respect for the privacy of each individual. This includes legislation that would create private remedies for consumers or regulatory schemes strengthen through civil and criminal sanctions.

Smart environments should be designed and developed to follow the above principles in order to mitigate, the inhabitant's complete actions and behavior and daily living activities, being traced, linked together, and accessed by unauthorized parties.

A large corpus of research and design knowledge has resulted in proposed strategies, mechanisms, frameworks, and policies for addressing privacy in smart environments. Haddadi et al. propose an analytic privacy framework that allows queries of personal data *without* compromising privacy by "verifying query code, and then launching it into the user community to perform its measurement tasks, collect verifiable statistics, and finally perform aggregation and fuzzing while remaining within the community" [44]. Myles et al. suggest a privacy-preserving location sensing system which is a general framework to address privacy concerns by enabling users to apply policies to control the distribution of their information [45]. Arabo et al. proposes an identity management framework which allows users to have full control of their personal information [46]. Nevertheless, privacy in smart homes is still an open research issue and residents of smart home environments still find it hard to manage their privacy with the available tools [47].

2.7 User's Concerns about Privacy

The role *ubicomp* plays in our lives has been recognized as beneficial, but it also causes some concerns for users, particularly about privacy matters [48]. Although users' concerns about privacy in ubiquitous computing have been studied, none of these studies cover the holistic aspect of the technology. The existing studies mainly focus on particular key technology elements, such as RFID, LBS, Smart Meters, and The Internet. Table 2.6 summarizes existing studies of major privacy concerns. Common factors from these studies relate to access to the stored data – most importantly who will access it; the use of the data – how it will be used and in which context, and what the residents will gain or lose from reveling this data; and the sensitivity of the information – how sensitive the data is perceived to be [49].

Table 2.6: Summary of users' privacy concerns in the existing literature

Description	Reference(s)
Being Accessed. Access to personal information without users' knowledge and consent.	[50], [51], [52]
Individual patterns. Determine users' general behavior patterns from their devices' usage.	[50], [52], [53], [54], [55]
Being Categorized. Lead to discrimination and profiling.	[51], [54], [55]
Real-time surveillance - tracking and tracing. Monitoring consumer behavior as it happens in real-time.	[50], [56]
Information dissemination and use. Selling pieces of information to third parties	[50], [51], [39] [54], [57]
Using a user's personal information **out of the context** for which it was originally collected.	[54],
Information maintenance. Not knowing for how long the personal information will be stored and when it will be irreversibly destroyed.	[51]
Physical invasion. Being victimized by individuals with malicious intent, for example to know whether or not a person is home for purposes of burglary or assault.	[50], [54]
Errors. Concern about the protections against deliberate and accidental errors in personal information produced by smart devices.	[52]
Identity theft based upon personal information	[58], [39], [54]
Lack of knowledge about what kind and how much personal information is being collected (feedback).	[51], [53]
Lack of control about the personal information collected by the devices.	[53]
Concern to **be/sign responsible** for each intelligent device the users own due to these devices being uniquely identified and in the case of crime of malicious acts the identity associated with the devices could be traced back to the owner who is mainly concerned about the use of this information by law enforcement.	[51], [54]

In a smart environment, the sensing capabilities of the intelligent devices are not only monitoring various attributes of the environment, which are necessary to provide the desired smart functionality; they are also collecting private and sensitive information about the user. This information has caused increasing concerns about the invasion of the individuals' privacy due to the possibility of the collected information being misused by external parties [5].

According to a report by Forrester, 97% of American consumers considered privacy matters their most pressing concern and 94% reported that they believe the benefits received for sharing their personal information do not compensate for their concerns [59]. A multi-national consumer privacy survey*, found that 78% of the respondents expressed that in the past, they have refused to provide information due to concerns about the misuse of their personal information [57]. A privacy survey by the Office of the Australian Information Commissioner concluded that 50% of the respondents normally provide incorrect personal data on purpose [60]. The same survey showed that 95% of the respondents are convinced that laws to protect personal information are necessary [60]. However, consumers are also aware that providing personal data can be worthwhile. The more detailed the information, the higher the quality of services that the users can get. As a result, users are willing to provide personal information, but only under certain conditions. Users will disclose their personal information if the benefits outweigh the risks that could occur if the information is misused [61].

According to Preibusch [55], concerns about privacy has emerged as a research topic in multiples disciplines (such as economics, law, and computer sciences). Despite there being a lot of work done to understand users' attitudes and opinions towards privacy, most of the work has been done in an *ad hoc* manner, causing the results to be unreliable. Therefore, to conduct meaningful research about users' privacy concerns requires the measurement instrument to be reliable. Preibush identified seven reliable scales to measure privacy concerns. Table 2.7 summarizes and describes these scales.

Table 2.7: Scales to measure users' privacy concerns [50]

Model	Description
The concern for information privacy model – CFIP by Smith, Milberg, and Burke [52]	This model consists of fifteen positive sentences on a seven-point scale by which responders express their level of agreement with each of the sentences. In this model, the privacy concerns were derived from a literature review and emerged as a latent variable form of privacy concerns.
The dimensional model for privacy concern proposed by Sheehan and Hoy [62]	This scale explores the framework proposed by Nguyen and Mynatt [47] and relates it to the FIPPs. It consists of fourteen privacy invasive scenarios that are presented to the responders who indicate their level of concern based on a seven-point scaled anchored by "not at all concerned" and "extremely concerned".
The Internet users' information privacy concerns model – IUIPC by Malhotra, Kim, and Agarwal [63]	This scale uses the same methodology as proposed by Nguyen and Mynatt [47]. A detailed explanation of this model is given in Section 3.7, starting on page 31.
The instrument for measuring online privacy concern suggested by Buchanan, et al.[64]	This model is structurally different from the previous ones presented (meaning not based on the findings of Nguyen and Mynatt [47]). On a five-point scale ranging from "not at all" to "very much", the authors ask responders about different aspect of privacy such as data misuse, misrepresentation and online fraud.

* IBM Multinational Consumer Privacy Survey.

Model	Description
The instrument for measuring privacy concern proposed by Earp, et al.[65]	This instrument uses the same methodology as Sheehan and Hoy [62] to measure responders' concerns about privacy invasive practices by Websites in a five-point scale anchored by "strongly disagree" and "strongly agree".
The two scales for privacy concern by Dinev and Hart [66]	This model uses the same methodology as Louis Harris & Associates, Inc. [57] based on the combination of two scales: (1) someone finding information about oneself and (2) abusing it. On a five-point scale, responders indicate their level of disagreement or agreement about the sentences.
The indirect measurement of privacy attitudes by Braunstein, Granka, and Staddon[67]	This model measures privacy concerns about the exposure of personal digital content and uses a ranking scale rather than a rating scale. In this model, privacy is seen as a moderating variable.

2.8 Market of personal information

Direct marketing is a very lucrative industry. According to the Direct Marketing Association (DMA) in 2012, US$168.5 billion was spent on direct marketing. This advertising investment generated about US$2.05 trillion in sales, which represented 8.7% of the total United States' Gross Domestic Product (GDP). The DMA calculates that direct marketing provides a return of around US$11.73 per dollar invested in direct marketing, while non-direct marketing only generates a return of US$5.23 for each dollar invested [68]. With consumers' personal information in their hands, marketers are able to increase the efficiency of their advertising by convincing and appealing to those prospects who are most likely to buy their services or products, and to create better promotion and reward programs that help to build customer loyalty [69]. To be able to use personal information marketers need to collect data from several sources and reuse the data collected for purposes other than the original purpose when the data was collected. Using consumers' personal information is not a new practice. For decades, marketers have used consumer information to guide their marketing campaigns. However, the information used was based on generalized characteristics of a consumer group, market segment, or geographic region, rather than specific individual data such as name, address, lifestyle, interest, and purchase history [70].

According to Phelps et al. the use of individual specific data is the primary source of concern among consumers. Ubicomp technologies can collect real-time information about every aspect of our life [70]. The resulting DBs contain valuable personal information. Hence these DBs are a lucrative asset.

2.9 Managing Privacy in Ubicomp

Managing privacy in ubiquitous computing environments is complex due to the characteristics of the technology (which as we noted earlier was *designed* to be transparent and open – see Section 2.1.1). Additionally, the multidisciplinary aspects of privacy and the numerous different stakeholders involved, each one of them with different perception of privacy, add complexity to the design of privacy tools [71]. Researchers have proposed several models, methods, and techniques to

design privacy tools for *ubicomp* environments, such as: privacy mirrors [47], confab [72], pawS [73], and AdLoc [74].

Designing privacy tools following one these models would facilitate the inhabitants of smart home environments understanding how their personal information may be used by external parties and how their personal information participates in the information flow of the *ubicomp* system, to control their personal information, and to allow them to decide how and when the information can be disclosed and used by third parties. Designing *ubicomp* systems under these models will *not* provide perfect privacy[*], but will allow the inhabitants of smart environments to make sense out of the ubiquitous computing world around them [47].

Traditionally, privacy tools were designed to hide, confuse, and control disclosure of personal information. Today there is a need for privacy tools that *provoke awareness* of the information security practices of a ubicomp system [76] and to enable users to manage the privacy of their personal information. Lederer et al. suggests that this situation occurs because the current design of *ubicomp* systems, which include SW and HW, inhibits users from understanding the privacy implications of sharing personal information [77]. Current systems do not provide users with any mechanism to control their personal information, to understand the tradeoffs between sharing personal information and privacy, or to provide users with intuitive tools that will allow them to understand how their personal information participates in or contributes to the flow of information in a *ubicomp* system [47].

Empowering privacy in smart home environments through privacy tools that provoke privacy awareness will permit inhabitants to limit the exposure of their personal information. If inhabitants perceive they have control over their personal information as generated in their own home, they will also perceive themselves as exercising their right to privacy [78]. Moreover, the design of such a privacy tool should be based on the inhabitants' interests, needs, and concerns as they know best how their personal information should be handle [4].

[*] According to Gavison an individual enjoys perfect privacy when three elements are present. They are secrecy, anonymity, and solitude. In perfect privacy *"no one has any information about X* (secrecy)*, no one pays attention to X* (anonymity) *, and no one has physical access to X* (solitude)". Loss of privacy occurs *"as others obtain information about an individual, pay attention to him, or gain access to him."* This means that perfect privacy only exists when a person is *"completely inaccessible to others"*. In this sense, the concept of privacy is better understood as a concern for restricting personal information accessibility [75].

3 Methodology

The purpose of this chapter is to provide an overview of the research method used in this thesis. Section 3.1 describes the research process. Section 3.2 details the research paradigm. Section 3.3 focuses on the data collection techniques used for this research. Section 3.4 describes the survey process, including the selection of the sampling, sample size, target population, and the development of the scale used in the survey. Section 3.5 explains the techniques used to evaluate the reliability and validity of the data collected. Section 3.6 describes the method used for the data analysis. Finally, Section 3.7 describes the framework selected to evaluate users' privacy concerns.

3.1 Research Process

Figure 3.1 shows the steps conducted in order to carry out this research. The first step was to review the relevant literature in order to gain a deeper understanding of the current state of research in this area. The synthesis of this literature review resulted in Chapter 2. The next step was to define the research design and methods. This includes the sampling strategy and the selection of a model to measure users' privacy concerns. Data was collected via a survey in order to identify and understand users' privacy concerns. Finally, the collected data was analyzed and discussed. The following section explains these steps in more detail.

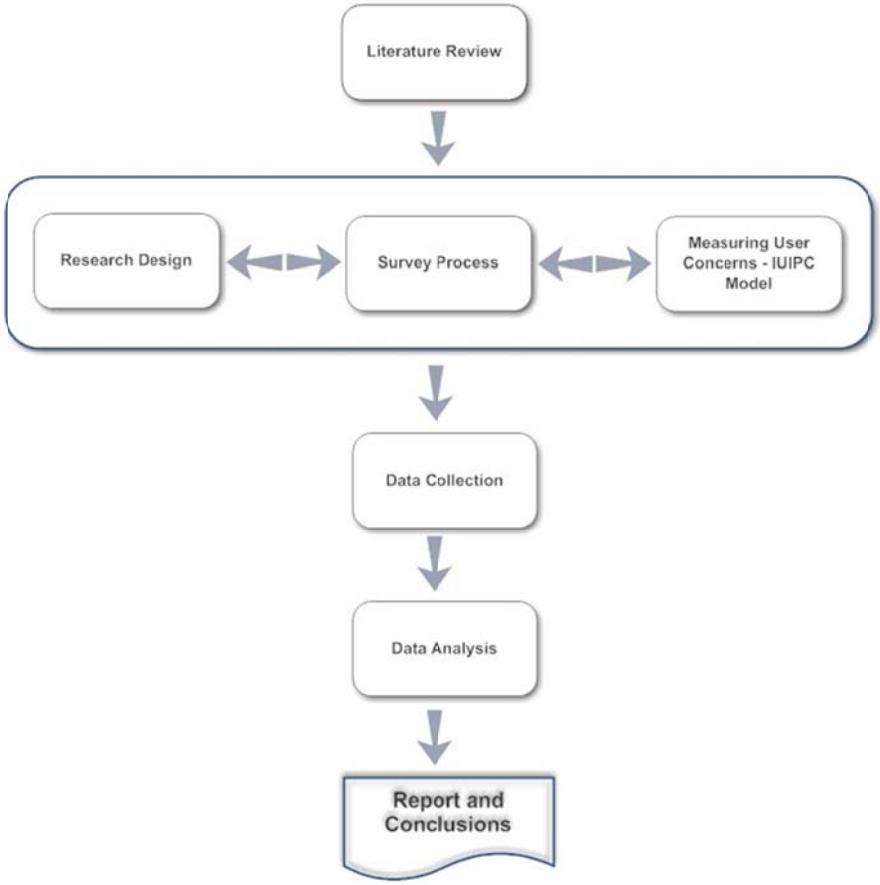

Figure 3.1: Research Process

3.2 Research Paradigm

According to Hevner et al. there are mainly two paradigms for research in the field of Information Systems: design-science and behavioral-science [79]. According to the design-science paradigm researchers approach their research by building innovative artifacts or by analyzing the performance or use of artifacts in order to understand or enhance aspects of the information system. According to the behavioral-science paradigm the information technology (IT) artifacts implemented are themselves the object of study by seeking theories that illustrate, explain, or predict the phenomena of interest [79]. The chosen research paradigm for this thesis is the behavioral-science approach since our study tries to understand users' privacy concerns in smart home environments, rather than create a new artifact.

After selecting the research paradigm, the next step was to determine the research design and methodology. In a scientific study, all the components should perfectly fit into the whole. To achieve this goal, the researcher needs to prepare a strategy for conducting the study, i.e., the research design. A research design includes the methods and procedures used to collect and analyze information in a research effort including how, when, and where the data will be collected [80]. This research design is the blueprint for conducting the study.

A research design can be classified in several ways, but in general terms there are three major types (shown in Figure 3.2) [81]. An *exploratory* research design goal is to provide a better understanding of a situation for the purpose of discovering ideas or providing insights. This exploratory research design can be applied to a small group of people who were *not* randomly selected to participate. Unfortunately, the results of this research cannot be generalized to the population at large. A *descriptive* research design's goal is to identify the characteristics of an observable phenomenon in order to discover the frequency with which something occurs and to examine correlations among entities or variables. This research provides data about the universe being studied. On the other hand, *casual* research design's goal is to examine cause-and-effect relationships through experiments. This type of research is appropriate to determine which variables are the cause of a phenomenon – *"If X then Y"* [82, 83].

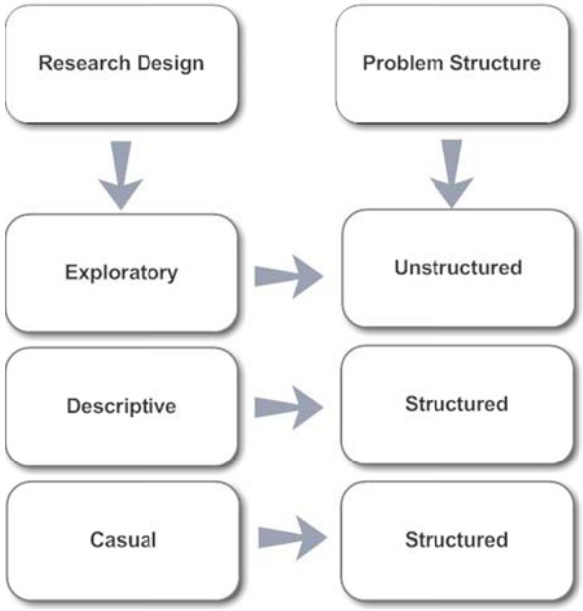

Figure 3.2: Type of research design and the structure of the problem

An important decision following the selection of the research design is to know what methodology the study will use. Selecting a methodology dictates *"what we can study as well as the range of possible results and conclusions"* [84]. The methodology choices usually are between qualitative or quantitative research studies. Quantitative research is the formal use of systematic and sophisticated procedures in which numerical data is used to obtain information about the world. These standardized measurement and sampling procedures increase the reliability and validity of the study [85]. Qualitative research is a research methodology where counting and statistical techniques are not the primordial focus. The focus is instead on discovering and understanding the experiences and thoughts of participants in their natural setting. There are a variety of qualitative research methods including case studies, content analysis, interviews, ethnomethodology, discourse analysis, and so on [86].

Due to the nature of this thesis project the approach that fit best is *explorative quantitative research*, since we are interesting in gaining greater insight into users' privacy concerns as well as the role perceived risk, trust, intention, and usefulness play for the users of ubiquitous technology. To achieve this an expert scenario-based survey was conducted based on the IUIPC theoretical framework [63]. Using this framework we identified inhabitants' privacy concerns and determined the level of privacy concerns, risk, trust, intention, and usefulness that inhabitants might perceive in a smart home environment. The results of the survey are discussed to serve as guidelines for designers and services providers of smart home technology. The aim is to help designers and services providers to gain a better understanding of privacy in smart environments based on inhabitants' privacy concerns.

3.3 Data Collection

In this study, there are two basic sources of data. First, the secondary sources of data which include documents such as journals, books, conference, articles, reports, and publications. Second, the primary sources of data which include the results of the survey. From the results of the survey a set of conclusions were drawn. A description of each of these methods is described in the following subsections.

3.3.1 Literature Review

Before conducting the survey, a comprehensive literature review was undertaken. An overview of the literature review process is shown in Figure 3.3. The first step in our literature review process was to define the problem and goal of this thesis project. This step helped us to identify the areas to be covered in this study. The main areas identified were smart home environments, ubiquitous computing, and information privacy concerns. The second step involved searching for relevant documents to support our study. In this step the search terms and databases were determined. The terms smart home, smart home environments, ubiquitous computing, *ubicomp*, pervasive computing, home automation, context-awareness, privacy personal information, privacy enhancing tools, privacy legislation, information disclosure, users' concerns, and measuring privacy concerns were rearrange and combined with Boolean operators to retrieve documents from scientific DBs. These DBs included ACM Digital Library, IEEE Xplore*, JSTOR, ScienceDirect, GoogleScholar, and SpringerLink. The third step involved the compilation, storage, and management of the documents retrieved following each DB query. The forth step consisted of reviewing, analyzing the material selected, and discarding irrelevant documents. The final step was to synthesize the findings - resulting in Chapter 2.

* IEEE Xplore is IEEE's Digital Library service.

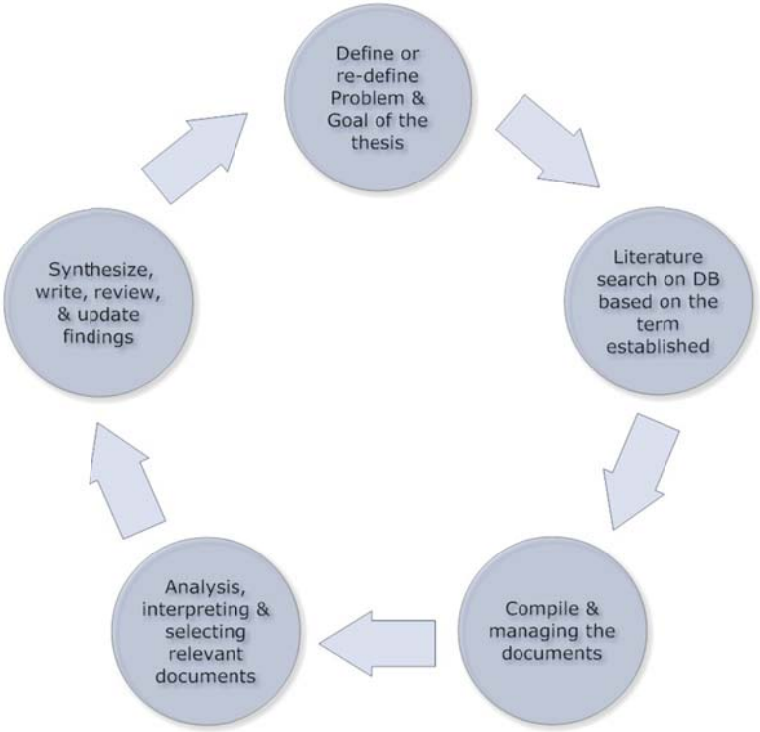

Figure 3.3: Literature review process

3.3.2 Scenario-based survey

This study adopted an expert scenario-based survey as one of its strategies since we are interested in gaining a *comprehensive* and *detailed* understanding of the current state of affairs regarding what inhabitants think about privacy and their concerns. We are also interested in understanding the quantitative relationships between variables (control, awareness, unauthorized secondary use, surveillance and intrusion) and the socio-technical context of the relationships (in this case the smart home), as well as how these concerns influence users' trust beliefs, risk beliefs, perceived usefulness and behavioral intention when releasing personal information. Since there are few actual users of such environment, we attempted to infer these user's concerns by surveying experts.

Survey questions were adapted from previous studies [63, 87] and modified based on our study context. This questionnaire allows us to measure privacy concerns with a reliable instrument, in this case the IUIPC framework [88], to give us a coherent picture of privacy concerns at the individual level. The complete questionnaire is included in Appendix A.

3.4 The survey Process

To carry out the scenario-based survey the process suggested by Gillian Raab, Professor of Applied Statistics at Napier University [89] was followed. This process is shown in Figure 3.4.

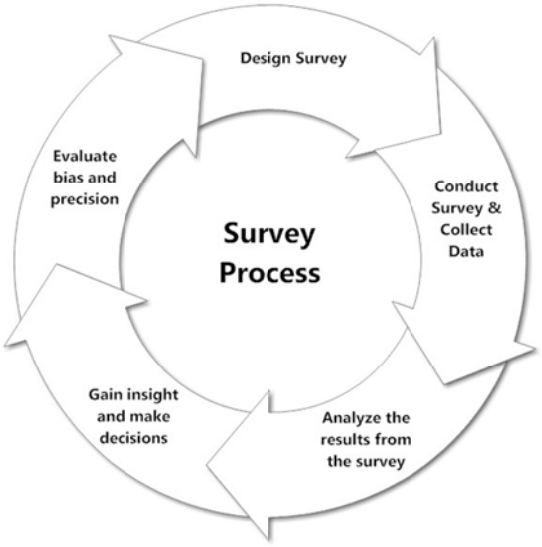

Figure 3.4: Survey Process

3.4.1 Sampling

When designing this study a decision needed to be made as to whether to use *probabilistic* or *non-probabilistic* sampling. To utilize *probabilistic* sampling two criteria must be fulfilled: (1) each member of the population must have an equal chance of being selected (random selection) and (2) the probability of selection is known for each selected member. Non-probabilistic sampling is used when the previous criteria cannot be fulfilled. In this thesis, the *non-probabilistic technique* was chosen because it was not possible to calculate the probability of getting a particular sample based on pure chance (random selection) [82].

There are four main types of *non-probabilistic* sampling [82]. Table 3.1 summarizes and describes these four types.

Table 3.1: Type non-probability sampling

Type of Sampling	Description
Convenience sampling	In this sampling method, the members of the population are chosen based on their easy access (convenience).
Purposive sampling	In this sampling method, the researcher selects members of the population based on the presumption that they represent a population of interest and/or meet the specific needs of the study. This sampling technique is usually used when there is limited number of people that have expertise in the area being researched.
Quota sampling	In this sampling method, members of the population are chosen based on quotas (e.g., 75% male and 25% female) established by the researchers who are free to choose any members as long as they fit the quota.
Snowball sampling	This sampling method involves locating members of the populations, who have the characteristics/qualifications needed for the study; and using these members to identify additional members who they consider have the desired qualifications to belong to the target population.

Due to the fact that we had access to a specific group of individuals working with key technologies that enable *ubicomp*, the sampling technique selected for this study was *purposive sampling a non-probabilistic* sampling technique. This sampling technique was chosen based upon our access to experts working in ubicomp as we considered they would be the most appropriate participants for this study. In this case members were selected based on their area of expertise and experience living in and working with smart environments [82]. By using this sampling technique we aimed to have a good basis for our research.

3.4.2 Sample Size

As mentioned previously non-probabilistic sampling does not rely on statistical calculations to estimate the sample size, rather it uses a pragmatic approach. This approach generally involves a small sample size – based on the good judgment of the researcher and what he or she considers will be sufficiently for the survey given the available resources (e.g., time, money, access to the population being studied, etc). According to Denscombe [82] this size should not be fewer than 30 people, in order the calculations executed on this research reflect the level of accuracy of larger samples.

3.4.3 Target Population

To perform studies relevant information must be collected. In the process of collecting the data, one of the important steps is to select the population for the study. The population of a study can be defined as all the set of items in the category of interest that are being researched [82]. Items indicate the organizations, people, objects, devices, etc. from which information would be collected. In this thesis project the selection of the target population was done taking into account the *exploratory* purposes of the research. Hence, the researcher looked for individuals who are knowledgeable or have experience in the area of study [82], rather than studying individuals who are currently living in smart home environments because such individuals were unavailable. Therefore, the selection criteria were set as:

> *All the participants should have experiencing working with at least one of the following technologies: Context Awareness, HA, Auto-ID, Location Base Technology, Sensor Technology, Smart Meters, or Smart Home Environment Technology.*

Experience in one of the above technologies was a criteria because these technologies form key elements to enable *ubicomp* or smart environments (as stated in Sections 2.1). Additionally, participation was voluntary and anonymous.

3.4.4 Scale Development

For accurate data results an appropriate scale is necessary. A seven-point Likert scale ranging from *strongly disagree* (1) to *strongly agree* (7) was used to ask the respondents their level of agreement or disagreement with each of the proposed statements. Table 3.2 presents the set of question used to measure each privacy concern. Section 3.7 explains in detail each item measured.

Table 3.2: Scale development

Items	Number of questions per item measured	Related Questions (number)*
Unauthorized Secondary uses (UN)	3	1, 2, 3
Control (CL)	3	4, 5, 6
Awareness (AW)	4	7, 8, 9, 10
Surveillance (SUR)	2	11, 12
Intrusion (INT)	3	13, 14, 15
Trust & Belief (TR)	3	16, 17, 18
Risk-Thresholds (RI)	2	19, 20
Perceived-Usefulness (US)	3	21, 22, 23
Perceived-Intention (ITE)	1	24
* *A description of each question is given in Appendix A.*		

3.4.5 Survey Administration

The survey was conducted as an Internet based survey. This survey was developed using the online web based tool Survey Gizmo (http://www.surveygizmo.com/), in which a link with the questionnaire was distributed via email to the sample population; in this case practitioners and experts at the Swedish Institute of Computer Science (SICS) and at a major telecommunications company. All of these potential participants had experience in one or more of the technologies mentioned in section 3.4.3.

Data collection started on October 18, 2013 and finished on November 18, 2013. The rate of response to the survey was 75% – with 30 out of 40 individuals participating. This high rate of participating might be because the author of this thesis had close collaboration with the target experts.

3.5 Measurements

In order to provide high quality outcomes the survey results must be demonstrated to be conclusively reliable and valid. This is achieved by ensuring that the scale used in the survey measures the intended construct* consistently and precisely (for reliability) and by ensuring that the scale measures the right construct (for validity) [91]. These points will be examined in the following two subsections.

3.5.1 Reliability

To be reliable, the results of the survey should be consistent. In other words, a reliable survey would produce the same results if several measurements are taken over time [92]. To determine if the results of our survey were reliable and to measure how closely each question was related to other questions in their group as well as to assess whether each item of our questionnaire manifests the same result as the entire survey questionnaire, Cronbach's α score was chosen. According to Nunnally [93] the measured value of each item of the questionnaire should have an

* In scientific research a construct is a theoretical concept used to explain a given aspect. For instance, a person's *communication skill* which might involve underlying concepts such as the person's *vocabulary, syntax,* and *spelling,* is considered a construct [90].

α score between zero and one. The higher the value of α the more reliable the construct is. Cronbach's α equal or above 0.5 can be considered reliable, but it will depend upon the type of research (e.g., in clinical applications a higher level of α, such as 0.95, is desirable).

3.5.2 Validity

To ensure that each question of the survey assesses what it was intended to measure, validity needs to be calculated. There are several approaches to assess validity. According to Bhattacherjee [90], validity should be assessed using theoretical and empirical approaches. Therefore, in this research validity was evaluated in terms of content validity and convergent validity.

Content validity is an evaluation of how well the measurement scale matches the content domain of the construct that it is trying to assess [90]. This is not done by quantified statistical methods, but rather individuals chosen by convenience assess the validity of the construct based on their judgment. Since we want to ensure that our questions fully represent the domain of study, two professionals at SICS, who have a solid background in ubiquitous computing environments and privacy, reviewed the survey questionnaire. After their feedback some of the questions were modified in order to reduce the ambiguity of the question. The modified questions are marked with an asterisk (*) in Appendix A.

Convergent validity refers to how much the measure is related to the construct that it intends to measure [90]. For convergent validity, the collected data was inspected using factor analysis techniques, varimax as the factor rotation, and principal components analysis (PCA) as the extraction method. By selecting the universally used varimax and PCA we were able to examine the relationship among the correlated variables, obtain a clear pattern of the loading, and reduce the variable observed into components that account for the most of the variance in the observed variables thus providing us a simple representation of the data collected [94]. Nine factors were tested in this study with a 24 scale loading as shown in Table 3.3 on page 34.

According to Hair et al. in order to assess the suitability of the data collected in the survey and consider PCA as a valid statistical method for research certain requirements should be fulfilled [95]:

- The correlation matrix should have at least two coefficients markings with the minimum loading. A rule of thumb proposed by Hair et al. [95] suggest these loadings values should be over *±0.30* for minimum, *±0.40* for important, and *±0.50* for significant correlations. Markings with a factor of *0.3* indicate that the variable accounts for *30%* of the relationship with the data.
- The Kaiser-Meyer-Olkin (KMO) index should be equal to or above *0.5*. If below the threshold, then an Anti-Image Correlation Matrix analysis would be required. The Anti-Image Correlation Matrix will show us the Measure of Sampling Adequacy (MSA) for each individual variable. Those variables with KMO below *0.5* should be discarded from further analysis. The calculation of MSAs suggests the level of the strength of the relationship among the variables in the model.

- The calculated ρ value of the Bartlett's Test of Sphericity *(Sig)* should be less than *0.001*. This indicates that the responses collected are valid and appropriated to the problem addressed in the survey.

Moreover, according Hair et al. in order to use factor analysis techniques it is essential to know how many factors are needed to be extracted. Several different extraction rules and approaches could be combined to assist researchers to decide how many factors to keep. For instance, the cumulative percent of variance extracted, Kaiser's criteria (an eigenvalue above to 1), the Scree Test, and parallel analysis. The rules used and their combination is a decision that must be made by the researcher.

3.6 Data Analysis

This section describes the data analysis techniques and software tool used in this research to analysis the survey results.

3.6.1 Data Analysis Technique

Linear regression analysis was used to analyze the data collected and to understand the relationship among the clustered observed variables suggested in the IUIPC. By using linear regression the overall regression relationship between the dependent variable and the independent variables should be less or equal to the level of significance $(\rho \leq 0.10)$ in order to support an existing relationship among the variables. A correlation relationship below *0.20* indicates a very weak relationship, between *0.20* and *0.40* indicates a weak relationship, between *0.40* and *0.60* indicates a moderate relationship, between *0.60* and *0.80* indicates a strong relationship, and above *0.80* a very strong relationship [95].

It is important to highlight that in [63] – the authors of the IUIPC framework – used the Structural Equation Technique (SEM) to analyze the data collected. However, due to the sample size constraints of this study, linear regression analysis was chosen based on the recommendation of Gefen, Straub, and Boudreau [96]. SEM techniques require a large sample size $(n \geq 100)$ while linear regression requires an smaller sample size $(n \geq 30)$. Moreover, the selected technique supports the type of research selected for this thesis, i.e., an exploratory one [96].

Additionally, PCA with varimax rotation was used to have a more comprehensive feeling of the five privacy concerns studied in this research. To fulfill the requirements that PCA is a valid statistical method we also followed the steps presented in Section 3.5.2. The resulting correlation matrix and factor loading present the inter-correlation among the concerns studied. This approach helps researchers to detected variables with similar characteristics and group them for further analysis.

3.6.2 Software Tool

Cronbach's α score, PCA, and linear regression analysis are calculated using the SPSS statistical software.

3.7 Internet Users' Information Privacy Concerns (IUIPC) Framework

As mentioned previously, the questions used in this survey were developed mainly based on the IUIPC model. This model was selected because it is one of the most reliable scales developed to measure users' privacy concerns at the individual level [88]. As a reliable instrument this framework has previously been slightly modified and applied in several different contexts (for instance, e-commerce [97], cloud-computing [98], mobile payments [87], Internet of Things [99], LBS [100], and social media [101]).

According to Malhotra, Kim, and Agarwa [63] concerns about the privacy of personal information is a very subjective issue - as individuals have different opinions about the collection of personal information and the use of this information. To address this matter, Malhotra, Kim, and Agarwa [63] drew upon social contract theory (SC)* and the CFIP scale [52] to develop a multidimensional scale aiming to capture individuals' concerns about organizational information privacy practices. The proposed model consists of three factors: *collection* of personal information, *control* over the collected personal information, and *awareness* of how the collected information is used. These three factors are expected to affected users' trust beliefs, risk beliefs, and perceived intention when releasing personal information at the request of an organization.

In addition to Malhotra, Kim, and Agarwa other practitioners and researchers have pointed out that when applying this framework *"the dimensionality is neither absolute nor static, since perceptions of advocates, consumers, and scholars could shift over time"* [63]. This implies that applications of the IUIPC should be reinvestigated as new technology emerges. Therefore, in order to apply the framework to the area of smart home environments two dimensionalities (Intrusion and Surveillance) were added to IUIPC model in order to cover all the privacy concerns identified in the literature review (see Section 2.7). Figure 3.5 illustrates the matching of these concerns into the modified framework.

* Social contract theory (SC) is grounded in philosophy and classical writings. In essence SC argues that *"humans, acting rationally, consent to the terms of some particular societal agreement"*. As result, SC has been used to studied perceptions of fairness and justice and has been applied to understand the relationship among consumers and organizations as well as to explain consumer behavior in the context of information privacy [63].

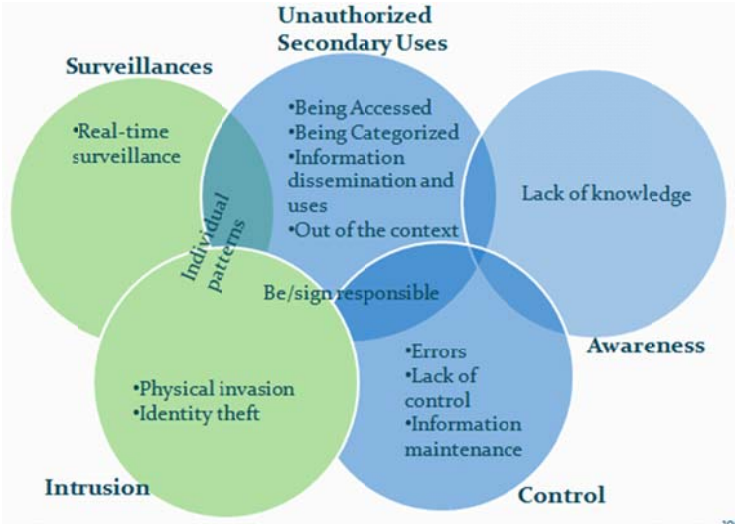

Figure 3.5: Privacy Concerns and its dimensionalities

3.7.1 IUIPC Factors

The IUIPC factors are:

Control (CL) — CL is a native construct in the IUIPC framework. In the context of this study, control is the users' belief in their ability to manage the release and dissemination of their personal information [102]. Because people want to have the ability to handle their personal information, control becomes fundamental in the context of informational privacy. According to Malhotra, Kim, and Agarwal [63] users are less worried about data collection when they have some decisions-making power over the information collected. Consequently, lack of such control increases users' privacy concerns.

Awareness (AW) — AW is a native construct in the IUIPC framework. According to Malhotra, Kim, and Agarwal [63] awareness in the field of privacy refers to the degree to which a consumer is concerned about his/her awareness of organizational information privacy practices. This includes issues of transparency and proprietary information and the disclosure of specific information. The higher the degree of awareness perceived by the consumer the higher the perception of fairness*.

* In this context fairness indicates the perception persons have that a peculiar activity (in which they are involved) is conducted fairly. According to Lind and Tyler [103] factors such as "control over actual outcomes" have an impact on the fairness perception of persons. Even when the effects/consequences are not positive for a person, the person would be less likely to be discontented with the negative effects/consequences if he or she believes that the procedures used to produce those effects/consequences were conducted in a fairly way.

Unauthorized second uses (UN)	UN is a native construct in the IUIPC framework. According to Smith, Milberg, and Burke[52] unauthorized second use refers to the situations in which the information from individuals is collected for one purpose and later used for another (e.g., profiling or categorizing individuals) or when the information is disclosed to third parties without authorization, consent, or awareness of the individuals. The possibility that this situation occurs generates a high level of distrust and terror among users who feel powerless and vulnerable [87].
Surveillance (SUR)	SUR is not part of the original IUIPC framework. Surveillance in the context of privacy is defined as *"watching, listening to, or recording of an individual's activities*". The characteristics of the *ubicomp* technology increase the probability of surveillance due to the aggressive degree to which detailed personal information is being collected; causing users to fear that their activities may be observed, traced, their movement track recorded, and shared with other organizations [87].
Intrusion (INT)	INT is not part of the original IUIPC framework. In *ubicomp,* ICT is embedded into people's daily activities. This ubiquitousness inevitably exposes these users to situations where they might feel intruded upon by invasive actions, unauthorized activities, or malicious activity (via attacks in wired or wireless networks) that make them feel uncomfortable [87].

3.7.2 Relationship between Trust, Risk, Usefulness, and Intention

Under the IUIPC it is important to understand the users' wiliness to release personal information to organization and how users decide to release or not to release their personal information. To achieve this Malhotra, Kim, and Agarwal [63] developed a casual model based on the trust-risk framework[*] and Theory of Reasoned Action (TRA) model[†]. The developed casual model describes the relationships among three variables: Trust & Belief (TR), Risk-Thresholds (RI), and Perceived-Intention (ITE). TR refers to the degree to which users believe organizations will protect consumers personal information [63]. RI refers to the degree to which users believe there is a potential hazard associated with the release of personal information [63]. If users have a higher degree of concern about the privacy of their personal information, then users are more likely to have low trust and high risk beliefs. If trust beliefs are high, then the risk perception will be low and *vice versa*. Therefore, the more trust users have in the organizations collecting their personal information the less likely they are to foresee a risk in providing

[*] The Trust Risk Model was proposed by Mayer, Davis, and Schoorman [104]. It was initially proposed to explain a trust relationship between two people. In this sense trust is defined as the *"willingness of a party to be vulnerable to the actions of another party"*. Risk is considered as requisite for trust, which means that a party must take a risk in order to engage in a trusting action.

[†] TRA was developed by Ajzen and Fishbein [105]. TRA is a model for the prediction of behavioral intention. According to this theory, individuals' attitude toward a behavior is based on individuals' belief that a particular behavior would leads them to a certain outcome. If the outcome is beneficial, individuals may then adopt a particular behavior. This intention is influenced by three variables: individuals' attitude toward the specific behavior, individuals' subjective norms, and individuals' perceived behavioral control.

personal information. ITE refers to those factors that influence the users' behavior [63]. These factors "*are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behavior"* [105]. Therefore, TR and RI will influence the user's intention to use services associated with the release of personal information. The justification for the existence of this relationship is established by the fact that users will not provide their personal information for a particular service unless they intend to use that service.

Perceived-Usefulness is defined as the degree to which users believes that using a particular system would enhance their job performance and the quality of their life [106]. The original IUIPC model does not include perceived-usefulness, but we adopted it from the Technology Acceptance Model (TAM)* because usefulness gives a strong basis to explain intention and because one of the main goals of smart homes environments is to increase the quality of life of its inhabitants. Therefore, usefulness was added to our model in order to explain in more detail the intention of users when opting to accept living in smart home environments. Table 3.3 presents all the factors measured and references to the related literature.

Table 3.3: Factors and sources

Construct	No. of Items	Related Literature
Unauthorized Secondary uses (UN)	3	[52, 63]
Control (CL)	3	[63]
Awareness (AW)	4	[63]
Surveillance (SUR)	2	[87]
Intrusion (INT)	3	[87]
Trust & Belief (TR)	3	[63]
Risk-Thresholds (RI)	2	[63]
Perceived-Usefulness (US)	3	[106]
Behavioral-Intention (ITE)	1	[63]

Figure 3.6 presents an overview of the modified framework and the relationships between the factors.

* Technology Acceptance Model – TAM was developed by Davis, Bagozzi, and Warshaw [106] adopted from TRA model. The goal of TAM is to model and provide explanation how users come to accept and use a technology. It also helps to identify the modifications need to be implemented or changed in the information system in order to make it acceptable to users. According to the TAM model there are two main factors that influence the acceptability of a system by the user: perceived usefulness and perceived ease of use.

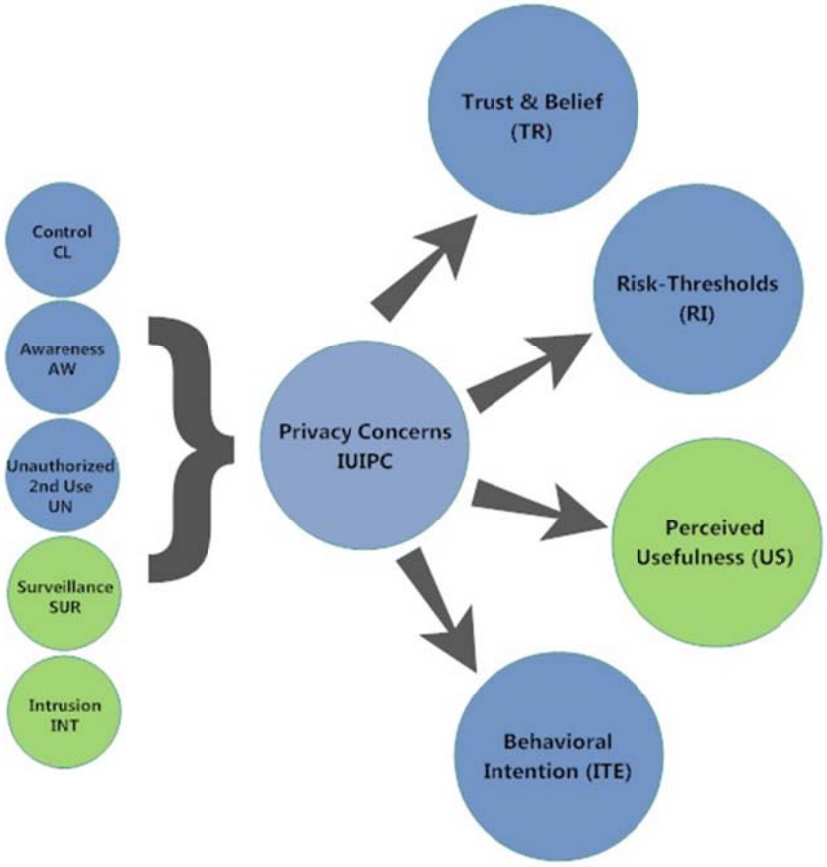

Figure 3.6: Framework overview and relationship among factors

Based on Malhotra, Kim, and Agarwal [63] framework as a reference we analyzed the eight relationships below to gain a deeper understanding of users' privacy concerns in smart home environments.

(1) Trust & Belief (TR) and Privacy Concerns	It is expected that smart home privacy concerns have a *negative* effect on TR. The *more* concerns users have about their privacy, the *less* trust a user has in smart home service providers when it comes to the handling of their personal information.
(2) Risk-Thresholds (RI) and Privacy Concerns	It is expected that smart home privacy concerns have a *positive* effect on RI, as the *more* concern users have about their privacy, the *more* likely users are to foresee risks related to the misused of their personal information.
(3) Perceived-Usefulness (US) and Privacy Concerns	It is expected that smart home privacy concerns have a *negative* effect on US, as the *more* privacy concerns users have, the *less* useful they would consider smart home environments.

(4) Behavioral-Intention (ITE) and Privacy Concerns	It is expected that smart home privacy concerns have a *negative* effect on ITE, as the *more* concern users have about their privacy, the *less* likely they are to disclose their personal information in order to receive smart home services.
(5) Trust & Belief (TR) and Risk-Thresholds (RI)	It is expected that TR has a negative effect on RI as trust beliefs are expected to mitigate risk perceptions. Therefore, the more trust the less likely users are to foresee risk.
(6) Risk-Thresholds (RI) and Behavioral-Intention (ITE)	It is expected that RI has a *negative* effect on ITE, as the *greater* the perceived-risk the less likely users are to adopt smart home technology.
(7) Trust & Belief (TR) and Perceived-Usefulness (US)	It is expected that TR has a *positive* influence on US, as the *more* trust users have in a smart home service provider and in the technology per se, the *more* likely users are to consider smart home environments as useful when it comes to increasing the quality their life.
(8) Trust & Belief (TR) and Behavioral-Intention (ITE)	It is expected that TR has a *positive* influence on ITE, as the *more* trust users have in smart home service provider, the *more* likely users are to adopt smart home services that release their personal information.

The relationships among the variables of the IUIPC model are diagramed in Figure 3.7.

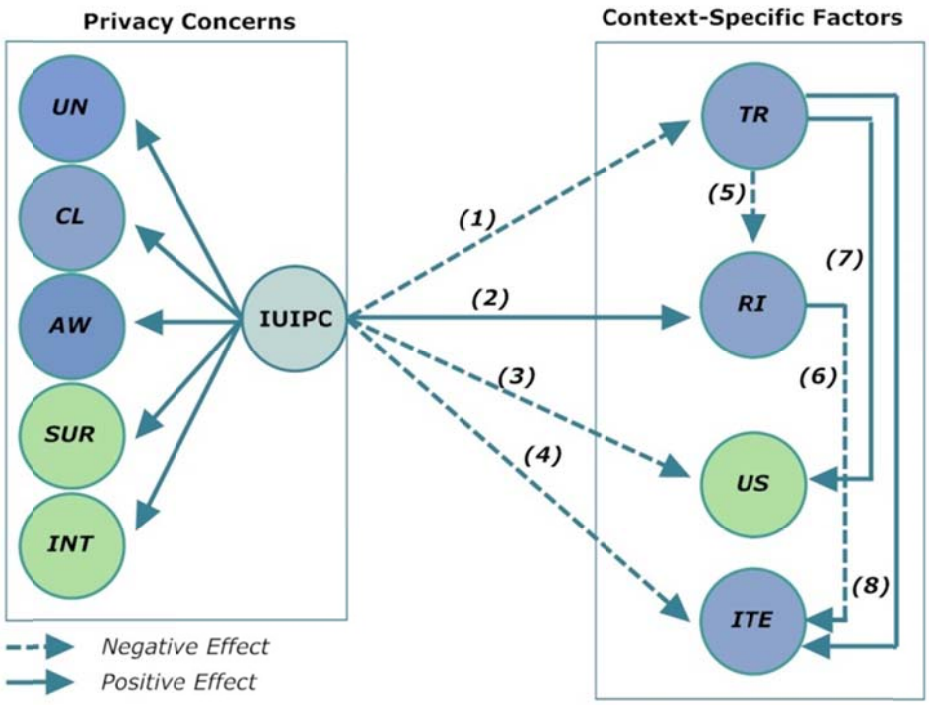

Figure 3.7: IUIPC Model variables relationships

4 Analysis

In this chapter, we present the survey results and discuss them. The results are analyzed and discussed in the following order. First, we calculate the reliability and validity of our survey questionnaire and its responses. Then, the data collected is analyzed and explained based on linear regression analysis and PCA. Finally, we discuss these results in terms of IUIPC factors. The complete survey responses are included in Appendix B.

4.1 Reliability Analysis

As noted in Section 3.5.1, to determine if the survey responses are internally reliability we calculate Cronbach's α. In terms of reliability the higher the Cronbach's α value is the higher the level of consistency. In this research, results are considered reliable if as suggested by Nunnally [93] the calculated Cronbach's α is equal or greater than *0.5*. Table 4.1 shows the reliability test results of our survey questionnaire. In this table the alpha values range from *0.515* to *0.937*. Hence, all eight construct were assessed as internally consistent and reliable. In other words, all items in each construct measure what was intended and they will produce similar results if the same constructs are applied in a different test or at a different time. Appendix C shows the SPSS reliability test results.

Table 4.1: Reliability Test Results

Construct	Number of Items	Cronbach's α *
UN	3	0.515
CL	3	0.767
AW	4	0.840
SUR	2	0.745
INT	3	0.813
TR	3	0.867
RI	2	0.831
US	3	0.937
** Number (n) of responses; n = 30; Scale: 1 = Strongly Disagree to 7 = Strongly Agree*		

4.2 Validity Analysis

PCA with Varimax as rotation was conducted to assess the convergent validity of our measurement model. The results show that there are correlation coefficients greater than the suggested threshold of ±0.30, as shown in Appendix D. This indicates that those variables share a level of correlation. To assess that the data collected properly fit the factor analysis KMO MSA and the Bartelet's Test of Sphericity were performed. The index value of KMO for the set of variables studied is 0.539, which meets the minimum requirement criteria suggested by Hair et al. [95]. Hence, it was unnecessary to examine the Anti-Image Correlation Matrix. Additionally, the Sig. value in the Bartelet's Test is 0.00 that lead us to conclude the responses are valid and suitable. Table 4.2 shows KMO Test and Bartelet's Test results.

Table 4.2: KMO and Bartlett's Test

Test	Values	
KMO MSA	0.539	
Bartlett's Test of Sphericity	Approximate Chi-Square	601.174
	Df	276
	Sig.	0.000

As noted in Section 3.5.2, to obtain a clear pattern of the loadings we used a 3-factor structure based on the *'Scree test'* since when using the eigenvalue rule we obtained a 6-factor structure in which we were not able to clearly differentiate the load on the factors. In the 3-factor structure, the questions related to the items UN2 and UN3 were removed from the dataset as their loading factors did not reached the required level. After removing these two items from the dataset, the validity test was run again and the results were satisfactory. The removal of these two items allowed us to achieve greater validity during the subsequent data analysis. Detailed information and the interactions performed to go from a 6-factor to a 3-factor structure are shown in Appendix E.

A 3-factor structure with 22-scale loading accounted for 62.47% of the total variance as is shown in Appendix E. This indicates that by choosing three components out of 22 we were able to explain ~62% of the information from the original variables. Moreover, the loaded factors marked with values above 0.50 demonstrate that most items tended to measure the same construct. Hence, the results provide adequate evidence of convergent validity according to the approach highlighted in Section 3.5.2. The final loading factor table is shown in Table 4.3.

Table 4.3: Validity Test Results

Items	Factor 1	Factor 2	Factor 3
UN1		0.613	
CL1	0.636		
CL2	0.703		
CL3	0.786		
AW1	0.583		
AW2	0.798		
AW3	0.663		
AW4	0.791		
SUR1	0.727		
SUR2	0.768		
INT1	0.633		
INT2	0.750		
INT3	0.807		
TR1		-0.790	
TR2		-0.745	
TR3		-0.815	
RI1	0.517		
RI2	0.657		
US1			0.911
US2			0.930
US3			0.949
ITE1		-0.593	

4.3 IUIPC Factors

By using linear regression analysis techniques, we gained a deeper understanding of privacy concerns and their relationship with TR, RI, ITE and US from the point of view of individuals who are knowledgeable or have experience working with the technology under study. An overview of the relationships between the dependent variables and the independent variables and their corresponding coefficient and significance values are shown in Table 4.4 to Table 4.11.

The linear regression analysis results shows that for eight of these results, three (regression1, regression4, and regression7) were **not** *significant ($\rho > 0.10$)*; one was statistically *significant ($\rho < 0.10$)*(regression6); and four were very statistically *significant ($\rho < 0.01$ or $\rho < 0.05$)* (regression2, regression3, regression5, and regression8). The detailed results of the linear regression analysis are shown in Appendix F.

The relationship between TR and privacy concerns is shown in Table 4.4. These results show that their relationship was **not** statistically significant, since the ρ value results are **not** statistically significant *($\rho > 0.10$)*.

Table 4.4: Regression1: Privacy concerns predicted to influence 'Trust & Belief'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
TR		0.520	0.270	1.777		3.260
	UN				-0.310	-1.710
	CL				0.162	0.484
	AW				0-.311	-0.784
	SUR				-0.099	-0.364
	INT				-0.148	-0.613

Table 4.5 shows the relationship between RI and privacy concerns. It was statistically *significant ($\rho < 0.01$)* and they both strongly correlate to each other *($R=0.719$)*. R^2 equals *0.517*, thus *~52%* of the variance in the dependent variable can be explained by the independent variables. Moreover, with *F* equals to 5.*129* we conclude that the regression analysis results do **not** happen by chance and that the regression significantly improves our ability to predict the outcome. The analysis of the beta weights indicates that the variables UN *($\beta = 0.144$)*, CL *($\beta = 0.447$)*, AW *($\beta = -0.130$)*, and *($\beta = -0.113$)* were statistically *insignificant ($\rho > 0.10$)* to predict RI. However, there is a *significant* correlation for the variable SUR *($\beta = 0.610$ and $\rho < 0.01$)*.

Table 4.5: Regression2: Privacy concerns predicted to influence 'Risk-Thresholds'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
RI		0.719	0.517***	5.129		-1.506
	UN				0.144	0.978
	CL				0.447	1.637
	AW				-0.130	-0.403
	SUR				0.610***	2.759
	INT				-0.113	-0.577
****indicates a significant level at $\rho \leq 0.01$*						

Regression3 shown on Table 4.6 presents the relationship between ITE and privacy concerns. The probability of the *F* statistics *(2.925)* for the overall regression was statistically *significant* ($\rho < 0.05$) and strongly correlates to each other *(R=0.615)*. Therefore, there is a relationship between the set of independent variables (in this case UN, and INT) measuring privacy concerns and the dependent variable ITE. The beta weights results show that UN ($\beta = -0.443$, $\rho < 0.01$) and INT ($\beta = -0.530$, $\rho < 0.01$) are statistically *significant* in predicting ITE with a negative relationship.

Table 4.6: Regression3: Privacy concerns predicted to influence Behavioral-Intention'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
ITE		0.615	0.379**	2.925		4.471
	UN				-0.443***	-2.647
	CL				0.037	0.121
	AW				0.091	0.250
	SUR				0.042	0.166
	INT				-0.530**	-2.385
***indicates a significant level at ρ≤0.05, ***indicates a significant level at ρ≤0.01*						

The results shown in

Table 4.7 suggest that privacy concerns do **not** have an effect on US. The ρ value for this regression was $\rho > 0.10$. This indicates that the relationship between US and privacy concerns (UN, CL, AW, SUR, and INT) was **not** statistically *significant*.

Table 4.7: Regression4: Privacy concerns predicted to influence perceived-usefulness'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
US		0.260	0.68	0.350		1.580
	UN				-0.029	-0.139
	CL				0.396	1.046
	AW				-0.392	-0.875
	SUR				0.325	1.060
	INT				-0.213	-0.783

The impact RI has on TR is shown in Table 4.8. The results show a statically *significant* relationship between these variables ($F = 4.663$, $\rho < 0.05$) with a weak relationship between each other as indicates $R=0.378$. The value of R^2 equal to *0.143* indicates that *~15%* of the variance in TR can be explained by RI. The beta weigh of $\beta = -0.378$ indicates the direction of the relationship between the dependent variable and the independent variable was inverse.

Table 4.8: Regression5: 'Risk-thresholds' predicted to influence 'Trust & Belief'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
TR		0.378	0.143**	4.663		5.282
	RI				-0.378**	-2.159
**indicates a significant level at $\rho \leq 0.05$*						

Table 4.9 shows the relationship between RI and ITE. The probability of $F = 3.149$ is statistically *significant* ($\rho < 0.10$). The R value equals to *0.318* indicates a weak correlation between the variables and R^2 results indicates that *~10%* of the variance in RI can be explained by ITE ($R^2 = 0.101$). Moreover, the beta weight show a negative relationship between the variables ($\beta = -0.318$).

Table 4.9: Regression6: 'Behavioral-intention' predicted to influence 'Risk-Thresholds'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
RI		0.318	0.101*	3.149		8.208
	ITE				-0.318	-1.774
*indicates a significant level at $\rho \leq 0.10$						

The relationship between US and TR is shown in Table 4.10. The results indicate that US does **not** influence TR, since the ρ value result is **not** statistically *significant* ($\rho > 0.10$).

Table 4.10: Regression7: 'Perceived-usefulness' predicted to influence 'Trust & Belief'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
TR		0.005	0.00	0.001		2.396
	US				-0.005	-0.028

Table 4.11 presents the results for ITE and TR. The R^2 results indicate that *~18%* of the variance in TR can be explained by ITE ($R^2 = 0.181$). The probability of $F = 6.168$ was statistically *significant* ($\rho < 0.05$). Moreover, this set of variables weakly correlates to each other with $R = 0.181$. It also reveals that ITE positively influences TR. This means that there is a direct effect of ITE on TR.

Table 4.11: Regression8: 'Behavioral-intention' predicted to influence 'Trust & Belief'

Dependent Variable	Independent Variable	R	R^2	F	β	τ
TR		0.425	0.181**	6.168		1.748
	ITE				0.425	2.483
**indicates a significant level at $\rho \leq 0.05$*						

Figure 4.1 shows the relationships among the variables of the IUIPC model based on the linear regression results.

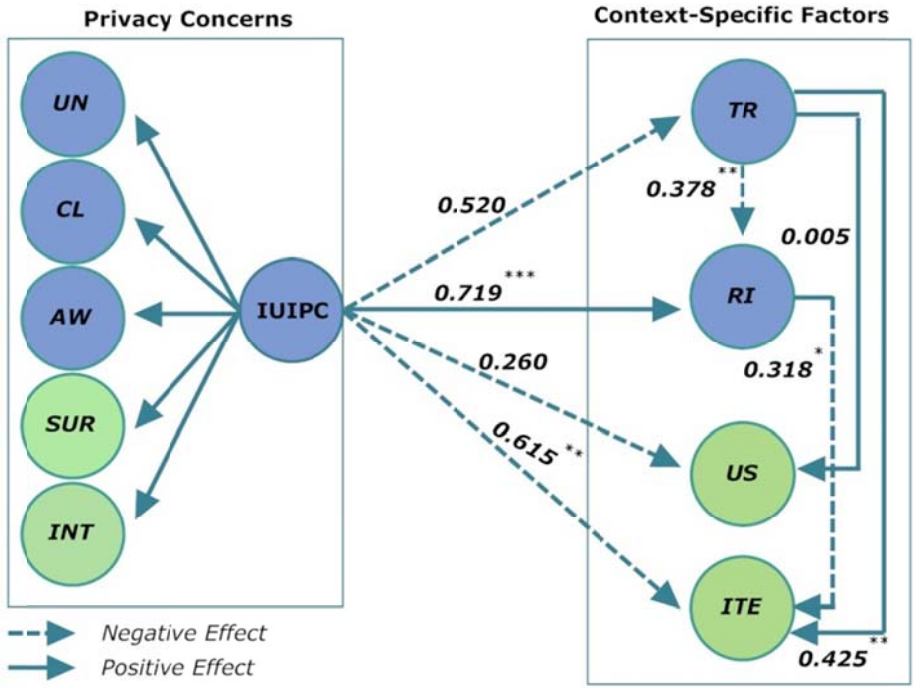

Figure 4.1: Linear Regression Analysis Results

To discover underlying dimensions among the privacy concerns measured and get a better understanding of the five privacy concerns explored in this research – UN, CL AW, SUR, and INT – PCA with varimax rotation was conducted. Appendix G gives detailed information about this PCA calculation.

To determine if the data collected for these five privacy concerns properly fit for PCA, the approach highlighted in Section 3.5.2 was followed. The correlation matrix results (see Table 4.13), marks at least two coefficients over the minimum loading of ±*0.30*. Moreover, the index value of the KMO is 0.600 which meets the minimum requirement criteria suggested by Hair et al. [95]. The *Sig*. value in the Bartelet's Test was 0.00. This outcome indicates the responses are valid and suitable for PCA. Table 4.12 shows the KMO Test and Bartelet's Test results.

Table 4.12: KMO and Bartlett's Test

Test	Values	
KMO MSA	0.600	
Bartlett's Test of Sphericity	Approximate Chi-Square	64.504
	Df	10
	Sig.	0.000

According to correlation matrix results of Table 4.13, the relationship among the variable UNA with CL, AW, SUR, and INT resulted in loading values above the minimum of ±0.30. As a result, the level of correlation of these variables is acceptable. AW *(r=0.826, ρ < 0.01)*, SUR *(r=0.320, ρ < 0.05)* and INT *(r= 0.393, ρ < 0.05)* when correlated with CL received positive significant correlations. Additionally, AW correlated with SUR *(r= 0.590, ρ < 0.01)* and INT *(r= 0.523, ρ < 0.05)* also received positive significant correlations. The last variable correlated SUR and INT also showed positive correlation *(r= 0.659, ρ < 0.01)*.

Table 4.13: Correlation Matrix Privacy Concerns

Privacy Concerns	UN	CL	AW	SUR	INT
UN	1.000				
CL	0.193	1.000			
AW	0.232	**0.826*****	1.000		
SUR	0.049	**0.320****	**0.590*****	1.000	
INT	0.002	**0.393****	**0.523****	**0.659*****	1.000

**significant level at ρ≤0.10, **significant level at ρ≤0.05, ***significant level at ρ≤0.01*

Table 4.14 shows the rotated component matrix based on the eigenvalues criteria. The first factor is associated with the largest eigenvalue and it accounts for *~54%* of the variance. Thus it is the most influential factor. The second factor accounted for *~21%* of the variance. Together, both factors accounted for *75%* of the total variance. Most of the five privacy concerns coefficient loaded highly – above *0.50*. Furthermore, they are sorted by the most substantial coefficient relevant in defining the factor's dimensionality.

The first factor shows high loading for INT, SUR and AW. Therefore, the fear for being watched and intrusion in the home environments are the most influential privacy concerns, followed by concerns about the organizations' practices. The second factor has high loading basically for UN. The high correlation among the variables in each factor indicates a common underlying dimension. For the first factor the dimension can be interpreted as more related to *territorial privacy* and for the second factor more related to the correct use of the information collected (*information privacy*). The rotated matrix did have variables with substantial loading on more than one factor. In this case CL proved to be complex variables. Therefore, control of the dissemination of personal information (CL), exist in both of the resulted dimensions.

Table 4.14: Factor Loading Privacy Concerns

Privacy Concerns	Factors	
	1	2
INT	**0.855**	
SUR	**0.847**	
AW	**0.790**	
CL	*0.627*	*0.565*
UN		**0.864**

Figure 4.2 illustrates the results for personal information protection. The majority of the survey participants admitted the importance of privacy protecting mechanisms as a fundamental component to safeguard their personal information from the dangers related with abuse or misuse of their personal data. Around *90%* of the participants feel their personal information should be protected by technical means. In addition to this technical aspect, 83% consider their data should be protected by international laws and *50%* consider, it should be protected by regulations proposed by private organizations. These results give a clear indication that experts working with smart home environments demand the design of legal and technical forces that provide a reasonable level of privacy protection.

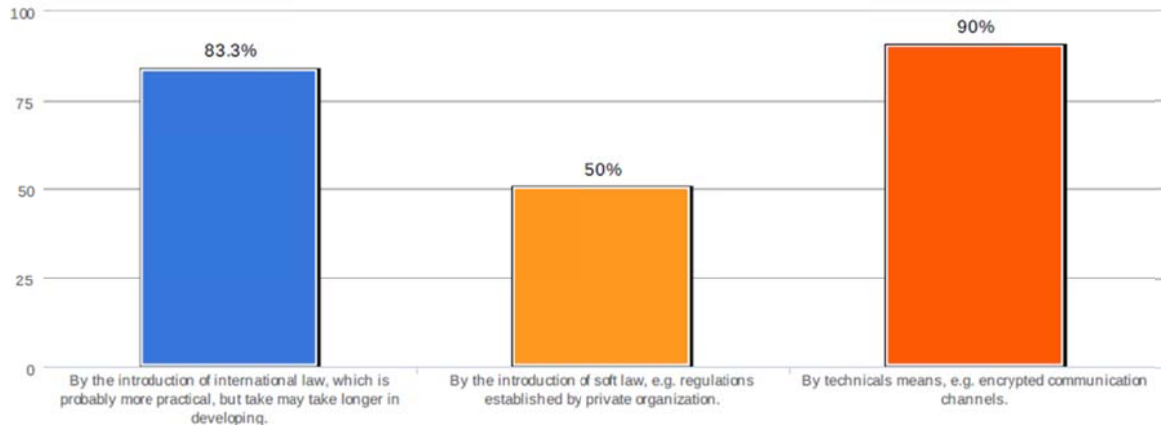

Figure 4.2: Data Protection

Figure 4.3 and Figure 4.4 indicate survey participants expect to receive detailed and constant notification of personal information uses. As shown in Figure 4.3, *73%* would like to receive detailed indication with regard to their personal information uses. Figure 4.4 indicates that *70%* of the participants prefer to receive notifications every time their personal information is used.

Figure 4.3: Level of details of personal information Notifications

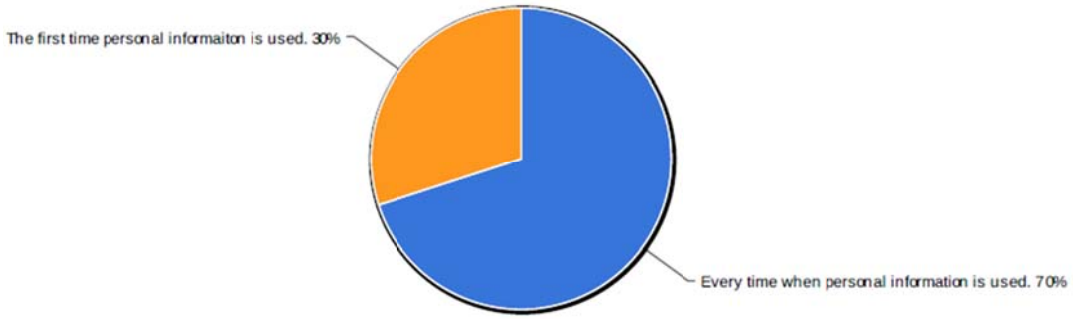

Figure 4.4: Frequency of Notifications

4.4 Discussion

Ubiquitous computing technology causes several concerns about the privacy of personal information [73]. The vast majority of the users are concerned about their privacy when interacting with this technology [59]. This highlights the need for smart home service providers and designers of smart home technologies to understand the informational privacy concerns of users. For these reason, this section discusses the results from the previous section in order to derive guidelines for service providers and designers of smart home technology. The guidelines below should be viewed as suggestions rather than mandatory principles to follow. In the domain of ubiquitous computing general principles are difficult to foresee due to the nature and complexity of the *ubicomp* technology. These guidelines were devised based upon the results of the linear regression and principal component analysis. We expect the arguments below to help designers and service providers of smart home environments to better address inhabitants' privacy concerns by designing appealing privacy-aware applications for smart home.

Our findings indicate that in the context of smart home environments privacy concerns exist as a real threat especially due to fact these concerns have a significant influence on the perceived risk related to misuse of the personal information and the resulting intention of the survey participants to disclose personal data. When evaluating risk, the results (in Table 4.5) support the authors of the IUIPC framework when they stated that there is a positive relationship between privacy concerns and perceived risks. This positive relationship means

that the more concerned survey participants are about their privacy, the higher the level of risk they are going to perceive. Therefore, for the respondents their privacy concerns increase with the degree to which they believe there could be a potential hazard associated with the release of their personal information.

The behavioral-intention outcome shown in Table 4.6 is also influenced by privacy concerns. These results pointed out that the participants of the survey were more willing to adopt the technology and allow the release of their personal information when they are less concerned about their privacy. These findings matched the results of Malhotra, Kim, and Agarwal [63] which indicate that the greater the level of privacy concerns people perceive, the lower their willingness to adopt systems which might expose their personal information.

Results further indicate that privacy concerns did **not** influence the trust participants have in smart home service providers and did **not** influence how useful smart home environments are considered, as shown in Table 4.4 and Table 4.7 (respectively). Table 4.4 reveals that even when the participants of the survey have high concerns about the privacy of their personal information, they do trust the vendor or service provider of smart home in charge of handling their data. This outcome is inconsistence with Malhotra, Kim, and Agarwal [63] findings which state that the higher the level of privacy concern, the less trust exist on the vendors or service providers. This discrepancy may be related to the fact that every person in the target population in my survey had experience working with the technology being studied; hence they know and trust the infrastructure behind it. To some degree, the survey participants believe that companies will **not** misuse their personal information and that their data would be handled in a proper, trustworthy, and appropriate way while keeping in mind the best interest of the users. Additionally, the results shown in Table 4.7 indicates that even when the survey participants are concerned about the privacy of their personal information, these concerns do **not** influence the participants' belief that using smart home technology will positively enhance the quality of their life. Therefore, the benefits the participants perceive of smart home technology overshadow any potential risk associated with the misuse of their data.

'Trust & Belief' was a *significant* affected by 'Risk-Thresholds' and Behavioral-Intention as Table 4.8 and Table 4.11 illustrate. Table 4.8 points out that the survey participants trust smart home service providers to properly handle their personal information only if they perceive there are few unexpected problems associated with misuse of their data. This relationship is in alignment with the findings of Malhotra, Kim, and Agarwal [63]. Additionally, the results shown in Table 4.11 demonstrate that the survey participants are willing to adopt smart home environments and disclose their personal data because they trust services provider **not** to misuse their personal information. This finding also corroborates the results presented by Malhotra, Kim, and Agarwal[63] which indicate the more trust people feel, the stronger their intention to engage in the exchange of their data in a smart home environment. In essence, service providers and designers of smart home should build trust beliefs in inhabitants and reduce the perceived risk, as these will encourage inhabitants to perceive the disclosure of their personal data as beneficial.

The results also suggest that perceived usefulness do **not** influence the trust of the participant in services providers. According to the theory developed by Ajzen and Fishbein [105] if individuals perceived as beneficial the adoption of certain technology to increase the quality of their life, these individuals are more likely to trust their personal information would be handled correctly. However, this relationship could **not** be found in our results (as shown in Table 4.10). This is a surprising result since the survey participants, even when they are experts in the field and work developing the technology, consider smart home environments useless. In addition, perceived risk has a significant influence on the intention of the respondents to adopt smart home services. The higher the perceived risk-threshold, the less willingness respondents are to disclose their data by adopting smart home technology due to the fear associated with the misuse of their personal information. Therefore, the relationship pointed out by Malhotra, Kim, and Agarwal [63] that perception of higher risk leads to lower intention to deal with smart home technology was corroborated in our findings (as shown in Table 4.9).

The most influential privacy concerns resulted to be intrusion and surveillance (see Table 4.14). Participants describe to be majorly concerns about the possibility of intrusion and being watched. The aggressive data collection and logging capabilities of ubiquitous computing systems induce the participants to believe that their behavior within their home could be constantly monitored and tracked. The lack of confidence generated by these privacy concerns represent a challenge for designer of smart home technology and further investigation is needed to be done to explore the best way to handle these aspects via a privacy aware system.

Another aspect from this research to highlight is that there is a fundamental need to design privacy protecting mechanisms for smart homes that take into account the legal aspects of privacy as *83%* of the participants believe their data should be protected by international laws and *50%* of them believe that their data should be protected by regulations proposed by private organizations. Although researchers have suggested several privacy models, methods, and techniques (see Section 2.9), none of these suggestions take into account the legal perspective. Therefore, we consider it important to take into account legal aspects of privacy when design a smart home system. Moreover, participants expect to receive detailed and constant notifications every time their personal information is shared or accessed by a service provider. This highlights the important for the survey respondents knowing details of what information about them is being captured and shared with which service provider. This supports the findings of Westin [36] who postulated that when it comes to ubiquitous computing technology and environments people feel the need to know when, how, and to what extent their information is shared with other parties.

5 Conclusions and Future work

In this chapter the conclusion are presented and suggestions made for further research as well as stating some of the limitations of this study that impact the quality of our findings.

5.1 Conclusions

The motivation for this thesis project was to understand privacy concerns in the context of smart home environments. Langheinrich [4] pointed out that the aggressive data collection practices by intelligent devices and the possibility that inhabitants personal information could be misused or maliciously disclosed creates discomfort and concerns among the users of such smart home environments. To address these concerns an initial step is to comprehend privacy concerns of experts in the field.

The study described in this thesis was designed to explore and understand the relationships among privacy concerns, the field experts' perceived trust of service providers (Trust & Belief), the willingness of the field experts to adopt smart home services and to allow the release of their personal information (Behavioral-Intention), the field experts' perception of the usefulness of smart environments (Perceived-Usefulness), and the risk perception associated with the disclosure of their personal data (Risk-Thresholds). The findings from the analysis presented in Chapter 4 provide clear support for five out of eight of the relationships explored. The three major predictors are the influence that privacy concerns have on risk-threshold, behavioral-intention, and the influence of behavioral-intention on trust & belief.

The fact that smart homes will become more common in the future, means that service providers and designers of these smart home environments must understand the issues exposed in this work and create privacy-awareness tools that appeal to the inhabitants of these smart home environments. Appropriate privacy-aware tools could help ease inhabitants' privacy concerns, improve the inhabitants' understanding of their privacy and autonomy, and support the inhabitants' perception of control over the data generated by smart devices.

5.2 Limitations

As with all research, this study also faced some limitations. First, we did not have access to inhabitants currently living in smart home environments - as we had originally planned. It was impossible to have access to such a population because the expected smart home environment is still under development phase and the technology is slowly shifting from research laboratories to commercial viable implementations. For this reason, our results are biased in that the sample population selected was knowledgeable or had experience working with at least one of the technologies that enable smart home environments. Therefore, this population is more willing to adopt smart home services and to trust the technology and infrastructure behind it. Consequently, a randomly sampling of participants is needed to increase the validity of our findings. Second, the scenario used in this study might have conditioned the survey responses. Thirdly, the sample size was too small. The use of a convenience sample of $n=30$ restricted the use of more

rigorous data analysis methods, such as SEM, linear structural relation (LISREL), or partial least square (PLS). Moreover, correlations among the coefficients that might be significant (even when they are weak) were not detected. A small sample size from a specific geographic area, in this case Sweden, represents a limitation for the generalization of these results to other population. Fourth, there were deficiencies in the measurement. The construct measuring Unauthorized Secondary uses (UN) exhibited unreasonable validity. Therefore, the items UN2 and UN3 were removed from the data analysis. Fifth, our IUIPC framework and the modification may not have covered all necessary aspects for our study of *ubicomp* environments. Therefore, future research should be done to develop instruments that natively evaluate privacy concerns in smart home environment.

Despite all of these limitations, we believe this study provides reasonable results given that biases and limitation are to some degree inevitable in research.

5.3 Future work

This study helps to identified potential future research to extend the body of knowledge about informational privacy concerns in ubiquitous computing environments, such as smart homes. Future studies should attempt to transform privacy concerns into a set of requirements for the design of smart home environments and services using data from these environments. Moreover, an effort should be made to increase the validity of the findings presented by reviewing and rechecking the current survey results. Researchers could explore other dimensions of privacy concerns in order to create an instrument that naturally supports smart home environments. It would be interesting to explore best practices and approaches that would help to ease privacy concerns by using suitable software applications. Particularly, interesting would be approaches that alleviate the privacy concerns of intrusion and surveillance.

Along with the above proposals, researchers could individually investigate each of the privacy concerns exposed in previous section (UN, INT, SUR, AW, CL), by creating of low-fidelity prototypes or technology probes to trigger feelings (e.g., by irritating them) to study privacy or to stimulate privacy awareness of the inhabitants. The inhabitants' reactions can be captured and analyzed by the use of ESM to provide a deeper understanding of privacy concerns and determine if the concept of privacy is evolving in the context of a smart home.

As there is still vague data protection rules in Sweden, further work should be done to bring the attention of the government and advance in the implementation of strictest data protection and privacy laws for ubiquitous computing technology. The legal norms must protect individuals from harmful consequences related to the collection of their personal data and rigorously regulate the maintenance, use, access and dissemination of the personal information.

5.4 Required reflections

One reflection about this thesis work is that in the **social** aspects we considered the discussion should be used in conjunction with the guidelines that we have suggested by business enterprises working with any of the key technologies that enable *ubicomp*. Another positive social effect is that by further transforming these

guideline into technical requirements that later are implemented in the technological infrastructure could enhance privacy in a smart home. This would lead to good balance of trust and respect from the inhabitants towards the *ubicomp* technology. The aim is not that the *ubicomp* system necessarily achieves perfect privacy and total security, but rather since the concept of privacy is dynamic and subjective from person to person we should seek to ease privacy concerns of the inhabitants of smart home environments.

One **ethical** aspect considered in this study is associated with the fact that the nature of term privacy by itself generates ethical discussions among practitioners and researchers. Moreover, the term privacy is one of the most prominent and permanent social issues discussed in *ubicomp* environments. U*bicomp* systems are coming to our homes. This is likely to bring dramatic changes in our understanding and perception of privacy. Therefore, service providers and designers of smart home environments should clearly understand inhabitants' privacy concerns in order to make these changes less disturbing for inhabitants as well as reducing the possibility for unethical practices by integrating privacy awareness tools into smart home environments.

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Appendix A: Smart Environment Experience

Basic Instructions:

The information collected by this scenario-based survey is used for the purpose of investigating privacy factors in Smart Home Environments. The survey follows a simple pattern: a scenario is presented and then several statements about privacy factor should be responded based on the scenario description.
It will take you approx. 10 minutes to complete this survey.

Your feedback is highly relevant for the design and implementation of privacy tools in Smart Home Environments. You will be able to see the results of this survey on http://kth.diva-portal.org when my thesis report is published.

Enjoy the survey now!

Disclaimer and Privacy Statement

Your answers will be treated anonymously, but we retain information about your age, gender and country of residence to analyze the results of the questionnaire and remove any bias. We will strictly follow the EU directive 95/46/EC ("Protection of personal data") and national guidelines.

Scenario:

Imagine you live in the below smart home environment.

Through a computer you are able to control every aspect of your house such as lighting, security, entertainment system, climate, and so on. At any time, you can connect remotely to your home, through mobile devices and change the settings of your house as desired.

The house is embedded with a several type of sensors, actuators, displays and computers elements that interact and exchange information between each other to give your home the smart functionality and provide you with automated, customized, and comfortable services.

The lights switch automatically on when you enter to a room and switch off when you leave. If there is too bright light coming through the windows, the blinds adjust automatically to the sun intensity. Your home adjusts the heating/cooling system, by combining data from outdoor and indoor temperature, weather forecast from the Internet, and your personal preferences.

The computer control and monitor the operation of all the household appliances such as washing machine, dishwasher, water heater, heating system, etc; with the goal of having an smarter and energy-efficient home.

When leaving home for work and closing your door, every window opened is automatically closed and the heating, electric devices, water and gas are turn off automatically to assure nothing would happen while you are not there.

Alerts about events that you might want to know about while you are gone like water leaks and unexpected access to your home are send to your mobile or to the police, security or utility company who can connect to your home and see what is happening. Health devices, which are capable of transmitting data to doctors and other relevant agencies in case of needed, are also connected to your home network.

Moreover, in your house you have the below smart devices:

- **"Smart" Refrigerator:** It generates your shopping list automatically and sends it to the supermarket. It also advices healthy receipts based on the items inside. Moreover, it notifies you when products (e.g. Milk, eggs) are running low.
- **"Smart" Smoke Detector:** Smoke sensors in your home turn off oven, microwave oven, and other devices and turn on the fan to ventilate the smoke out of the kitchen.
- **"Smart" Bathroom:** The toilet analyzed your waste (e.g. urine or excrement) and advises about any possible medical condition. The analysis is send periodically to doctor who will record it as a part of your medical history.
- **"Smart" Wardrobe:** The wardrobe digitally looks up the weather forecast and advises what to wear based on the outside environment.

General Information:

How old are you?
( ) under 25
( ) 25-35
( ) 35-44
( ) 45-54
( ) Over 65

Users Privacy Factors:

1. Companies or other institutions accessing the information generated by my smart home devices should not use my personal information for other purposes than the original without notifying me or getting my authorization.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

2. Companies or other institutions accessing the information generated by my smart home devices should not share my information with other companies/entities without my authorization.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

3. Companies or other institutions accessing the information generated by my smart home devices should never sell my personal information in their computer databases to other companies.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

4. It is important to me to control how much information is collected by my smart home devices.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

5. I consider consumer privacy is a matter of consumers' right to exercise control and autonomy over decisions about how their information is collected, used, and shared.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

6. I believe that my privacy is invaded when I am unable to control how much information is collected by my smart devices.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

7. It is important to me that I am aware and knowledgeable about how my personal information will be used.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

8. It is important to me to know how much personal information is collected by the smart devices.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

9. It is important to me to know who much personal information is collected by the companies/institutions accessing the information generated by my home.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

10. I am concerned that smart devices are collecting too much information about me.

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

11. I am concerned that companies or other institutions accessing the information generated by my home may be monitoring me.*

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

12. I am concern that companies accessing the information produced by my smart home devices may be analyzing my behavioral patterns based on my devices usages (e.g how long TV was ON or OFF).*

( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

13. I feel that as a result of living in a smart home environment, external may know more about me than needed and I do not feel comfortable with it.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

14. I believe that as a result of having an smart home, information about me that I consider private is now more readily available to others than I would want.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

15. I feel that as a result of interacting with my smart home, information about me is out there that, if used, will invade my privacy.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

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Users Privacy Factors:

16. Companies or other institutions accessing the information generated by my smart home devices provide their services in a safe way. Therefore, my personal information can be exchanged with others.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

17. Companies or other institutions accessing the information produced by my smart home devices would be trustworthy in handling my personal information.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

18. I trust that companies or other institutions accessing the information generated by my smart home devices would keep my best interests in mind when dealing with (the information).*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

19. It would be risky to give my personal information (the one generated by my smart home devices) to companies or other institutions.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

20. Providing companies or other institutions with information generated by my smart home devices would involve many unexpected problems.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

21. I expect that by living in a Smart Home Environment I can improve my performance.
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

22. I expect that by living in a Smart Home Environment I can improve my productivity.
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

23. I expect that by living in a Smart Home Environment I can improve my effectiveness.
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

24. I am likely to disclose my personal information in order to receive services for my smart home enviroment.*
( ) Strongly disagree ( ) Moderately disagree ( ) Slightly disagree ( ) Neutral ( ) Slightly agree ( ) Moderately agree ( ) Strongly agree

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Evaluations:

25. How do you expected your personal information to be best protected?
[ ] By the introduction of international law, which is probably more practical, but take may take longer in developing.
[ ] By the introduction of soft law, e.g. regulations established by private organization.
[ ] By technical means, e.g. encrypted communication channels.

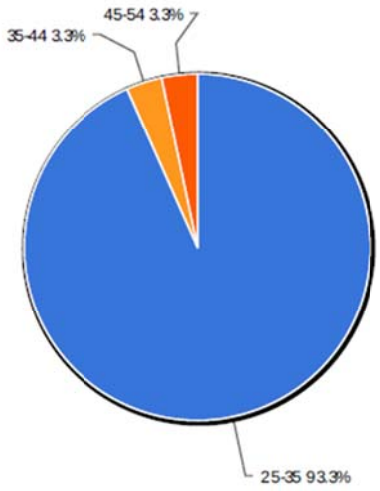
26. How would you like to be informed that your personal information will be used?
[ ] General indication without any details of potential use of personal information.
[ ] Specific and detailed indication including potential use of personal information.

27. How often would you like to be informed that your personal information will be used?
( ) Every time when personal information is used.
( ) The first time personal information is used.

Thank You!

Appendix B: Survey Results

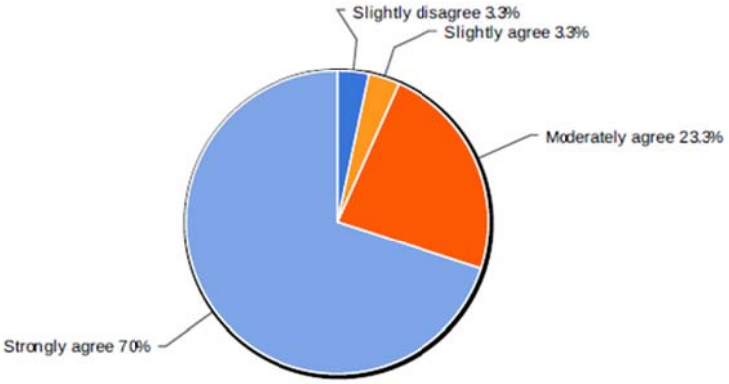
1. How old are you?



Value	Count	Percent %
under 25	0	0.0%
25-35	28	93.3%
35-44	1	3.3%
45-54	1	3.3%
Over 65	0	0.0%

Statistics	
Total Responses	30
Sum	780.0
Avg.	26.0
StdDev	4.0
Max	45.0

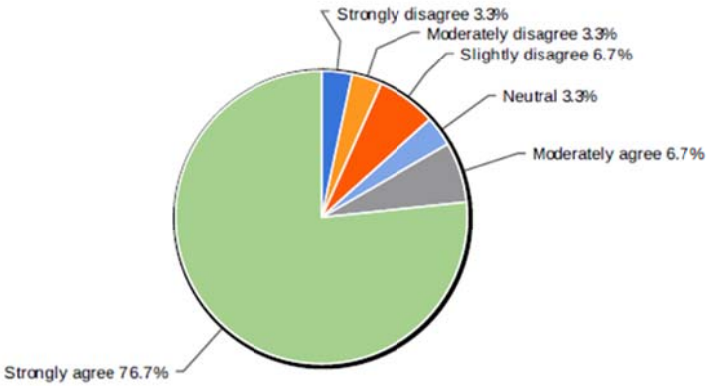
3. Companies or other institutions accessing the information generated by my smart home devices should not use my personal information for other purposes than the original without notifying me or getting my authorization.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	0	0.0%
Slightly disagree	1	3.3%
Neutral	0	0.0%
Slightly agree	1	3.3%
Moderately agree	7	23.3%
Strongly agree	21	70.0%

Statistics	
Total Responses	30
Sum	197.0
Avg.	6.6
StdDev	0.8
Max	7.0

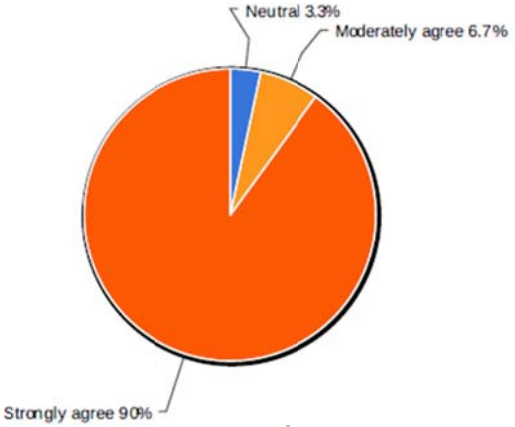
4. Companies or other institutions accessing the information generated by my smart home devices should not share my information with other companies/entities without my authorization.



Value	Count	Percent %
Strongly disagree	1	3.3%
Moderately disagree	1	3.3%
Slightly disagree	2	6.7%
Neutral	1	3.3%
Slightly agree	0	0.0%
Moderately agree	2	6.7%
Strongly agree	23	76.7%

Statistics	
Total Responses	30
Sum	186.0
Avg.	6.2
StdDev	1.7
Max	7.0

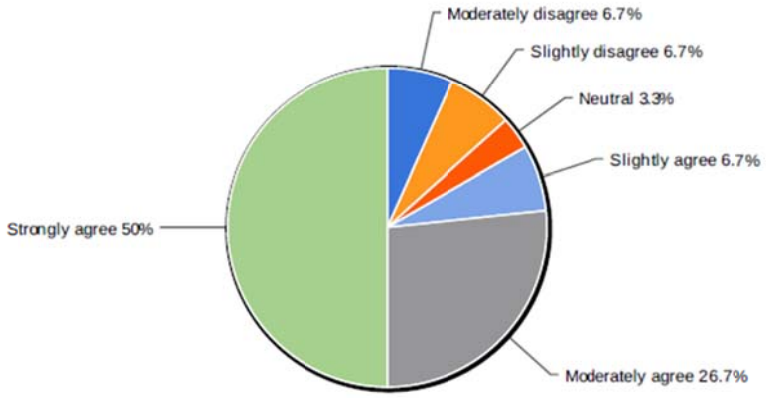
5. Companies or other institutions accessing the information generated by my smart home devices should never sell my personal information in their computer databases to other companies.



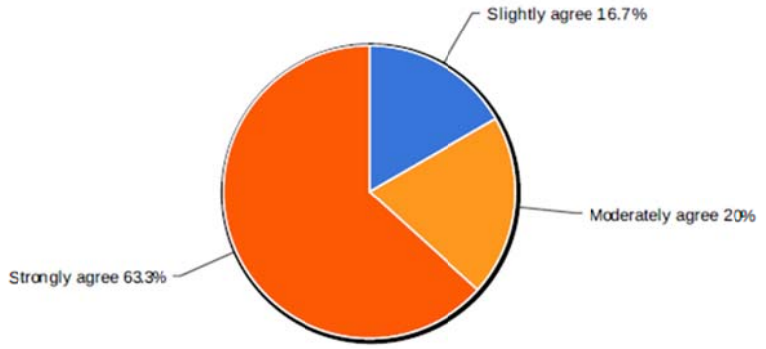
Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	0	0.0%
Slightly disagree	0	0.0%
Neutral	1	3.3%
Slightly agree	0	0.0%
Moderately agree	2	6.7%
Strongly agree	27	90.0%

Statistics	
Total Responses	30
Sum	205.0
Avg.	6.8
StdDev	0.6
Max	7.0

6. It is important to me to control how much information is collected by my smart home devices.



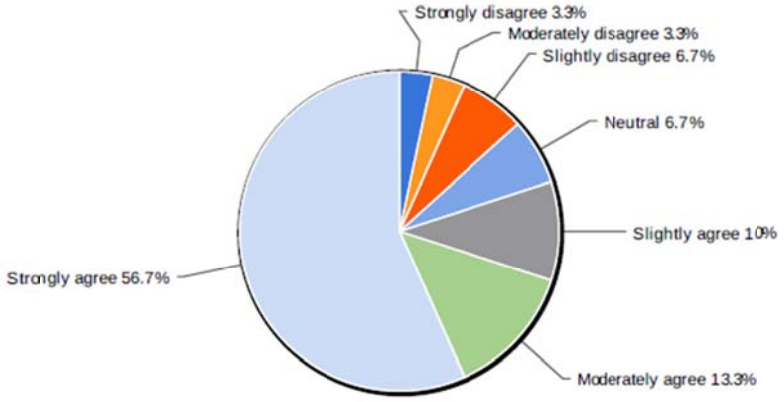
7. I consider consumer privacy is a matter of consumers' right to exercise control and autonomy over decisions about how their information is collected, used, and shared.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	0	0.0%
Slightly disagree	0	0.0%
Neutral	0	0.0%
Slightly agree	5	16.7%
Moderately agree	6	20.0%
Strongly agree	19	63.3%

Statistics	
Total Responses	30
Sum	194.0
Avg.	6.5
StdDev	0.8
Max	7.0

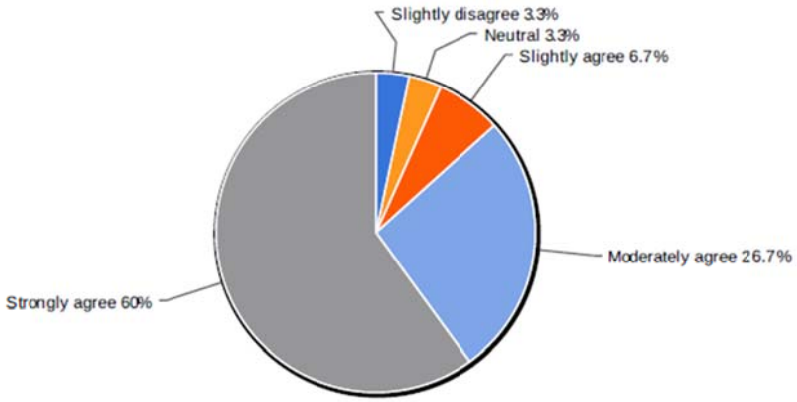
8. I believe that my privacy is invaded when I am unable to control how much information is collected by my smart devices.



Value	Count	Percent %
Strongly disagree	1	3.3%
Moderately disagree	1	3.3%
Slightly disagree	2	6.7%
Neutral	2	6.7%
Slightly agree	3	10.0%
Moderately agree	4	13.3%
Strongly agree	17	56.7%

Statistics	
Total Responses	30
Sum	175.0
Avg.	5.8
StdDev	1.7
Max	7.0

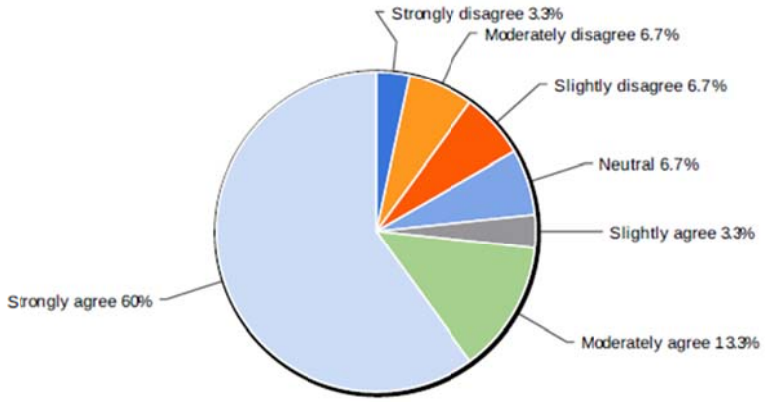
9. It is important to me that I am aware and knowledgeable about how my personal information will be used.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	0	0.0%
Slightly disagree	1	3.3%
Neutral	1	3.3%
Slightly agree	2	6.7%
Moderately agree	8	26.7%
Strongly agree	18	60.0%

Statistics	
Total Responses	30
Sum	191.0
Avg.	6.4
StdDev	1.0
Max	7.0

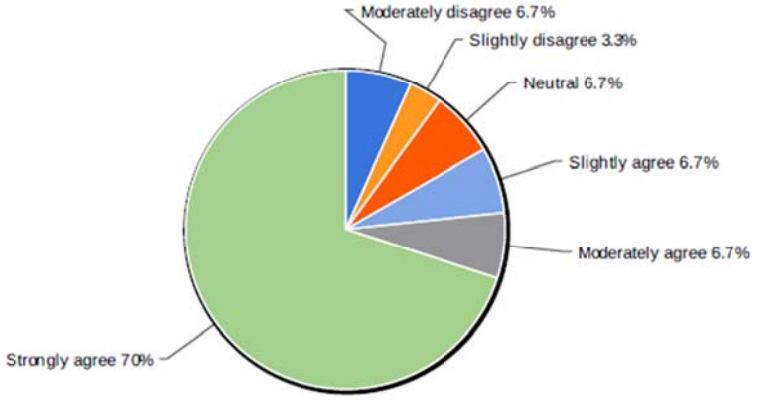
10. It is important to me to know how much personal information is collected by the smart devices.



Value	Count	Percent %
Strongly disagree	1	3.3%
Moderately disagree	2	6.7%
Slightly disagree	2	6.7%
Neutral	2	6.7%
Slightly agree	1	3.3%
Moderately agree	4	13.3%
Strongly agree	18	60.0%

Statistics	
Total Responses	30
Sum	174.0
Avg.	5.8
StdDev	1.8
Max	7.0

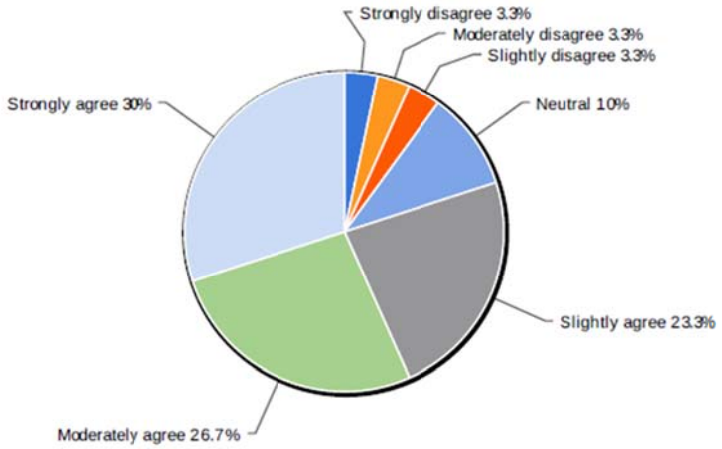
11. It is important to me to know who much personal information is collected by the companies/institutions accessing the information generated by my home.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	2	6.7%
Slightly disagree	1	3.3%
Neutral	2	6.7%
Slightly agree	2	6.7%
Moderately agree	2	6.7%
Strongly agree	21	70.0%

Statistics	
Total Responses	30
Sum	184.0
Avg.	6.1
StdDev	1.5
Max	7.0

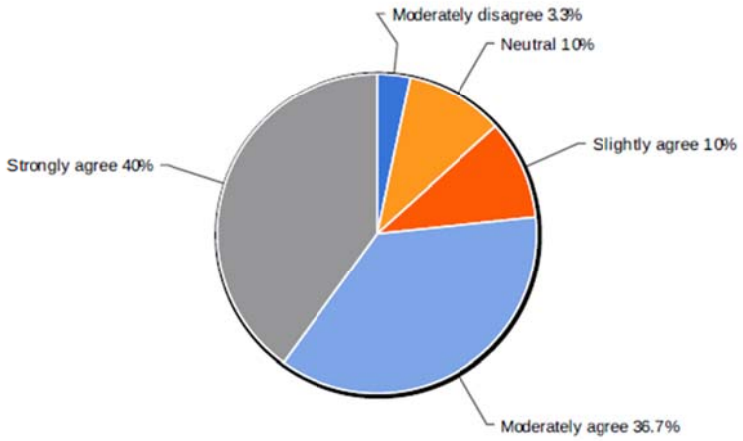
12. I am concerned that smart devices are collecting too much information about me.



Value	Count	Percent %
Strongly disagree	1	3.3%
Moderately disagree	1	3.3%
Slightly disagree	1	3.3%
Neutral	3	10.0%
Slightly agree	7	23.3%
Moderately agree	8	26.7%
Strongly agree	9	30.0%

Statistics	
Total Responses	30
Sum	164.0
Avg.	5.5
StdDev	1.5
Max	7.0

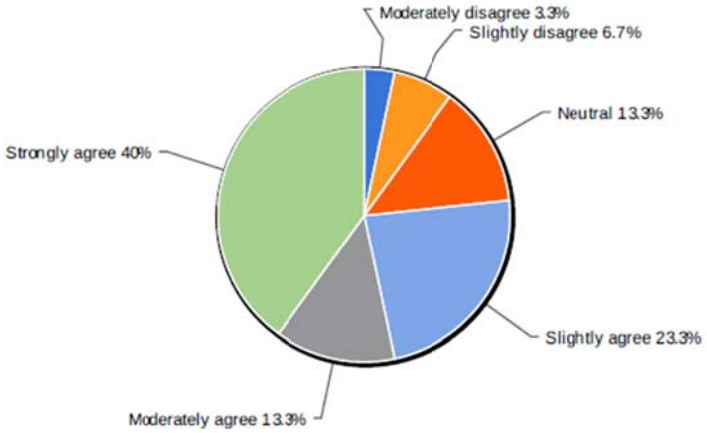
13. I am concerned that companies or other institutions accesing the information generated by my home may be monitoring me.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	1	3.3%
Slightly disagree	0	0.0%
Neutral	3	10.0%
Slightly agree	3	10.0%
Moderately agree	11	36.7%
Strongly agree	12	40.0%

Statistics	
Total Responses	30
Sum	179.0
Avg.	6.0
StdDev	1.2
Max	7.0

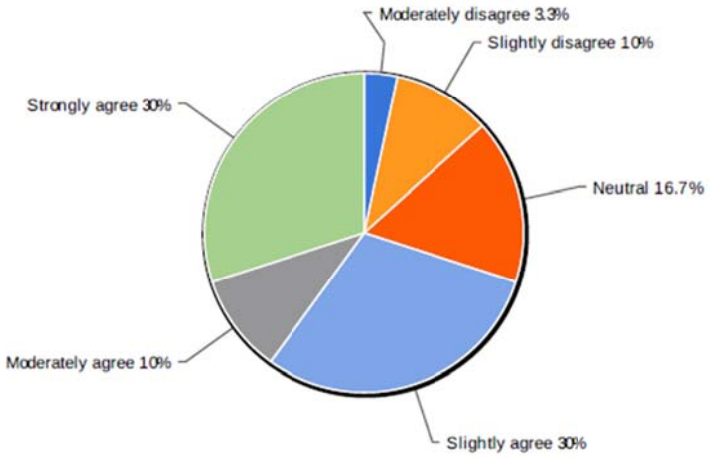
14. I am concern that companies accesing the information produced by my smart home devies may be analyzing my behaivoral patterns based on my devices usages (e.g how long TV was ON or OFF).



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	1	3.3%
Slightly disagree	2	6.7%
Neutral	4	13.3%
Slightly agree	7	23.3%
Moderately agree	4	13.3%
Strongly agree	12	40.0%

Statistics	
Total Responses	30
Sum	167.0
Avg.	5.6
StdDev	1.5
Max	7.0

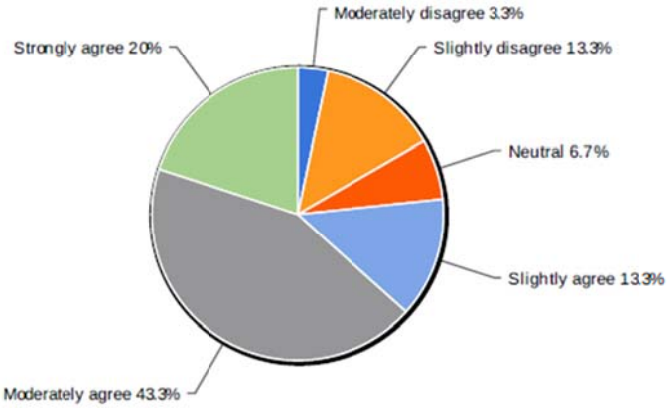
15. I feel that as a result of living with in a smart home enviroment, external may know more about me than needed and I do not feel comfortable with it.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	1	3.3%
Slightly disagree	3	10.0%
Neutral	5	16.7%
Slightly agree	9	30.0%
Moderately agree	3	10.0%
Strongly agree	9	30.0%

Statistics	
Total Responses	30
Sum	157.0
Avg.	5.2
StdDev	1.5
Max	7.0

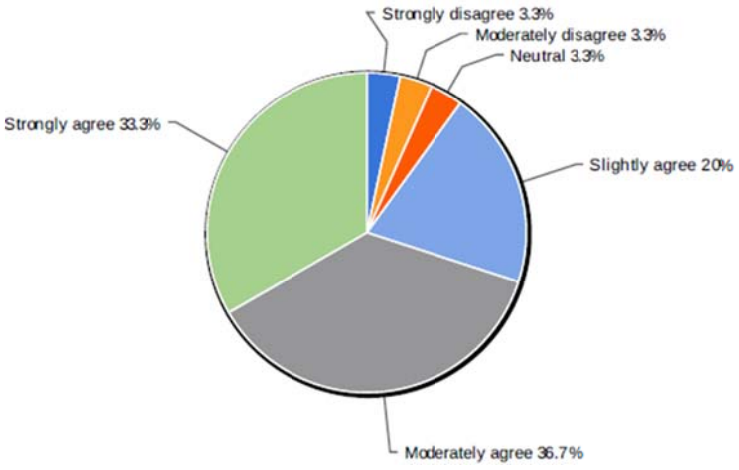
16. I believe that as a result of having an smart home, information about me that I consider private is now more readily available to others than I would want.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	1	3.3%
Slightly disagree	4	13.3%
Neutral	2	6.7%
Slightly agree	4	13.3%
Moderately agree	13	43.3%
Strongly agree	6	20.0%

Statistics	
Total Responses	30
Sum	162.0
Avg.	5.4
StdDev	1.4
Max	7.0

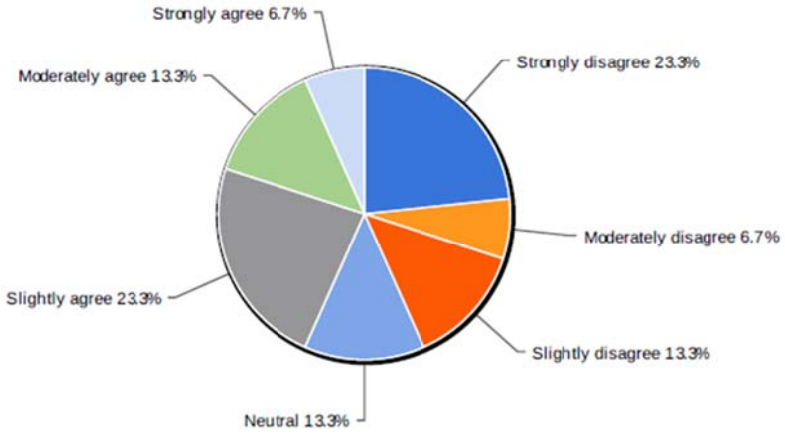
17. I feel that as a result of interacting with my smart home, information about me is out there that, if used, will invade my privacy.



Value	Count	Percent %
Strongly disagree	1	3.3%
Moderately disagree	1	3.3%
Slightly disagree	0	0.0%
Neutral	1	3.3%
Slightly agree	6	20.0%
Moderately agree	11	36.7%
Strongly agree	10	33.3%

Statistics	
Total Responses	30
Sum	173.0
Avg.	5.8
StdDev	1.4
Max	7.0

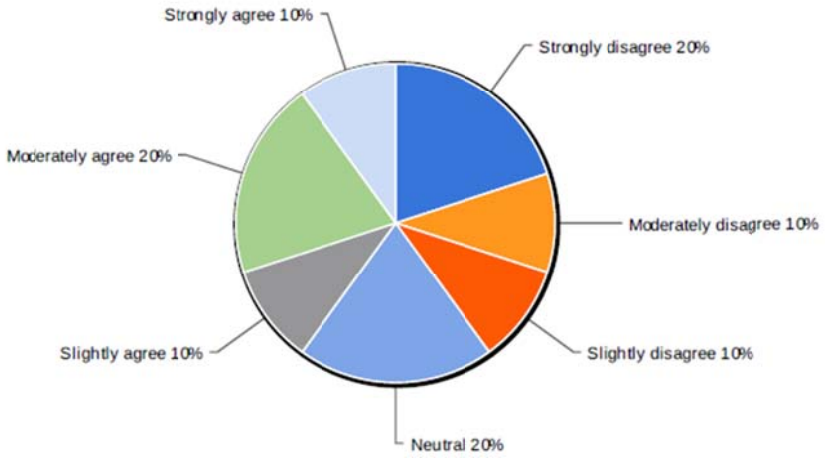
18. Companies or other institutions accesing the information generated by my smart home devices provide their services in a safe way. Therefore, my personal information can be exchanged with others.



Value	Count	Percent %
Strongly disagree	7	23.3%
Moderately disagree	2	6.7%
Slightly disagree	4	13.3%
Neutral	4	13.3%
Slightly agree	7	23.3%
Moderately agree	4	13.3%
Strongly agree	2	6.7%

Statistics	
Total Responses	30
Sum	112.0
Avg.	3.7
StdDev	1.9
Max	7.0

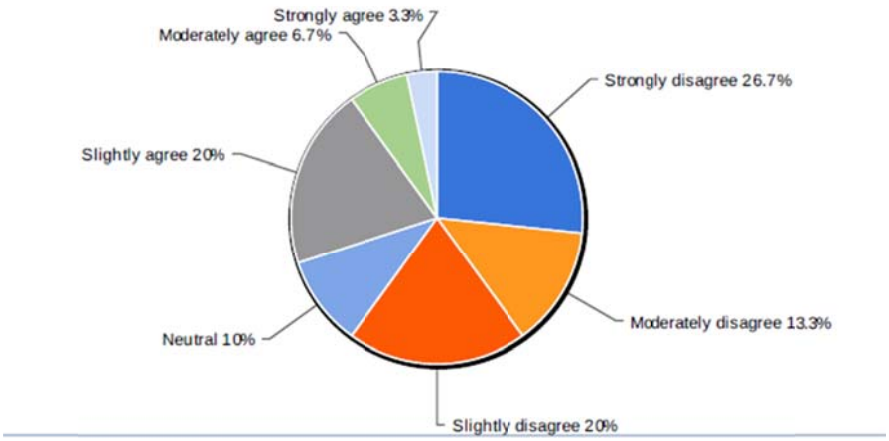
19. Companies or other institutions accesing the information produced by my smart home devices would be trustworthy in handling my personal information.



Value	Count	Percent %
Strongly disagree	6	20.0%
Moderately disagree	3	10.0%
Slightly disagree	3	10.0%
Neutral	6	20.0%
Slightly agree	3	10.0%
Moderately agree	6	20.0%
Strongly agree	3	10.0%

Statistics	
Total Responses	30
Sum	117.0
Avg.	3.9
StdDev	2.0
Max	7.0

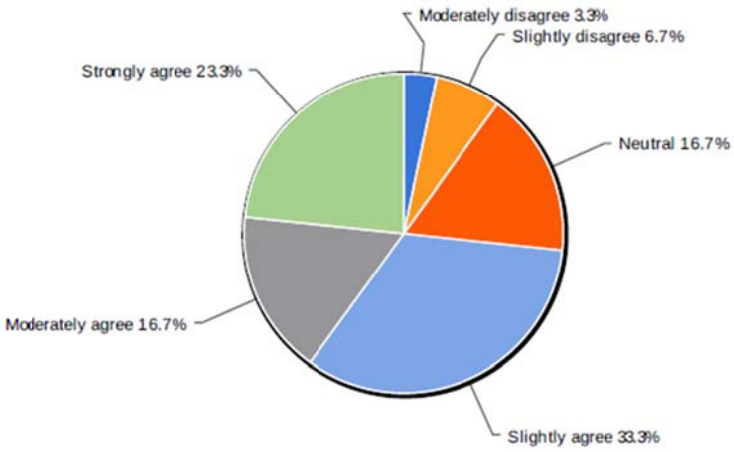
20. I trust that companies or other institutions accesing the information generated by my smart home devices would keep my best interests in mind when dealing with (the information).



Value	Count	Percent %
Strongly disagree	8	26.7%
Moderately disagree	4	13.3%
Slightly disagree	6	20.0%
Neutral	3	10.0%
Slightly agree	6	20.0%
Moderately agree	2	6.7%
Strongly agree	1	3.3%

Statistics	
Total Responses	30
Sum	95.0
Avg.	3.2
StdDev	1.8
Max	7.0

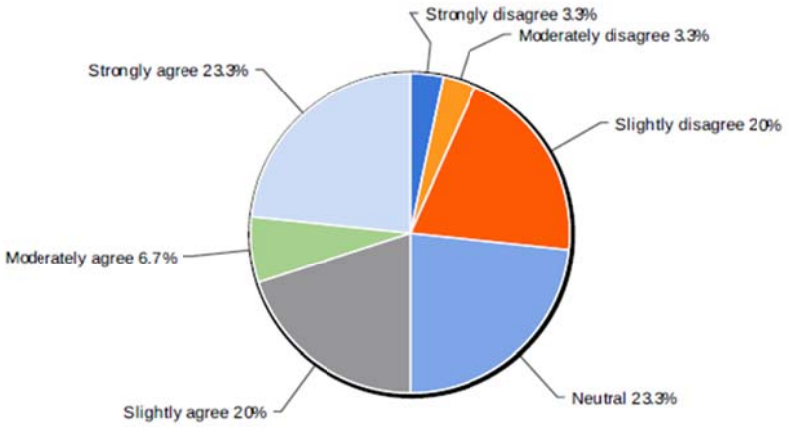
21. It would be risky to give my personal information (the one generated by my smart home devices) to comapnies or other institutions.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	1	3.3%
Slightly disagree	2	6.7%
Neutral	5	16.7%
Slightly agree	10	33.3%
Moderately agree	5	16.7%
Strongly agree	7	23.3%

Statistics	
Total Responses	30
Sum	157.0
Avg.	5.2
StdDev	1.3
Max	7.0

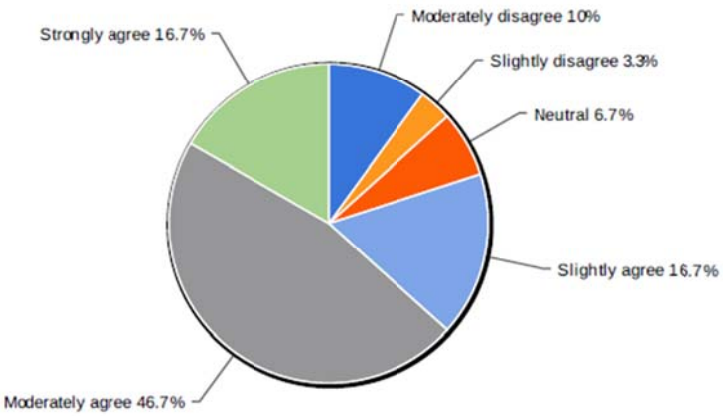
22. Providing companies or other institutions with information generated by my smart home devices would involve many unexpected problems.



Value	Count	Percent %
Strongly disagree	1	3.3%
Moderately disagree	1	3.3%
Slightly disagree	6	20.0%
Neutral	7	23.3%
Slightly agree	6	20.0%
Moderately agree	2	6.7%
Strongly agree	7	23.3%

Statistics	
Total Responses	30
Sum	140.0
Avg.	4.7
StdDev	1.7
Max	7.0

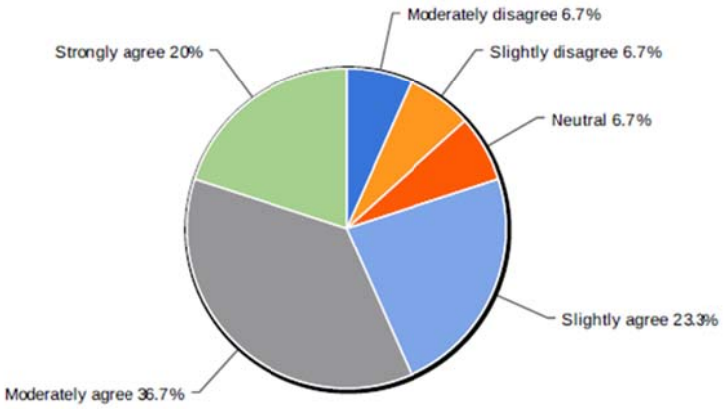
23. I expect that by living in a Smart Home Environment I can improve my performance.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	3	10.0%
Slightly disagree	1	3.3%
Neutral	2	6.7%
Slightly agree	5	16.7%
Moderately agree	14	46.7%
Strongly agree	5	16.7%

Statistics	
Total Responses	30
Sum	161.0
Avg.	5.4
StdDev	1.4
Max	7.0

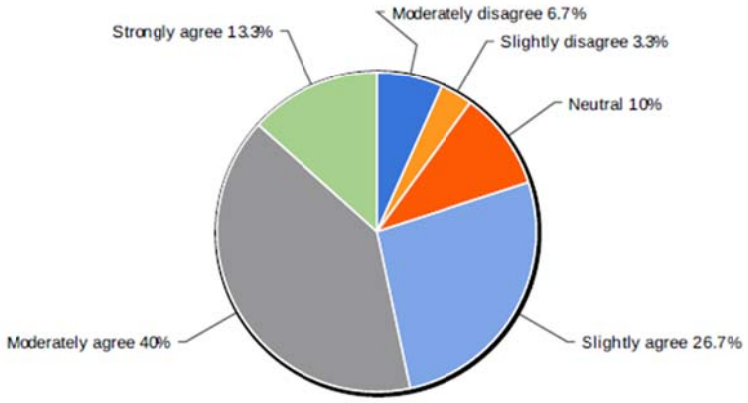
24. I expect that by living in a Smart Home Environment I can improve my productivity.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	2	6.7%
Slightly disagree	2	6.7%
Neutral	2	6.7%
Slightly agree	7	23.3%
Moderately agree	11	36.7%
Strongly agree	6	20.0%

Statistics	
Total Responses	30
Sum	161.0
Avg.	5.4
StdDev	1.4
Max	7.0

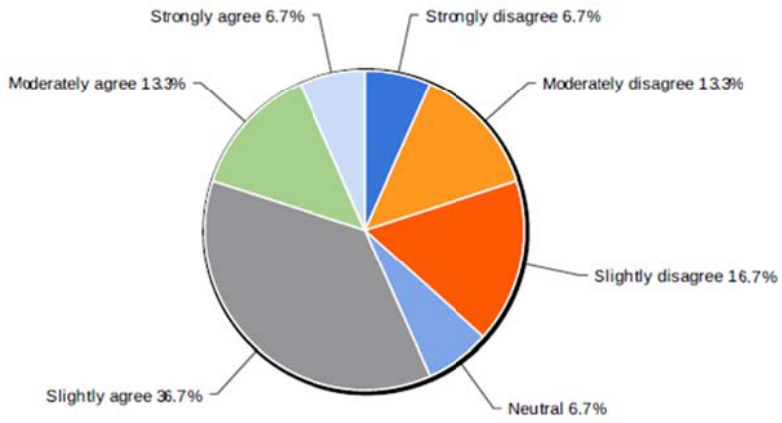
25. I expect that by living in a Smart Home Environment I can improve my effectiveness.



Value	Count	Percent %
Strongly disagree	0	0.0%
Moderately disagree	2	6.7%
Slightly disagree	1	3.3%
Neutral	3	10.0%
Slightly agree	8	26.7%
Moderately agree	12	40.0%
Strongly agree	4	13.3%

Statistics	
Total Responses	30
Sum	159.0
Avg.	5.3
StdDev	1.3
Max	7.0

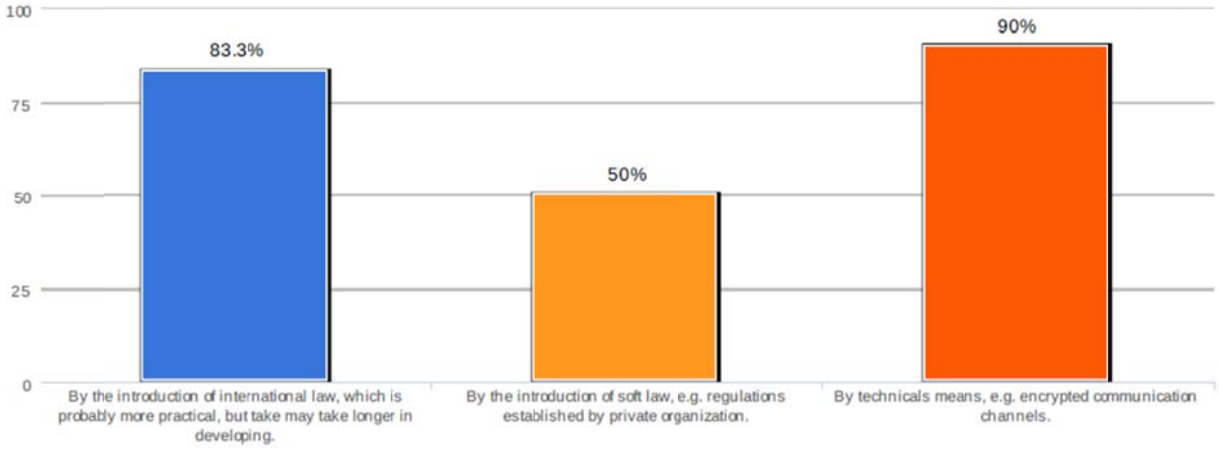
26. I am likely to disclose my personal information in order to recieve services for my smart home enviroment.



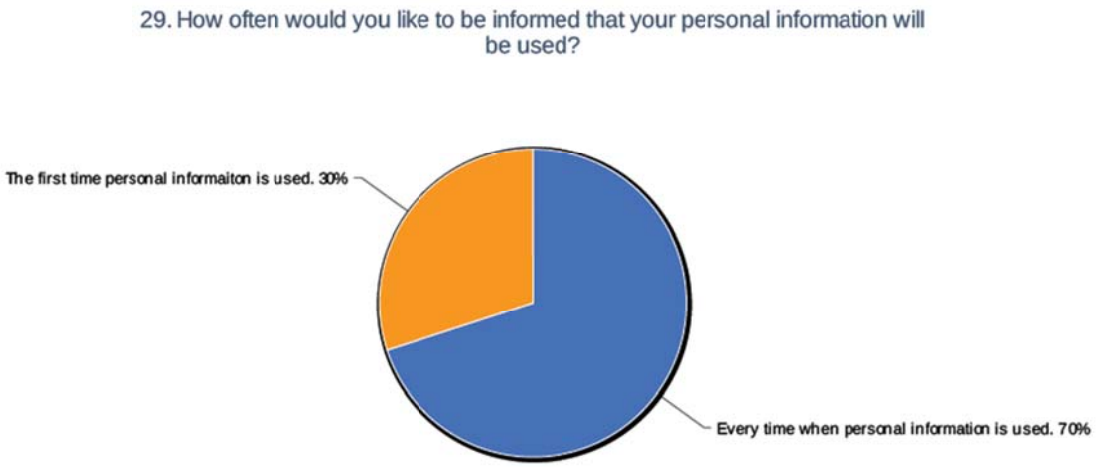
Value	Count	Percent %
Strongly disagree	2	6.7%
Moderately disagree	4	13.3%
Slightly disagree	5	16.7%
Neutral	2	6.7%
Slightly agree	11	36.7%
Moderately agree	4	13.3%
Strongly agree	2	6.7%

Statistics	
Total Responses	30
Sum	126.0
Avg.	4.2
StdDev	1.7
Max	7.0

27. How do you expected your personal information to be best protected?




28. How would you like to be informed that your personal information will be used?
100
75
50
25
0
40%
73.3%
General indication without any details of potential use of personal information.
Specific and detailed indication including portential use of personal information.


29. How often would you like to be informed that your personal information will be used?
The first time personal informaiton is used. 30%
Every time when personal information is used. 70%

Appendix C: SPSS Statistics Results - Reliability

Cronbach's Unauthorized Secondary Uses (UN)

Cronbach's Alpha	N of Items
0.515	3

Mean	Variance	Std. Deviation	N of Items
19.60	6.110	2.472	3

Cronbach's Control (CL)

Cronbach's Alpha	N of Items
0.767	3

Mean	Variance	Std. Deviation	N of Items
18.20	12.303	3.508	3

Cronbach's Awareness (AW)

Cronbach's Alpha	N of Items
0.840	4

Mean	Variance	Std. Deviation	N of Items
23.77	25.220	5.022	4

Cronbach's Surveillance (SUR)

Cronbach's Alpha	N of Items
0.745	2

Mean	Variance	Std. Deviation	N of Items
11.53	5.844	2.417	2

Cronbach's Intrusion (INT)

Cronbach's Alpha	N of Items
0.813	3

Mean	Variance	Std. Deviation	N of Items
16.40	13.697	3.701	3

Cronbach's Trust (TR)

Cronbach's Alpha	N of Items
0.867	3

Mean	Variance	Std. Deviation	N of Items
10.80	27.200	5.215	3

Cronbach’s Risk (RI)

Cronbach's Alpha	N of Items
0.831	2

Mean	Variance	Std. Deviation	N of Items
9.90	8.024	2.833	2

Cronbach’s Usefulness (US)

Cronbach's Alpha	N of Items
0.937	3

Mean	Variance	Std. Deviation	N of Items
16.03	15.826	3.978	3

Appendix D: Correlation Matrix

	UN1	UN2	UN3	CL1	*CL2*	CL3	AW1	AW2	AW3	AW4	SUR1	SUR2	INT1	INT2	INT3	TR1	TR2	TR3	RI1	RI2	US1	US2	US3	ITE1
UN1	1.00	.437	.192	.198	*.211*	.113	.232	.224	.249	.080	.085	.010	.055	.006	-.029	-.314	-.318	-.283	.179	.230	-.034	.050	-.095	-.414
UN2	.437	1.00	.307	-.018	*-.073*	-.070	.056	-.019	-.023	.120	.119	-.074	.090	.135	.090	-.055	.133	.089	-.199	.060	-.249	-.144	-.303	-.360
UN3	.192	.307	1.00	.168	*.250*	-.028	.165	.031	.025	.201	.183	.033	.085	.204	.034	-.186	-.127	-.229	.093	.253	-.007	.075	.022	-.172
CL1	.198	-.018	.168	1.00	*.723*	.609	.599	.798	.836	.420	.198	.250	.474	.343	.282	-.210	-.239	-.273	.516	.484	.001	.048	-.035	-.097
CL2	.211	-.073	.250	.723	*1.00*	.473	.661	.639	.711	.473	.273	.513	.713	.572	.474	-.499	-.251	-.350	.581	.518	.056	.089	.061	-.363
CL3	.113	-.070	-.028	.609	*.473*	1.00	.377	.805	.646	.728	.605	.458	.395	.462	.599	-.266	-.365	-.309	.430	.513	-.070	-.002	-.159	-.237
AW1	.232	.056	.165	.599	*.661*	.377	1.00	.540	.517	.487	.351	.391	.430	.304	.424	-.454	-.233	-.205	.494	.463	.046	.290	.071	-.290
AW2	.224	-.019	.031	.798	*.639*	.805	.540	1.00	.870	.583	.498	.468	.418	.471	.589	-.388	-.347	-.284	.442	.592	-.060	.067	-.031	-.217
AW3	.249	-.023	.025	.836	*.711*	.646	.517	.870	1.00	.470	.327	.368	.387	.391	.367	-.376	-.316	-.310	.357	.460	.038	.131	.047	-.153
AW4	.080	.120	.201	.420	*.473*	.728	.487	.583	.470	1.00	.613	.604	.328	.536	.658	-.318	-.321	-.102	.341	.484	.013	-.002	-.088	-.235
SUR1	.085	.119	.183	.198	*.273*	.605	.351	.498	.327	.613	1.00	.605	.330	.603	.768	-.261	-.332	-.137	.255	.515	.026	.206	.006	-.382
SUR2	.010	-.074	.033	.250	*.513*	.458	.391	.468	.368	.604	.605	1.00	.458	.689	.570	-.323	-.219	-.062	.499	.590	.028	.143	.069	-.116
INT1	.055	.090	.085	.474	*.713*	.395	.430	.418	.387	.328	.330	.458	1.00	.624	.483	-.378	-.117	-.246	.453	.350	-.072	-.042	-.197	-.351
INT2	.006	.135	.204	.343	*.572*	.462	.304	.471	.391	.536	.603	.689	.624	1.00	.671	-.326	-.314	-.199	.288	.429	.108	.112	.081	-.277
INT3	-.029	.090	.034	.282	*.474*	.599	.424	.589	.367	.658	.768	.570	.483	.671	1.00	-.412	-.278	-.117	.331	.509	-.073	-.058	-.108	-.494
TR1	-.314	-.055	-.186	-.210	*-.499*	-.266	-.454	-.388	-.376	-.318	-.261	-.323	-.378	-.326	-.412	1.00	.687	.663	-.476	-.460	-.048	-.050	.032	.552
TR2	-.318	.133	-.127	-.239	*-.251*	-.365	-.233	-.347	-.316	-.321	-.332	-.219	-.117	-.314	-.278	.687	1.00	.713	-.350	-.367	-.226	-.105	-.090	.363
TR3	-.283	.089	-.229	-.273	*-.350*	-.309	-.205	-.284	-.310	-.102	-.137	-.062	-.246	-.199	-.117	.663	.713	1.00	-.240	-.127	.169	.175	.252	.403
RI1	.179	-.199	.093	.516	*.581*	.430	.494	.442	.357	.341	.255	.499	.453	.288	.331	-.476	-.350	-.240	1.00	.728	.180	.168	.095	-.352
RI2	.230	.060	.253	.484	*.518*	.513	.463	.592	.460	.484	.515	.590	.350	.429	.509	-.460	-.367	-.127	.728	1.00	.273	.396	.264	-.290
US1	-.034	-.249	-.007	.001	*.056*	-.070	.046	-.060	.038	.013	.026	.028	-.072	.108	-.073	-.048	-.226	.169	.180	.273	1.00	.804	.848	.136
US2	.050	-.144	.075	.048	*.089*	-.002	.290	.067	.131	-.002	.206	.143	-.042	.112	-.058	-.050	-.105	.175	.168	.396	.804	1.00	.857	.169
US3	-.095	-.303	.022	-.035	*.061*	-.159	.071	-.031	.047	-.088	.006	.069	-.197	.081	-.108	.032	-.090	.252	.095	.264	.848	.857	1.00	.298
ITE1	-.414	-.360	-.172	-.097	*-.363*	-.237	-.290	-.217	-.153	-.235	-.382	-.116	-.351	-.277	-.494	.552	.363	.403	-.352	-.290	.136	.169	.298	1.00

Appendix E: SPSS Statistics Results – Validity

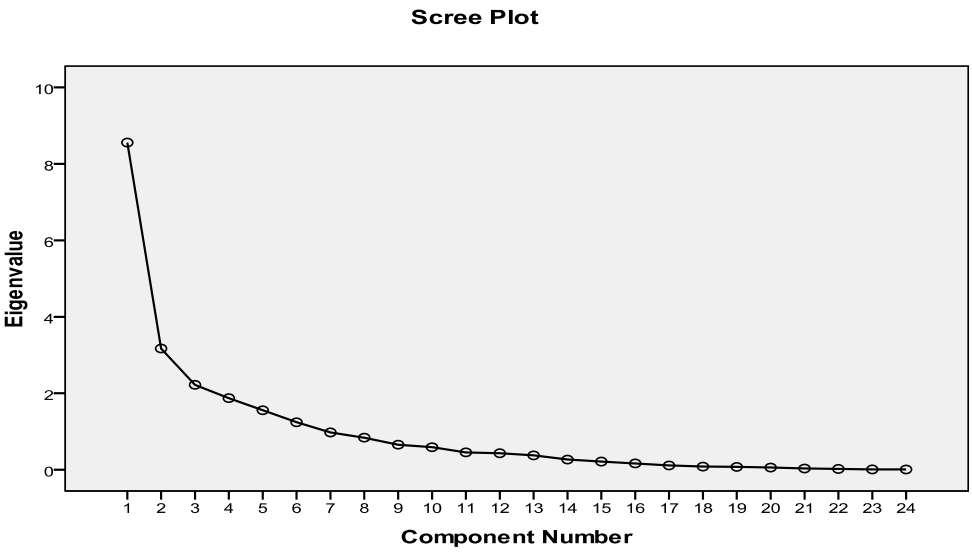
6-factor loading structure with 24 items
Interaction No. 1

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
UN1						0.683
UN2						0.849
UN3						0.583
CL1		0.886				
CL2		0.532			0.717	
CL3	0.600	0.655				
AW1		0.501				
AW2		0.824				
AW3		0.869				
AW4	0.730					
SUR1	0.878					
SUR2	0.706					
INT1					0.769	
INT2	0.704					
INT3	0.848					
TR1				0.772		
TR2				0.873		
TR3				0.854		
RI1					0.579	
RI2						
US1			0.908			
US2			0.933			
US3			0.947			
ITE1						

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 6 iterations.


Scree Plot
Eigenvalue
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Component Number

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.557	35.654	35.654	8.557	35.654	35.654	4.287	17.863	17.863
2	3.172	13.216	48.870	3.172	13.216	48.870	3.864	16.099	33.962
3	2.222	9.257	58.126	2.222	9.257	58.126	3.098	12.908	46.870
4	1.873	7.805	65.931	1.873	7.805	65.931	2.837	11.820	58.690
5	1.557	6.488	72.419	1.557	6.488	72.419	2.563	10.678	69.368
6	1.243	5.178	77.597	1.243	5.178	77.597	1.975	8.229	77.597
7	0.977	4.069	81.666						
8	0.840	3.499	85.165						
9	0.656	2.733	87.899						
10	0.589	2.456	90.355						
11	0.455	1.894	92.249						
12	0.432	1.801	94.050						
13	0.377	1.570	95.620						
14	0.267	1.113	96.733						
15	0.215	0.895	97.628						
16	0.166	0.692	98.320						
17	0.113	0.470	98.790						
18	0.084	0.348	99.139						
19	0.075	0.314	99.452						
20	0.059	0.244	99.696						
21	0.034	0.141	99.837						
22	0.022	0.090	99.927						
23	0.009	0.039	99.966						
24	0.008	0.034	100.000						

3-factor loading structure with 24 items
Interaction No. 2

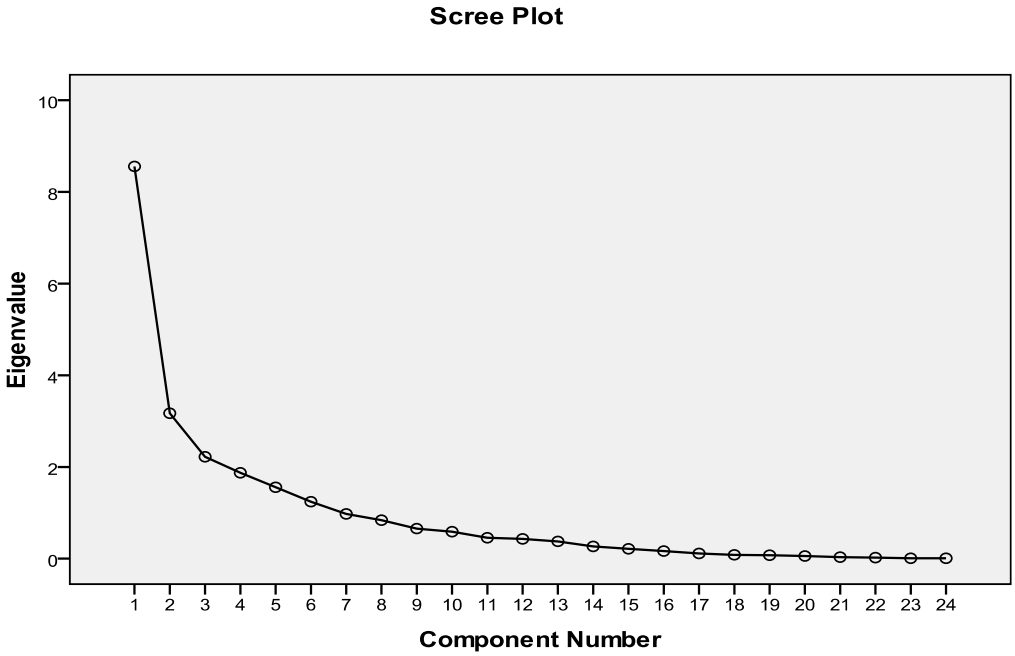
Rotated Component Matrix[a]

	Component		
	1	2	3
UN1		0.654	
UN2*			
UN3*			
CL1	0.664		
CL2	0.721		
CL3	0.806		
AW1	0.595		
AW2	0.823		
AW3	0.695		
AW4	0.782		
SUR1	0.706		
SUR2	0.761		
INT1	0.638		
INT2	0.735		
INT3	0.798		
TR1		-0.774	
TR2		-0.713	
TR3		-0.767	
RI1	0.541		
RI2	0.657		
US1			0.903
US2			0.907
US3			0.950
ITE1		-0.619	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

*. Removed in next interaction due to no loading value


Scree Plot
Eigenvalue
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Component Number

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.557	35.654	35.654	8.557	35.654	35.654	7.384	30.765	30.765
2	3.172	13.216	48.870	3.172	13.216	48.870	3.415	14.228	44.993
3	2.222	9.257	58.126	2.222	9.257	58.126	3.152	13.133	58.126
4	1.873	7.805	65.931						
5	1.557	6.488	72.419						
6	1.243	5.178	77.597						
7	0.977	4.069	81.666						
8	0.840	3.499	85.165						
9	0.656	2.733	87.899						
10	0.589	2.456	90.355						
11	0.455	1.894	92.249						
12	0.432	1.801	94.050						
13	0.377	1.570	95.620						
14	0.267	1.113	96.733						
15	0.215	0.895	97.628						
16	0.166	0.692	98.320						
17	0.113	0.470	98.790						
18	0.084	0.348	99.139						
19	0.075	0.314	99.452						
20	0.059	0.244	99.696						
21	0.034	0.141	99.837						
22	0.022	0.090	99.927						
23	0.009	0.039	99.966						
24	0.008	0.034	100.000						

Extraction Method: Principal Component Analysis.

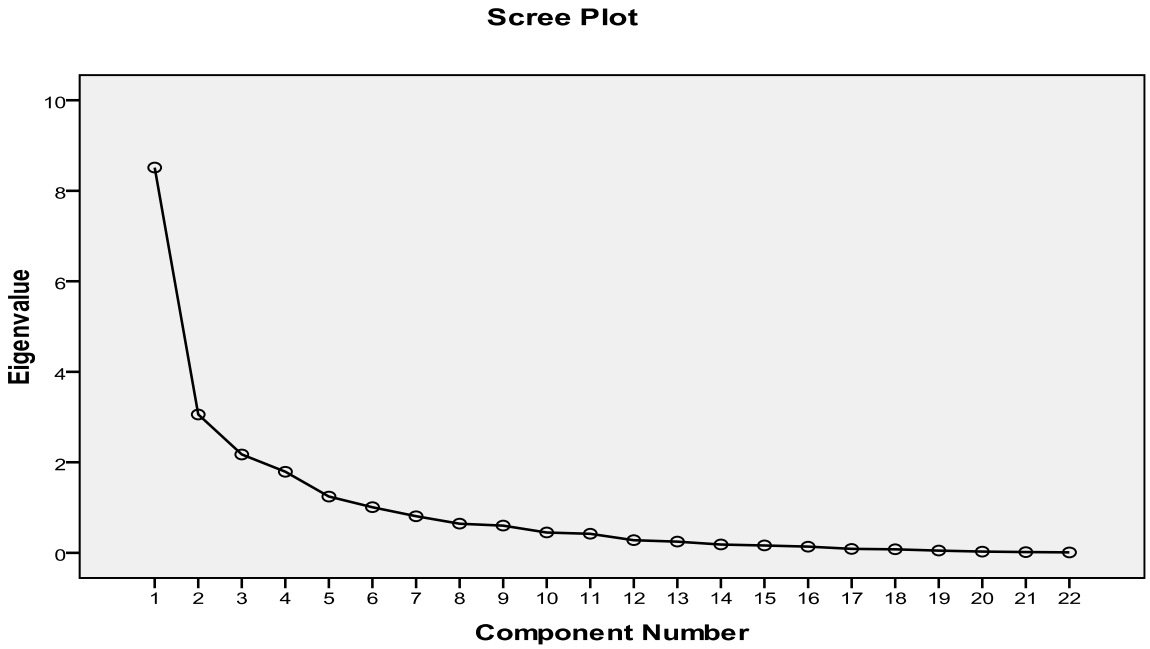
3-factor loading structure with 22 items
Interaction No. 3

Rotated Component Matrix[a]

	Component		
	1	2	3
UN1		0.613	
CL1	0.636		
CL2	0.703		
CL3	0.786		
AW1	0.583		
AW2	0.798		
AW3	0.663		
AW4	0.791		
SUR1	0.727		
SUR2	0.768		
INT1	0.633		
INT2	0.750		
INT3	0.807		
TR1		-0.790	
TR2		-0.745	
TR3		-0.815	
RI1	0.517		
RI2	0.657		
US1			0.911
US2			0.930
US3			0.949
ITE1		-0.593	

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.


Scree Plot
Eigenvalue
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Component Number

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8.513	38.693	38.693	8.513	38.693	38.693	7.211	32.778	32.778
2	3.058	13.898	52.591	3.058	13.898	52.591	3.481	15.823	48.600
3	2.174	9.881	62.472	2.174	9.881	62.472	3.052	13.872	62.472
4	1.792	8.147	70.620						
5	1.244	5.655	76.275						
6	1.008	4.584	80.858						
7	0.809	3.677	84.536						
8	0.645	2.932	87.468						
9	0.602	2.736	90.204						
10	0.450	2.046	92.250						
11	0.421	1.913	94.164						
12	0.280	1.272	95.436						
13	0.248	1.127	96.563						
14	0.185	0.839	97.402						
15	0.164	0.746	98.148						
16	0.136	0.620	98.768						
17	0.087	0.394	99.162						
18	0.079	0.358	99.520						
19	0.051	0.232	99.752						
20	0.028	0.128	99.880						
21	0.017	0.077	99.957						
22	0.009	0.043	100.000						

Extraction Method: Principal Component Analysis.

Appendix F: Regressions

Regression1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.520[a]	0.270	0.118	1.82223	0.270	1.777	5	24	0.156

a. Predictors: (Constant), INT, UN, CL, SUR, AW

ANOVA[b]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	29.508	5	5.902	1.777	0.156[a]
	Residual	79.692	24	3.321		
	Total	109.200	29			

a. Predictors: (Constant), INT, UN, CL, SUR, AW

b. Dependent Variable: TR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	11.168	3.426		3.260	0.003
	UN	-0.701	0.410	-0.310	-1.710	0.100
	CL	0.264	0.544	0.162	0.484	0.633
	AW	-0.413	0.526	-0.311	-0.784	0.441
	SUR	-0.159	0.436	-0.099	-0.364	0.719
	INT	-0.215	0.351	-0.148	-0.613	0.546

a. Dependent Variable: TR

Regression2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.719[a]	0.517	0.416	1.17003	0.517	5.129	5	24	0.002

a. Predictors: (Constant), INT, UN, CL, SUR, AW

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	35.105	5	7.021	5.129	0.002[a]
	Residual	32.855	24	1.369		
	Total	67.960	29			

a. Predictors: (Constant), INT, UN, CL, SUR, AW

b. Dependent Variable: RI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3.313	2.200		-1.506	0.145
	UN	0.258	0.263	0.144	0.978	0.338
	CL	0.572	0.350	0.447	1.637	0.115
	AW	-0.136	0.338	-0.130	-0.403	0.690
	SUR	0.772	0.280	0.610	2.759	0.011
	INT	-0.130	0.225	-0.113	-0.577	0.569

a. Dependent Variable: RI

Regression3

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.615[a]	0.379	0.249	1.46412	0.379	2.925	5	24	0.034

a. Predictors: (Constant), INT, UN, CL, SUR, AW

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	31.352	5	6.270	2.925	0.034[a]
	Residual	51.448	24	2.144		
	Total	82.800	29			

a. Predictors: (Constant), INT, UN, CL, SUR, AW

b. Dependent Variable: ITE

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	12.306	2.753		4.471	0.000
	UN	-0.872	0.330	-0.443	-2.647	0.014
	CL	0.053	0.437	0.037	0.121	0.905
	AW	0.106	0.423	0.091	0.250	0.805
	SUR	0.058	0.350	0.042	0.166	0.869
	INT	-0.672	0.282	-0.530	-2.385	0.025

a. Dependent Variable: ITE

Regression4

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.261[a]	0.068	-0.126	1.44094	0.068	0.350	5	24	0.877

a. Predictors: (Constant), INT, UN, CL, SUR, AW

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3.635	5	0.727	0.350	0.877[a]
	Residual	49.832	24	2.076		
	Total	53.467	29			

a. Predictors: (Constant), INT, UN, CL, SUR, AW

b. Dependent Variable: US

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.280	2.709		1.580	0.127
	UN	-0.045	0.324	-0.029	-0.139	0.890
	CL	0.450	0.430	0.396	1.046	0.306
	AW	-0.364	0.416	-0.392	-0.875	0.390
	SUR	0.365	0.345	0.325	1.060	0.300
	INT	-0.217	0.277	-0.213	-0.783	0.441

a. Dependent Variable: US

Regression5

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.378[a]	0.143	0.112	1.82845	0.143	4.663	1	28	0.040

a. Predictors: (Constant), RI

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15.590	1	15.590	4.663	0.040[a]
	Residual	93.610	28	3.343		
	Total	109.200	29			

a. Predictors: (Constant), RI

b. Dependent Variable: TR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	5.903	1.117		5.282	0.000
	RI	-0.479	0.222	-0.378	-2.159	0.040

a. Dependent Variable: TR

Regression6

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.318[a]	0.101	0.069	1.47709	0.101	3.149	1	28	0.087

a. Predictors: (Constant), ITE

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	6.870	1	6.870	3.149	0.087[a]
	Residual	61.091	28	2.182		
	Total	67.960	29			

a. Predictors: (Constant), ITE

b. Dependent Variable: RI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.018	0.733		8.208	0.000
	ITE	-0.288	0.162	-0.318	-1.774	0.087

a. Dependent Variable: RI

Regression7

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.005[a]	0.000	-0.036	1.97481	0.000	0.001	1	28	0.978

a. Predictors: (Constant), US

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.003	1	0.003	0.001	0.978[a]
	Residual	109.197	28	3.900		
	Total	109.200	29			

a. Predictors: (Constant), US

b. Dependent Variable: TR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3.641	1.520		2.396	0.024
	US	-0.007	0.270	-0.005	-0.028	0.978

a. Dependent Variable: TR

Regression8

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.425[a]	0.181	0.151	1.78774	0.181	6.168	1	28	0.019

a. Predictors: (Constant), ITE

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	19.712	1	19.712	6.168	0.019[a]
	Residual	89.488	28	3.196		
	Total	109.200	29			

a. Predictors: (Constant), ITE

b. Dependent Variable: TR

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.551	0.887		1.748	0.092
	ITE	0.488	0.196	0.425	2.483	0.019

a. Dependent Variable: TR

Appendix G: Privacy Concerns PCA

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.600
Bartlett's Test of Sphericity	Approx. Chi-Square	64.504
	df	10
	Sig.	0.000

Correlation Matrix[a]

		AW_	SUR	INT	UN	CL
Correlation	AW	1.000	0.590	0.523	0.232	0.826
	SUR	0.590	1.000	0.659	0.049	0.320
	INT	0.523	0.659	1.000	0.002	0.393
	UN	0.232	0.049	0.002	1.000	0.193
	CL	0.826	0.320	0.393	0.193	1.000
Sig. (1-tailed)	AW		0.000	0.002	0.109	0.000
	SUR	0.000		0.000	0.399	0.042
	INT	0.002	0.000		0.496	0.016
	UN	0.109	0.399	0.496		0.154
	CL	0.000	0.042	0.016	0.154	

a. Determinant = .088

	Component	
	1	2
INT	0.855	-0.079
SUR	0.847	-0.040
AW	0.790	0.495
CL	0.627	0.565
UN	-0.094	0.864

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

TRITA-ICT-EX-2014:34