Accepted Manuscript

Understanding the Impact of Emotions on Software: A Case Study in Requirements Gathering and Evaluation

Maheswaree Kissoon Curumsing, Niroshinie Fernando, Mohamed Abdelrazek, Rajesh Vasa, Kon Mouzakis, John Grundy

PII: S0164-1212(18)30134-1
DOI: 10.1016/j.jss.2018.06.077
Reference: JSS 10186

To appear in: *The Journal of Systems & Software*

Received date: 1 July 2017
Revised date: 4 May 2018
Accepted date: 26 June 2018

Highlights

- A requirements engineering method to model emotional goals in software is introduced
- A case study presents the design of the Sofihub smart homes emotion and goal models
- An empirical evaluation has been carried out for elderly people using SofiHub
- Results show that the developed solution has met the emotional goals identified
- Findings from case study are used to refine the research method and evaluation tools

Understanding the Impact of Emotions on Software: A Case Study in Requirements Gathering and Evaluation

Maheswaree Kissoon Curumsing, Niroshinie Fernando, Mohamed Abdelrazek, Rajesh Vasa, Kon Mouzakis, John Grundy

Deakin University, Australia

Abstract

Smart home technology has received growing interest in recent years with a focus on automation and assistance, for example, Alexa, Google Home, Apple HomePod, and many cheap IoT devices. Better supporting elderly people to continue live in their home using smart home technology is a key target application. However, most of the existing smart home solutions for the elderly are not designed with people's emotional goals in mind, leading to lack of adoption, lack of engagement, and failure of the technology. In this paper, we introduce an emotion-oriented requirements engineering approach to help identifying, modeling and evaluating emotional goals. We also explain how we used this technique to help us develop SofiHub - a new smart home platform for elderly people. SofiHub comprises a range of devices and software for sensing, interaction, passive monitoring, and emergency assistance. We have conducted multiple trials including initial field trials for elderly people in real houses. We have used our emotion-oriented requirements techniques to evaluate the participants' emotional reactions before, during, and after trials to understand the impact of such technology on elderly people's emotions to the Sofihub solution. Our analysis shows that SofiHub successfully alleviates their loneliness, makes them feel safer and cared about. We also found that the trial participants developed a strong relation with the system and hence, felt frustrated when SofiHub did not respond in ways expected or desired. We reflect on the lessons learned from the trials related to our emotion-oriented design and evaluation experimental approach, including refining our set of evaluation tools.

Keywords: Smart Home, Elderly, Independent Living, Emotions, Loneliness, Emotion-Oriented development approach

1. Introduction

Software professionals often design a product from a set of desired functional and non-functional goals based on *their* understanding of the system, resulting in an end-product which fails to fulfill the needs of its intended users. A growing concern can be found in literature where researchers [1, 2, 3, 4] pointed out that software engineers fail to give adequate consideration to user's emotional needs when designing systems, leading to unhappy end-users. Even though the consideration of emotion is becoming predominant in the area of design, including human-computer interaction, this consideration has not been successfully mapped to the software engineering field [5]. Evidence [1, 2, 6, 7], on the other hand, suggests that user emotions are a key determinant in the acceptance of a technology, particularly with regards to domestic and social systems.

Home-based age-care has emerged as a key alternative to address the growing burden of aged care and elderly people generally prefer to stay at home and enjoy their privacy and independence. However, this introduces a substantial burden on the government to fund and develop enough skilled staff (such as nurses) to look after the growing number of older adults. Smart home technology introduces a promising solution to this problem with the aim to help elderly people stay at home and live independently while maintaining a good quality of life for far less cost and human resources. Even though several smart home technologies already exist in the market, evidence suggests that many elderly people are not fully keen on using these systems [1, 2, 5]. One of the major reasons identified for this lack of interest points towards the failure to consider human, social and organizational factors along with technical factors when building such systems [1, 2, 5, 8].

Building socio-technical or people-oriented systems such as smart home technologies has never been more challenging with the increasing need to understand the social requirements of users. As social beings, users have emotional needs, such as to be independent, to feel cared about and feel secure. Given that these needs cannot be easily converted into functional or non-functional requirements using the existing software engineering methodologies, they are often ignored or trivialised within the current software development processes [9]. These social needs, which we refer to as *"users' emotional goals"* [10], are critical to the acceptance of a system and therefore cannot be ignored.

Existing efforts [10, 11, 12] have highlighted the importance of considering users' emotional expectations from the inception phase of the software project. They also presented a set of emotion-oriented techniques to capture, model and evaluate users' emotional goals. We followed a similar emotion-oriented approach to develop a new smart home solution – called SofiHub – designed to support independent living among elderly people, thus addressing a key problem of aging population. This technology was designed as an ambient system using non-intrusive motion sensors to alleviate elder people's concerns regarding their privacy, and also 'feeling old' when they have to put wearables on.

Research Questions. In this paper, we focus on three key research questions:

- RQ1: What are the key emotional goals necessary when building a smart home solution for elderly people?
- RQ2: How to engineer a smart home solution to address these goals?
- RQ3: How to verify that SofiHub meets elderly people's emotional goals?

In order to address these research questions, we have used our emotion-oriented techniques developed earlier [10] to identify and model users' pain points, and came up with an emotion model and goal model. We then used the goal model to guide the design and implementation of SofiHub. The goal model was then used to guide the design of our trials to make sure that we captured participants' emotions as part of the survey and interviews, that we conducted before, during and after the trials.

In this paper, we reflect on the implications of using an emotion-oriented design approach to develop SofiHub taking into consideration people's emotions. We also discuss the emotion related findings from the trials testing the system, within the homes of 10 participants. In particular, we focus on evaluating the long term impact that smart homes, such as SofiHub, can have over people's emotions and their willingness to adopt the technology over time. The timeline for our trial was conducted over only three months but our analysis shows that SofiHub improves and amplifies the affordances of a home (compared to a 'dumb' home) [13]. In addition, it addresses users' emotional expectations from such systems.

Contributions. This paper has the following contributions:

- An industrial case study of using an Emotion-oriented Requirements Engineering approach to the design of a Smart home emotion model and goal model. The emotion model captures users' pain points and translates them into a set of goals. The goal model represents the key emotional goals that need to be taken into consideration when building a smart home technology.
- A smart home solution that has emotions as a first class citizen, with detailed descriptions of how SofiHub was designed with emotional goals in mind.
- Reflections on real world trials of smart home technology. We present a detailed description of the trials we have conducted to evaluate how elderly people perceived SofiHub with emotions baked into the system.

The rest of this paper is organised as follows: In section 2, we outline the key efforts in smart home technologies, and highlight the need to consider emotions when designing smart home systems. In section 3, we present an overview of the set of emotion-oriented requirements engineering techniques that were used to design SofiHub. In section 4, we describe the features of SofiHub, present the protocol used for the trial, identify the emotional goals and discuss the key relevant decision rationale. In section 5, we describe our evaluation process, key findings and the implications of these findings on the next generation of SofiHub. In section 6, we discuss the threats to validity and in section 7, we reflect on our findings and emotion-oriented approach.

2. Background

2.1. Smart Home Technologies

The world is facing an increasing demographic challenge due to observed population aging. People above

60 will make 22 percent of the world population by 2050. In Europe, citizens aged above 65 are expected to represent 30 percent of the population by 2050. According to the Australian Bureau of Statistics (ABS), by 2030, the population above 65 will increase by 84 percent to be 5.1 million representing 18 percent of the population. This poses many challenges related to how we can provide proper care for this cohort of the population, such as accommodating the increasing number of older people within the existing aged-care centers and training staff to look after their health and medical issues, wellbeing, dependency and disability. The use of smart home technologies have been proposed as a key approach to this problem.

The term 'smart home', or 'smart house' was first used in 1984 by American Association of House Builders [14]. Since then, it has been given a number of definitions, including "a residence equipped with computing and information technology which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond" [14], "an electronic butler" [15] and "computer software that uses sensors and artificial intelligence techniques to perceive and reason about the state of the home's physical environment and its residents, and then initiates action to achieve specified goals" [16].

Although the initial focus of smart home research was to provide ambient intelligence in domestic environments, there is currently a growing interest in utilising smart homes to provide various specialised services targeting specific user goals, such as healthy living, energy-aware houses and aged-care. Studies show that many senior adults prefer to continue living in their home as long as possible to maintain one's independence [17, 18, 19]. Smart home technology can realise this by providing assisted living services at home. For example, bed sensors can be used to detect user's activity level, time spent in bed, heart rate, respiration and restlessness, and motion sensors can be utilised to identify if user is visiting the bathroom at irregular times [20, 19]. In recent times, rapid advancements in technology in areas such as wearable devices, network connected sensors, pervasive computing and robotics, has accelerated growth in both commercially available services as well as research initiatives in the area of smart home services for aged care. Table 1 shows a collection of commercially available aged care products in the market. As can be seen, aged care technologies in the market fall into five main categories; namely personal alarms, environment monitors, smart devices, mobile apps and smart systems.

Personal alarms are used to summon help in situations that escalate to emergencies in a short period of time, such as when an elderly user suffers a fall. There are many products in this category at present. While some require the user to be able to initiate the alarm by pressing a button [23], others are able to automatically detect falls via the sensors in the alarm that measure acceleration and motion [21, 22]. However, the automatic detection feature is often error prone and not always accurate. Environment monitors are used to sense changes in the environment that might lead to an emergency situation such as flooding and fire [24, 25, 26, 27]. These devices can offer a security net for seniors living by themselves and with reduced capacity to detect such emergencies.

There is a plethora of smart devices that cater to specific functions. The i-pot [28] is an electric kettle that keeps track of when it's used and wirelessly sends usage data to a remote server. Carers can subscribe to the service and see how it has been used and changes in usage can indicate if the carer needs to check in with the elderly user. The ManDown app [31] continuously monitors the phone's movement and notified carers if phone is motionless for a certain period of time. Apps such as Anna Cares [32] provide various notifications to engage with elderly users and promote healthy behaviour change. Smart systems such as GrandCare [33] , HealthSense [34], Independa [35] and Lively [36] encompass multiple devices including sensors and wearables to provide situational notifications and enable remote monitoring.

Most applications and devices targeting elderly users have a focus on offering transactional services for users' functional goals. However, their effect on users' emotional goals are not clear, even though emotional goals play a key part in user acceptance and adoption. Portet et al. [37] discusses a case study of smart homes for elderly users, where some elderly users were hesitant to use automated functions (such as opening blinds in the morning) because they feared that automating parts of their daily routines would leave them with nothing to do, and make them feel useless. In this case, even though the functional goal of the system was accurately implemented, it contradicted the users' emotional goals (independence and feeling useful).

Moreover, unlike typical software, smart home systems are intended to be part of a user's 'home', which inherently has strong emotional connotations [13, 38]. It is therefore vital that the role of emotions be considered in the design and development of software used in smart home systems.

	Example	Functional Goal
Personal alarms	Tunstall iVi Pendant [21], LiveLife Mobile Alarm [22]	Wearable alarm with automatic fall detection.
	Tunstall wall mounted alarm [23]	Contact Tunstalls response centre in emergencies.
Environment monitors	Tunstall flood detector [24], Quell Smoke Alarm [25], Swann Anti-Flood Alarm [26]	Emits a warning sound when the sensor is in contact with fluids/smoke/gas.
	Stove Guard Motion Sensor [27]	Turns off the stove when there is no activity around the stove.
Smart devices	I-pots [28]	An electric kettle that keeps track of when it's used and notifies carers of a sudden change in habits.
	OlloMobile [29]	A matchbox sized phone, which notifies carers when seniors need assistance.
	Tricella Smart Pillbox [30]	A pillbox with sensors in its chambers that can detect when pills are taken and notify if not taken/wrong taken.
Apps	ManDown App [31]	Sounds alarms if phone is motionless for a certain period of time and notifies selected recipients.
	Anna Cares [32]	A tablet-based virtual personal assistant that provides and facilitates communication with carers.
Smart systems	GrandCare [33]	Touchscreen system enabling remotely caring for the occupant via remote in-home activity sensing and notifications.
	HealthSense [34]	Provides health and safety information to carers. Includes a wearable pendant.
	Independa [35]	Remote monitoring system with custom smart TV enabling communication and information and reminders.
	Lively [36]	Provides health and safety information and reminders. Needs to wear a safety watch.

Table 1: Examples for commercially available aged care products

2.2. Role of Emotions within Smart Home Systems

A growing concern can be found in literature surrounding the adoption of technology by the elderly people where researchers [3, 39, 40, 1, 2] point out that software engineers *fail to give adequate consideration to users' emotional needs when designing systems*, leading to unhappy end-users. Users' emotions – which relate to the way users *feel* or how they *want to feel* – are rarely explicitly considered in software development [41, 42, 43, 44, 3]. Evidence, on the other hand, suggests that users' emotions play a determining role in the acceptance of a technology, particularly with regards to domestic and social systems [41, 42, 43, 39, 40, 1, 2, 7].

Several studies in the area of socio-technical systems for the elderly have highlighted the importance of users' emotions during system design [1, 45, 2]. For example, a study conducted by Demiris et al. [1] investigated the way older adults perceive smart home technologies installed in their homes. The findings revealed issues related to *violation of privacy* and *independence* which refer to the way the users *feel* about the system. Another study by Pedell et al. [2] was geared towards the issues that older adults face when using emergency alarm pendants. Issues such as *lack of independence*, *feeling old*, *frail*, *stigmatised* and *uncared for* were some of the most common comments found from the interviews conducted with those older adults. The findings also showed that these people wanted to feel connected to their loved ones and cared about. These issues and expectations clearly do not relate to a functional or quality goal of a system. They refer to the emotional expectations that users have from the system. Given that these emotional issues act as barriers to the adoption of technology, they cannot be ignored and have to be somehow reflected in the design of the technology.

These findings reiterate the need to address users' emotional goals when designing socio-technical systems. Addressing user's emotional goals in software design entails a number of challenges. First of all, emotion in itself is a very complex and subjective concept, making it hard to capture and measure [46, 11]. In addition, existing software methodologies barely address the concept of user emotional expectations [5, 10]. This leaves software engineers with little guidance on how to incorporate user emotional expectations within their existing software development life cycles.

While emotion is a well-researched topic in disciplines such as design (including human computer interation), affective computing and information systems, it has been barely explored in the area of software engineering. The literature involving emotion and software development is mainly focused on requirements gathering and modelling [47, 48, 4, 49, 50, 51]. For example, Thew and Sutcliffe [49], Sutcliffe and Thew [50] and Sutcliffe [51] referred to people's feelings as *'soft issues'* and argued how vital it is to consider user beliefs and values for the success of a software. They proposed a taxonomy consisting of a set of values and motivations and determined the severity of their impact on the requirements. Proynova et al. [52] considered personal values to find requirements which may have remained hidden. In the area of requirements modelling, Eric [53] proposed the *i** framework with an attempt to represent some aspects of social modeling which they termed *soft goals*. Along with the traditional non-functional requirements such as "reliability", soft goals such as "trustworthy", which are more aligned with user emotional expectations, were also represented. In this perspective, the work of Ramos et al. [4] is better aligned with our approach in that they present examples of projects failing due to requirements being affected by emotions. They further advocate the need to identify such issues as soon as they arise and to handle them through a number of psychological techniques.

Miller et al. [5] and Lopez-Lorca et al. [54] adapt the work of Marshall [55] to the area of software engineering. In this context, Miller et al. [5] refers to emotion as a feeling that characterises a state of mind and includes examples such as feeling of *joy*, *terror* or *safety*. Based on this definition, an emotional goal is defined as *"the way people feel about a system and also captures their engagement in the greater socio-technical system"*. Miller et al. [5] further categorise emotional goals into two types, namely *personal emotional goals* and *system-dependent emotional goals*. Personal emotional goals refer to "the way a person wants to feel such as feeling *loved*, *safe* or *angry*" and are independent of the existence of a system. System dependent emotional goals refer to "the way a person feels about a system for example, feeling *engaged* or *frustrated* with the system". Unlike personal emotional goals, system dependent emotional goals rely on the existence of the system and if the system is removed, these emotional goals are eliminated.

While there has been some early progress on incorporating the concept of emotion in software solutions [47, 48, 4, 49, 51], to the best of our knowledge, there is no structured software methodology or framework to capture, model and incorporate user emotional goals within the software development life cycle. In a recent work [10], one of the authors, presented a set of emotion-informed techniques to capture, represent and evaluate user emotional expectations. These techniques were applied and tested within three case studies in different domains with different stakeholders. In this work, we apply the same set of techniques to the design and evaluation of our smart home technology for the elderly. The next section discusses these emotion-oriented techniques in more details.

3. Emotion-Oriented Software Engineering

3.1. Emotions and Emotional Goals

Table 2 provides a summary of some of the classifications of emotion over time [10]. This highlights the different classifications of emotion as presented within different disciplines such as psychology, philosophy, neuroscience, medicine and computer science.

An important finding is that the terms used to identify emotion such as *anger*, *disgust*, *fear*, *joy*, *sadness* and *surprise* do not relate to user emotional expectations. Our focus is to incorporate user emotional expectations within the software development life cycle, to ensure that users' emotional needs are addressed by the software. User emotional expectations for a particular system, such as a smart home technology, could be "feeling cared for", "feeling connected" and "feeling independent". These terms do not fit under any of the classifications of emotion listed in Table 2.

For instance, how do we map "cared for" to a list of emotions consisting of terms like *anger*, *disgust*, *fear*, *joy*, *sadness* and *surprise*. Even though user emotional expectations relate to the way users feel or want to feel, they are not emotions. User emotional expectations relate mainly to the way users perceive the end product. For instance, the term "feeling cared for" depends on how the users think that using a software can make them "feel cared for". Given the subjectivity and complexity of emotion, there is no way to guarantee that users will

Table 2: Classification of Emotions

Theorist	Reference	#Emotions	Basic Emotions
Plutchik	Plutchik [56]	8	Acceptance, anger, anticipation, disgust, joy, fear, sadness, surprise
Arnold	Arnold [57]	11	Anger, aversion, courage, dejection, desire, despair, fear, hate, hope, love, sadness
Ekman, Friesen, and Ellsworth	Ekman et al. [58]	6	Anger, disgust, fear, joy, sadness, surprise
Frijda	Frijda [59]	6	Desire, happiness, interest, surprise, wonder, sorrow
Gray	Gray [60]	3	Rage and terror, anxiety, joy
James	William [61]	4	Fear, grief, love, rage
Matsumoto	Matsumoto et al. [62]	22	joy, anticipation, anger, disgust, sadness, surprise, fear, acceptance, shy, pride, appreciate, calmness, admire, contempt, love, happiness, exciting, regret, ease, discomfort, respect, like
McDougall	McDougall [63]	7	Anger, disgust, elation, fear, subjection, tender-emotion, wonder
Mowrer	Mowrer [64]	2	Pain, pleasure
Oatley and Johnson-Laird	Oatley and Johnson-laird [65]	5	Anger, disgust, anxiety, happiness, sadness
Panksepp	Panksepp [66]	4	Expectancy, fear, rage, panic
Parrott	Parrott [67]	6	anger, fear, joy, love, sadness, surprise
Tomkins	Tomkins [68]	9	Anger, interest, contempt, disgust, distress, fear, joy, shame, surprise
Watson and Rainer	Watson and Rayner [69]	3	Fear, love, rage
Weiner and Graham	Weiner and Graham [70]	2	Happiness, sadness

actually *feel cared for* after using the end-product. It all depends on the way they *perceive* the system.

Based on the analysis of the different theories of emotion, Kissoon Curumsing [10] argues that while most theorists agree that the four components, namely *cognitive processes*, *affect or subjective feelings*, *physiological arousal* and *behavioural responses* are important, debate is still going on regarding the mandatory presence of all four of them in every emotional event and the sequence in which they should occur. Different theories of emotion have been proposed over time which elaborate on the different sequence of components related to emotion, but in general most theorists agree that perception is at the beginning of each sequence of components. That is, perception is generally accepted as the trigger for an emotion. Hence, our consideration of perception is justified. In our work, users' emotional expectations or users' emotional goals refer to how users perceive the end product.

When asked about what they want from a system, users very often tend to describe their expectations by highlighting features that they do not want. In other words, they describe their requirements in terms of pain points or in terms of negative emotions [54], for example, *"I don't want to feel old" and "I don't want to feel dependent on others"*. Lopez-Lorca et al. [54] and Kissoon Curumsing [10] describe how these negative emotions can be mapped to one or a group of functional, quality and/or emotional goals that the system should achieve in order to document and then counteract these negative emotions through an **emotion model**. We refer to these pain points as *'emotional threats'*. They help to maintain traceability between negative emotions, identified during the elicitation process, and the system's goals.

3.2. Emotion-Oriented Methods

In this section, we describe the emotion-oriented techniques, which were used (i) during the design and development of the Sofihub technology, (ii) to analyse the data collected from the Sofihub trial and (iii) to identify any new requirements arising from the findings of these trials. The next section describes how these techniques were applied within the different development stages of SofiHub. Figure 1 illustrates the emotion-oriented development approach used for this case study.

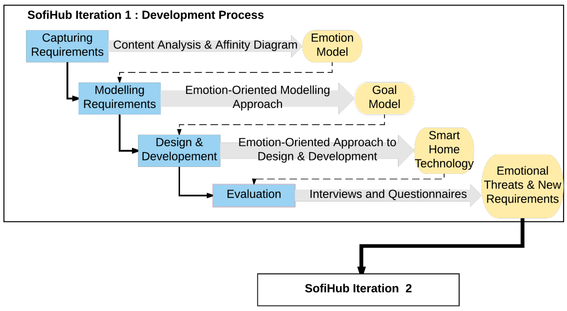

Figure 1: Emotion-Oriented Development Processes

3.2.1. Emotion-Oriented Requirements Modelling

In recent work [12], a comprehensive set of emotion-oriented models were designed to support early-phase requirements to detailed design to demonstrate how to capture the viewpoints of stakeholders, in particular the emotional viewpoints, throughout the entire process. Earlier agent-oriented models were extended to represent three types of goals namely, functional, quality and emotional.

Table 3 summarises the modelling suppport we use for this Emotion-Oriented Requirements Engineering (EORE).

Role Model

The **role model** enables us to model key user roles in the system and associate emotional goals and expectations with each role. For example, in our smart home system scenario key roles include cared-for ageing person, family member, professional carer, and maintenance personnel. The expectations of the older adult is to feel cared about, safe, independent, in touch and unburdened of the obligation of routinely getting in touch with their relative/carer (personal emotional goals). In addition to that, they want a system that feels integrated in their life and they also want to feel in control of the system (system-dependent emotional goals).

Goal Model

The **goal model** represents the functional goals of the system to be developed along with any quality and emotional goals linked to the functional goals. The goal model is a valuable tool widely used during discussions with stakeholders. It provides an overall picture of the system in terms of its goals (functional, quality and emotional) and roles associated to these goals. It also represents how each functional goal can be further decomposed and shows the link between the quality, emotional and functional goals. The model also identifies the quality goals and emotional goals attached to each particular functional goal.

A high level modelling icon set was developed to represent the different goals as illustrated in Figure 2 where the conventional parallelogram and the cloud was used to represent the functional and quality goals respectively. The heart shape was introduced to represent the emotional goals. In this work, we briefly describe two of those models which we applied in our case study.

Figure 2: Icon set for functional, quality and emotional goals

Figure 3 provides a meta-model for our goal models used in the case study in this paper. A set of Roles and Goals are linked. Goals may be Functional, Quality or Emotional goals of the system or user. Sub-functional and Sub-quality goals allow for refinement of models. Emotional goals may be positive or negative, that is, reflect positive reactions or negative reactions to the system and its features. Each role has a set of emotional goals they need to have either fulfilled (positive) or avoided/minimised (negative) in the system being modelled. Multiple emotional goal models are used for large systems.

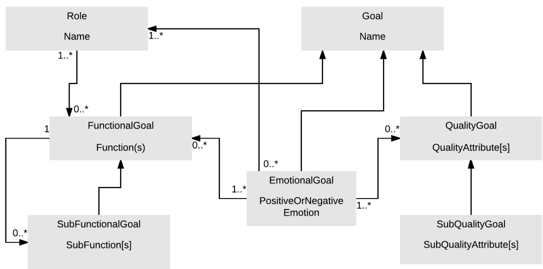

Figure 3: Meta-model for the emotion-based goal model

A number of checks can be performed on the emotion-oriented goal models relating to completeness, correctness, and consistency.

- completeness checks
  - all emotional goals should be associated to a role, for instance, in our case study, the emotional goals *safe*, *independent*, *empowered*, *in*

Table 3: Emotion-oriented Requirements Engineering enhanced models

Model	Description	Emotional Goals Captured
Role Model	provides an overview of the different roles involved in the system by listing out the responsibilities, constraints and emotional goals associated with each role	personal emotional goals system-dependent emotional goals
Goal Model	represents the functional goals of the system to be developed along with any quality and emotional goals linked to the functional goals	positive emotional goals negative emotional goals
Motivational Scenarios	high-level purpose of the overall system including functional, quality and emotional goals	emotional description
Interaction Model	describes the interactions between agents making up the system	annotated interactions with positive emotions annotated interactions with negative emotions
Scenario Model	describes collective activity of how goals are achieved in system	rows to describe generally the emotional goals achieved by the scenario columns for each activity to highlight the relevant emotions
Behaviour Model	describes what individual agents do in the system	annotations on states to model relevant emotions

control, *integrated*, *comfortable* and *privacy secured* are associated to the elderly person while the emotional goal *reassured* is associated to the carer/relative;

- all emotional goals should be related to at least one functional and/or quality feature of the system, for example, in the goal model represented in Figure 5, the emotional goal *reassured* is linked to the functional goal *support independent living*, which implies that carers/relatives feel reassured if the system is able to support independent living;
- all functional goals should be refined to appropriate sub-goals, for instance, in our smart home case study, the functional goal *support independent living* is decomposed into *learn user's routine and behaviour* which is further decomposed into *issue notifications* and *learn user's routine and behaviour*;
- any missing emotional goals should be detected. This can be done during the process where the goal model is validated with key stakeholders of the system;

- correctness checks
  - constraints as to which emotional goals can be linked to which functional and quality goals need to be checked, for instance, in our SofiHub scenario, the emotional goal *safe* is linked to the goal *detect anomaly* because elderly people feel safe knowing that in case of an anomaly such as a fall, the system will detect the anomaly and escalate the incident to the service provider and/or carer. Similarly, carers/relatives feel *reassured* knowing that the service provider is supporting their elderly relatives in their day to day living;
- consistency checks
  - conflicting functional, quality and emotional goals should be resolved, for instance capturing people's movement while ensuring that they feel independent;

– conflicting emotional goals, for example, positive and negative emotion for the same sub-goal should be resolved;

Examples of goal models for our smart home scenario are given and described later in this paper. The other emotion-augmented modelling techniques outlined below have also been enhanced with this approach.

Motivational Scenarios

Motivational Scenarios provide the high-level description of the purpose of the system in terms of functional, quality and emotional goals. It reflects how the agents enacting a particular role are going to achieve the goals assigned to them. For example, in our smart home scenario we have an overarching goal of providing technology-support care via passive monitoring. We capture scenario descriptions from carer, relative and elderly adult viewpoints including quality goals. We also capture emotional goals such as reassurance of well-being (family), adherence to medication and exercise (carer), and independence and safety (elderly adult).

Interaction Model

The **interaction model** represents a set of interactions that exist between the different agents within the system. It is expected to have several interaction models for a particular system whereby each model represents a particular scenario or functionality of the system. We model this on UML-style sequence diagrams and annotate the interactions between system and user with appropriate emotional goals to document where these impact usage. For example, in our smart home scenario we capture potential anxiety around elderly adult and remembering to take medication, and security for relative provided by the medication reminder function.

Scenario Models

A **scenario** is a behaviour model which represents a collective activity that models how a particular goal is achieved by agents enacting particular roles. A system can have more than one scenario depending on its complexity and number of functionalities involved. Each scenario provides information about a particular functionality by identifying the associated quality and emotional goals, the initiator of the function, how the function gets triggered and the set of activities linked with this function. We added rows and columns to capture emotional goals associated with activities. For example, when the system calls for help in terms of a detected anomaly, emotional goals such as safety is being contributed to.

Behaviour Models

A **behaviour model** focuses on what individual agents do within the system. There are two kinds of behaviour models namely behavioural interface models and agent behaviour models. The behavioural interface model captures the different behavioural units (activity) and interface (trigger, pre-condition and post-condition) for each unit. The agent behaviour model describes the behaviour of an agent in terms of rules and triggering messages. We annotate with additional rows to capture relevant emotional goals for activities, triggers and conditions.

3.2.2. Emotion-Oriented Requirements Elicitation Process

We make use of an adaptation of two existing techniques, namely *content analysis* [71] and *affinity diagram* to elicit emotion-oriented requirements Kissoon Curumsing [10]. Content analysis is a technique for analysing content that may consist of words, meanings, pictures, symbols, ideas, themes, or any message that can be communicated [71]. The text is searched for recurring words or themes to identify core consistencies and meanings. Content analysis involves identifying, coding, categorising, classifying and labelling primary patterns in the data. The coding process starts with a complete view of all the collected data. In the initial reading, the analyst can start visualising some coding categories and patterns but the actual coding occurs in the second reading. Content analysis relies on the skill of the analyst in being able to recognise patterns in the data and being able to find appropriate terms to label them.

During the analysis session, an *affinity diagram* is then used to organise the identified patterns and codes into a hierarchy to draw higher-level concepts out of the data [72, 73]. The patterns and codes are grouped together by related themes to create a story about the phenomena studied [74]. The affinity diagram is built bottom up. Individual ideas are grouped into common themes, suggesting categories to which they belong, using an inductive process.

3.2.3. Emotion-Oriented Design and Implementation

Incorporating users' emotions during the software design and development phases is an area that has only barely been explored to date and no well defined technique has yet been proposed to incorporate emotional goals during the design and implementation phases. Personas have been used to bridge the gap between the requirements and design phases but nothing beyond that has so far been mentioned [10].

Our team is currently exploring ways to formalise the process of including emotional goals during the design and implementation phases. In this case study, the users' emotional goals were communicated to the engineers through the emotion and goal models. We also conducted discussions and workshops to ensure that the engineers (i) understood the importance of each goal and (ii) included these goals within the design and implementation phases of the project. Further details on how these goals were included during the design and implementation phases will be provided in Section 4.2.

3.2.4. Emotion-Oriented System Evaluation

In previous work [11], we described the iterative design of an emotion-oriented questionnaire which was used as an evaluation tool within a case study involving elderly people. This tool was then further refined to address the shortcomings of the previous version [10]. The main problems with the initial version consisted of (i) too many statements to fill, which were tiring for elderly people (ii) difficulty in understanding the meaning of the terms used and (iii) difficulty to quantify the data.

The new version was based on the Attrakdiff questionnaire, an approach used to assess users' feelings through a 28 item questionnaire where each pole consists of opposite adjectives, for instance, "confusing - clear", "ugly - attractive", "good - bad" [75]. A similar questionnaire was designed for our case study, consisting of a set of corresponding emotional threats and goals, placed at different ends of each pole. The terms used to describe the emotional goals were also simplified to make them simple to understand by common people. This tool was provided to participants at different intervals. Further information on the case study and the trial are provided in the next section.

4. Case Study of Using Emotion-Oriented Requirements Engineering

This section introduces our case study example of a smart home technology, SofiHub, and describes our case study of using Emotion-oriented Requirements Engineering for SofiHub's analysis, feature design and validation using human trials. It also describes how the emotion-oriented techniques were applied at different stages of the development process.

4.1. SofiHub Features

SofiHub is a smart home for elderly people, developed to provide assistive services to enable older people to continue to live in their own homes. The technology differentiates itself due to use of network connected low-cost sensors, having an IoT platform with an aged-care component and built-in AI capability that can learn and adapt to a users behaviour. The goal of this system is to provide reminders (hydration, medication), identify potential security risks (back door has been left open), identify anomalous situations and to automate the physical environment (heating, cooling).

The SofiHub project has been developed by a team of software engineers, data scientists and academics working together. The team skills consist of software design and development, product and team management, mathematical modeling, data analysis, software testing and requirements capture. Their experience ranges from graduate level to senior engineers and academics. The team follows the Agile development process. Work on SofiHub started in early 2015 and is due to conclude soon.

The system functions include, issuing user specific reminders such as appointments and special events, hydration and medication reminders that can be setup to be triggered by user activity, issuing alerts when anomalous behaviour is detected (eg: user is spending an abnormal time in bed), and a carer UI which enables family and carers to check on user activity and receive customizable reports summarizing user behaviour.

4.2. Sofihub Emotion-oriented Requirements Engineering

Prior to designing the smart home technology, we conducted a literature review on similar products already existing in the market, focusing mainly on users' expectations and concerns regarding these systems. We applied the concept of content analysis while going through each research paper, survey and field study to identify the pain points and needs of the users. Some of the concerns identified during this process were with regards to privacy issues, complexity of the system, invasiveness and, the users feeling monitored, dependent and controlled [13]. An affinity diagram was used to group the key words, identified during the content analysis process, into different categories namely threats, emotional goals, functional goals and quality goals. The identified threats were further explored to derive corresponding emotional, functional and/or quality goals. For example, *'feeling dependent on others'*, *'controlled'* and *'monitored'* were mapped to the functional goal *'supporting independent living'* and the emotional goals *'independent'* and *'in control'*. An emotion model, represented in Figure 4, was then used to represent the mapping between the identified threats and their corresponding set of functional, quality and emotional goals.

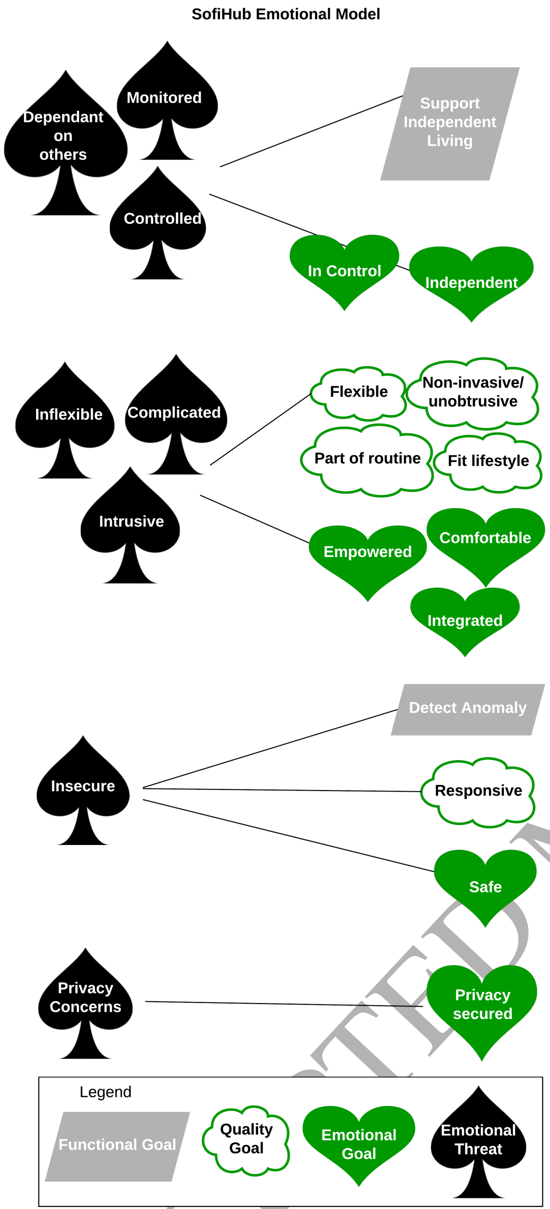

Figure 4: Sofihub Emotion Model

The output from this process and the emotion model (functional, quality and emotional goals) were then used to generate the goal model which we present in Figure 5. We briefly describe each key emotional goal identified for the Sofihub system:

- *Reassured*: The main goal of relatives and carers of the older person was to feel reassured of the well-being of the older person. By supporting independent living, the aim of the system was to reassure the relatives and carers of the wellbeing of their older relative.
- *Independent*: The elderly adults wanted to feel independent by being able to live as they please. They did not like being monitored by others.
- *In control*: The elderly adults wanted to have full control over their life.
- *Safe*: Knowing that someone or the system can detect an anomaly (for example in case they had a fall) made the older person feel safe.
- *Integrated*: The system had to be well integrated into the daily lives of the older adults.
- *Comfortable*: Many older people are afraid of using technology. One of the emotional goal was therefore to make them feel at ease with the technology in place.
- *Empowered*: The system made the users feel more confident in controlling their lives by building up their comfort and confidence around technology use.
- *Privacy secured*: Users are relieved about the privacy of their information. Data collected through the sensors are well secured and no intruders can hack those sensitive information.

These identified goals were then communicated to the design and development team via a series of workshops, and then the first iteration of SofiHub was developed. During these workshops, the goal model was used as a baseline to initiate discussions on the functionalities that the system should have. For instance, to ensure that users felt in control, only two set of messages were included in the system, namely, the morning messages and the medication reminders. The rationale behind this decision was to avoid overwhelming the users with too many messages. Similarly, in order to ensure privacy, all the data captured by the sensors were kept within the hub and nobody, except for those authorised by the ethics committee, had access to these data.

4.3. Trial and Sofihub Emotion-oriented Evaluation

The initial phase of SofiHub was trialled by deploying it in ten homes of elderly people, for twelve weeks, to test its technical functionality as well as to investigate if the system is capable of meeting users' emotional goals. Figure 6 illustrates the research model employed

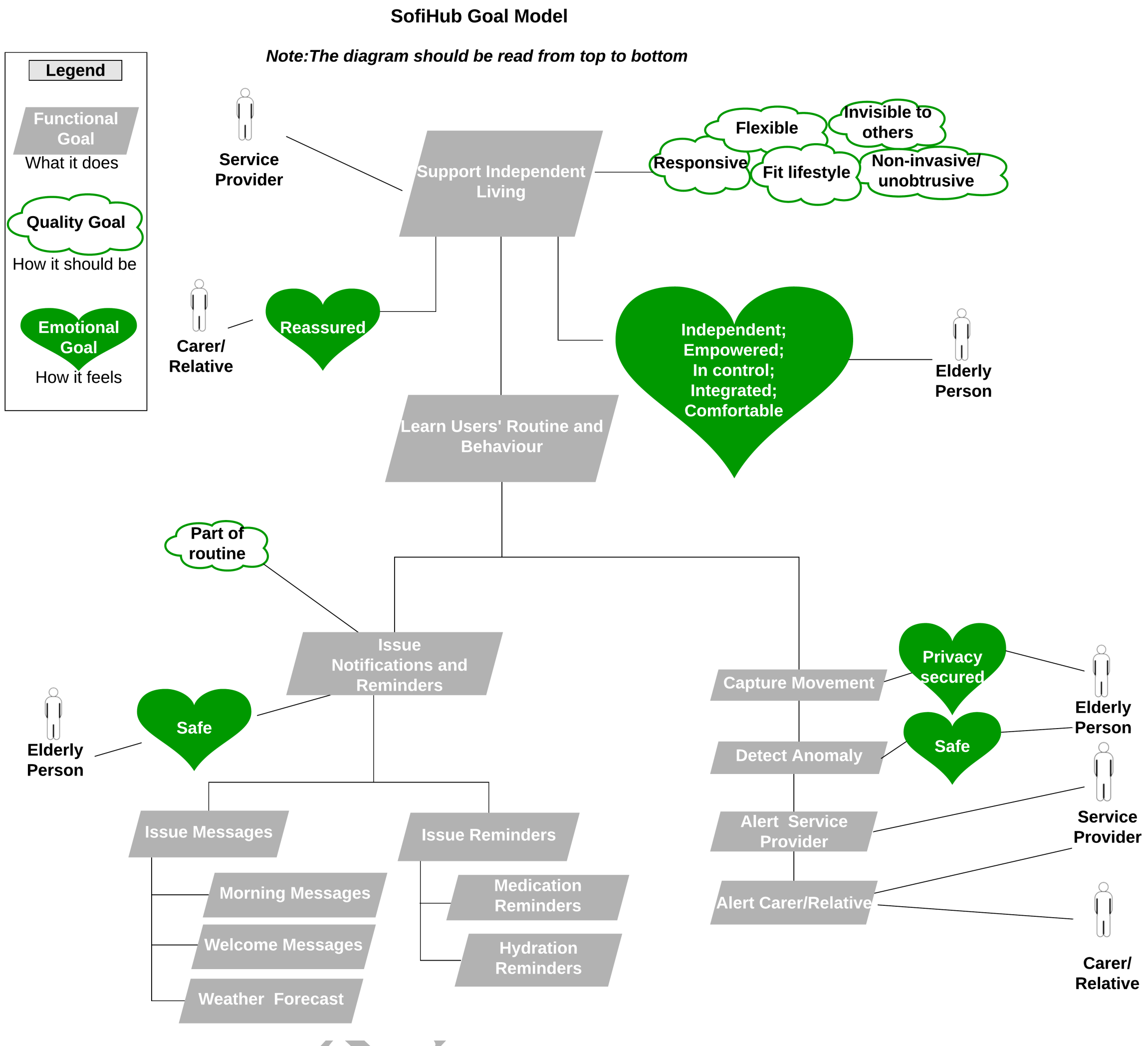

Figure 5: Goal Model

in the trial. As can be seen in Figure 6, the trial was carried out in several key stages. Firstly, the participants were interviewed prior to installing SofiHub in their homes to capture how they viewed technology. Before the start of the first interview, the participants were provided with a description of the smart home technology and informed about its functionality. Trial participants were also required to nominate a family member/carer to monitor their progress for the duration of the trial.

SofiHub was then installed in their homes, and six weeks after installation, the participants' views were captured again to examine their experience with SofiHub. At the end of the twelve week period, SofiHub was removed from the participants' homes, and at that point, they were interviewed again to evaluate the impact of the smart home technology and if it has affected their emotions. Finally, one week after SofiHub was uninstalled, the participants and their nominated carers were interviewed again about their experience with SofiHub.

The participants were recruited according to the following criteria:

1. over the age of 65 years,
2. living independently, or with a partner or pet, in private dwellings ,
3. relatively fit and healthy, requiring only minor assistance in their day-to-day activities
4. able to communicate confidently in English

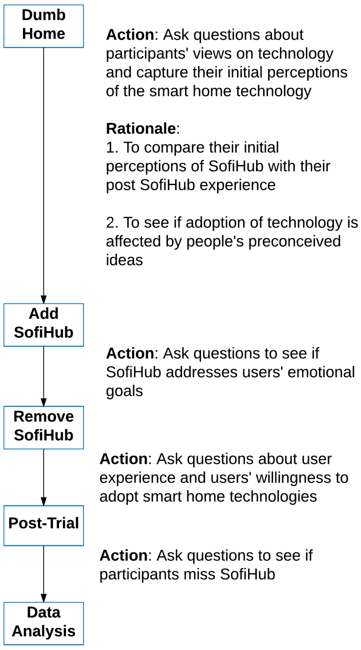

Figure 6: Research Model

4.3.1. Data Collection Tools

We used four data collection tools namely (i) sensors, (ii) daily checklists, (iii) interviews and (iv) emotion-oriented questionnaires.

Sensor data was collected from the motion and contact sensors installed in the homes. These recorded motion, opening and closing of specific doors, air temperature and humidity. The main uses of sensor data were to test the accuracy of sensors and the AI component of SofiHub. The data was locally stored in the SofiHub, while the researchers were able to retrieve data dumps at selected periods to carry out the testing.

Daily checklists were used to record information about particular activities in participants' daily schedule. These included information about going to bed in the night, waking up, visitors, doors that were kept open, going out of the home and returning home. The participants were requested to fill the checklists on a daily basis. These checklists were then cross checked against the data recorded by the sensors during the weekly face-to-face interviews. The main objective of this was to establish ground-truth to verify the results of SofiHub's AI component and to validate the sensor data.

The emotion-oriented **questionnaire** was designed based on the technique proposed by Kissoon Curumsing [10]. For each emotional goal identified, we (i) identified the corresponding emotional threat from the emotion model and (ii) defined common terms for both the emotional goal and emotional threat, which can be easily understood by common people. For example, the terms *'I feel comfortable about being monitored'* and *'I feel anxious about being monitored'* were used to assess the emotional goal *'independent'*. A Likert scale of 5 points was used to facilitate the analysis of results. The complete questionnaire is provided in the appendix.

Interviews were conducted at different intervals. The initial interview questions were designed to find out about (i) the participants' background; (ii) use of technology; and (iii) routines, for example, time they wake up and go to bed and medications. Each participant was asked to describe their daily routine within a typical day and provide details about their living circumstances. In terms of technology use, participants had to provide information about how far they are conversant with using technology and how they see technology as an everyday support. A weekly interview was also conducted to cross check the data collected from the sensors against the data inserted in the checklist. The main aim of this interview was to check the validity of the data picked by the sensors. The mid interview questions were centered around the user's experience with the smart home technology in terms of (i) the messages, (ii) its frequency, (iii) the tone, (iv) content and (v) whether they were annoying or obtrusive in any way. The post interview was designed to find out about (i) the user's overall experience with the tool, (ii) their willingness to buy a similar product and (iii) whether they missed SofiHub. A complete set of the interview questions is available in the appendix.

5. Emotion-oriented Evaluation Process

The SofiHub trials generated a large amount of data in terms of interview transcripts and questionnaires. In this section, we present the emotion-oriented method used to analyse these data and present the findings from this process. We also reflect on the implications of these findings for our next set of trials and design changes.

5.1. Qualitative Data Analysis Method

5.1.1. Analysis of Interview Transcripts

We applied content analysis described in Section 3 to each of the interview transcripts and with the use of an affinity diagram, we derived a set of themes related to our study. Three researchers were involved in the whole process. Two of them went through the whole set of interview transcripts, generated from the trial and followed the following process:

- highlighted content which was relevant to the study, for example, words or phrases such as *"The fact that Im old, I dont like change"*, *"I wait for it each morning"* and *"I miss the morning messages"*.
- included highlighted content to a different document (content analysis results document) with proper annotations, so that they could be traced back to their source. For example, if a fifth statement from the second interview of participant one was being included, then the statement was annotated as P01.2E, where P01 referred to participant one, 2 referred to the second interview and E referred to the fifth highlighted statement in the original document.
- using an affinity diagram, organised the identified emotion-oriented patterns/content under relevant themes, for example, *"It feels less lonely"* and *"In a way, it feels as there's somebody looking after you"* relate to the emotional goal "less lonely" and hence these contents were added under a theme "Reduced loneliness".

Once all the transcripts were analysed by both researchers, the notes on both affinity diagrams were reviewed and reconciled by all three researchers to ensure consistency and objectivity. Similar patterns were grouped together, existing themes were merged and in some cases, new themes were created to provide a clearer representation of all the key findings. A screenshot of the affinity diagram is provided in the Appendix.

5.1.2. Analysis of Data from Emotion-oriented Questionnaires

Each participant had to fill three set of questionnaires throughout the trial. For each participant, the data from each questionnaire was recorded and a set of charts was generated to show the trend in their perception of SofiHub at different intervals. Another set of charts were generated to portray the evolution of users' perceptions over time for each item in the questionnaire. Both set of charts are available in the Appendix.

5.2. Sofihub Findings and Wider Implications

The findings from the Sofihub evaluation revealed different aspects related to the functionalities of SofiHub and the users' emotional reactions and experience. Here we focus on the findings related to the impact that SofiHub had on users' emotions and generalise these to emotion-oriented software requirements engineering more generally.

SofiHub was shown to successfully have addressed the target users' key emotional goals, in particular, SofiHub made its users feel safe, supported, cared about, reassured, reduced their loneliness and, the technology was well integrated in their lives. In the next sections, we reflect on findings with regard to each of these key emotional goals and their more general implications for emotion-oriented requirements engineering.

5.2.1. Reduced Loneliness

'Loneliness', often used interchangeably as 'social isolation' refers to a subjective concept resulting from a "perceived absence or loss of companionship" [76]. Social isolation, on the other hand, refers to the lack of structural and functional social support. While social isolation can be a chosen path or imposed due to the circumstances of the person, loneliness is always involuntary [76]. Both Loneliness and perceived social isolation are major problems faced by many older adults living at home [77]. Retirement, the death of close ones and friends, living alone, low morale, limited mobility coupled with restricted access to private transport and the decline in their physical and mental capacity to go out or interact with people, create barriers in forming new and maintaining existing relationships with people [78, 79, 76].

Our evaluation analysis showed that SofiHub helped in alleviating the feeling of loneliness among several participants. This came as a surprise, given that we did not cater for this emotional goal within our initial design. During the time that SofiHub was in their homes, participants reported that they looked forward to the messages and felt that 'someone' was in the house with them. Another set of feedback retrieved during the post interviews, a week after SofiHub was uninstalled revealed that most participants missed the "voice", that "somebody" in their house. They also talked about how lonely it felt without SofiHub. Similar findings were found from the interviews with the relatives of the participants.

This unexpected addressing of what turned out to be a key emotional goal of stakeholders - combating loneliness - suggests that emotion-oriented requirements engineering requires considerable feedback between requirements, design and evaluation, but also support to try and find "missing" emotional goals, positive or negative.

Our analysis also shows that while the elderly persons felt lonely and seek company from their close ones, they still wanted to maintain their independence and have control over their lives. At this stage of their lives, they wanted to feel cared about and in touch with their loved ones. Unfortunately, in many cases, this is often misunderstood as the elderly person requiring constant care and support. This often results in the relatives/children forcing the elderly person to move to a nursing home [2, 10] as a show of care and concern for the elderly. Having SofiHub around the house made the elderly person feel cared about as they felt that someone was concerned about them and talked to them on a daily basis, something which, in many families, relatives/children do not have time to do.

This loneliness vs independence vs control emotional goal interaction highlights how different emotional goals interact in complex ways and impact on functional and quality goals of the system. It also highlights how these must be carefully balanced when reasoning about goals impacting functional features and how to prioritise and balance goals. Should alleviating loneliness take precedence over reducing dependence? Should sense of control be less or more important than carer's understanding of need for support? Do different users have differing priorities between these goals, and if so, how do we best design the system to support this?

5.2.2. Feeling Safe and reassured

One of our key initial goals identified for SofiHub was to make elderly adults feel safe and reassure them, as well as their relatives, that SofiHub can support them in their day to day activities. During the interviews, all of the participants confirmed that they felt safe with SofiHub around.

Data from the questionnaires (administered pre-trial, mid-trial and post-trial) showed that four out of ten participants remained constant (over the three collection points) on how safe they felt with SofiHub. The questionnaire used the Likert scale range 1 to 5, with 1 being "I feel insecure with SofiHub around" and 5 being "I feel secure with SofiHub around". At the start of the trial, one participant out of ten reported a value less than 4, which showed overall positive perception of SofiHub, and at end of the trial all participants reported a value of 4 or more on feeling secure with SofiHub (See Appendix D).

Our findings revealed that the participants felt supported throughout the duration of the trials, they felt safe and reassured that in case something happened, the system would alert someone.

This highlights how reaction to a system meeting emotional goals may well change over time of deployment (positively or negatively) and hence may require feedback to the requirements priorities and trade-offs. As in the previous goal interaction example, it may also require the system to support different priorities between goals for different users.

5.2.3. System is Integrated in User's Life

One of the reasons linked to the failure of the adoption of technology by older adults is because older people perceive new technology as being complex, hard to learn and thus leading to frustration. When asked about their views on technology use, one participant mentioned *"Its a nuisance, everything's a nuisance ..."* while others termed it as *"scary"* and *"frustrating"*. While designing SofiHub one of the most important considerations was to ensure that the system is well integrated in the user's life i.e. to ensure its functional features and quality goals minimize these negative technology reactions. Interestingly, during the mid and post interviews when asked about their experience with SofiHub, in particular its interaction messages, the same participants reacted positively to SofiHub.

The relevant questionnaire item used the Likert scale range 1 to 5, with 1 being "I feel that SofiHub gets in my way" and 5 being "I feel that SofiHub improves my day to day life". At the start of the trial only two participants out of ten reported a value of 3 (the minimum value reported), and at the end of the trial also, only two participants reported a minimum value of 3 (See Appendix D). The general consensus was that SofiHub was part of their routine and they waited for the morning messages.

As discussed in Section 2, research into smart homes and emotions and software has consistently shown that such technologies will not be adopted, or not used to their best potential, without fitting well into users lives. In systems where there are similar critical goals that must be met, emotion-oriented requirements engineering and evaluations need to prioritise the achievement of such outcomes. Thus emotional goals are not all created equal - some are absolutely critical to meet (positive) or minimize/eliminate (negative) else the system as a whole will fail.

5.2.4. In Control

Section 2 highlighted that feelings relating to loss of control is a key concern affecting elderly users in technology adoption [80, 13]. In particular, the perception that assistive technology may 'control' the user in their own home can invoke negative emotions.

In this trial, this was measured from questionnaire item using the Likert scale range 1 to 5, with 1 being "I feel that I am being controlled with SofiHub" and 5 being "I feel that I am in control with SofiHub". At the start of the trial only one participant out of ten reported a value of 3 (the minimum value reported), and at the end of the trial also, only the same participant reported a minimum value of 3 (See Appendix D). This shows that overall, the participants felt that they were in control when using SofiHub.

As in the previous subsection, this maintaining control / not feeling ”being controlled” by technology solutions are top priority emotional goals of the target end-users of the system. In other systems, there may be other top priority emotional goals to meet to ensure its adoption and sustainable usage.

5.2.5. Privacy and Invasiveness

Another design consideration was made to ensure that the privacy of the occupants were not threatened. This was measured using two relevant questionnaire items, both using the Likert scale range 1 to 5. The first item evaluated how the participants felt about having sensors in their home and in effect, monitoring their activities. Here, level 1 was “I feel anxious about being monitored” and level 5 was “I feel comfortable about being monitored”. At the start of the trial only one participant out of ten reported a value of 3 (the minimum value reported), and at the end of the trial, all of the participants reported values of 4 and more (See Appendix D).

The second item evaluated if the participants were concerned about their privacy being violated by having SofiHub in their homes. Here, level 1 was “I feel concerned about my privacy with SofiHub around” and level 5 was “I feel that my privacy is secure with SofiHub around”. At the start of the trial all of the participants reported values of 4 and more, and this was the same at the end of the trial (See Appendix D).

Thus, findings from interview and questionnaire data shows that overall, participants did not feel that SofiHub was being invasive nor did they feel that their privacy was being violated.

Privacy of data and personal behaviour, location and movement has become central to many Internet of Things / Smart Environment solutions. Many such systems will need to try and maximise positive feelings about privacy support, and minimize negative feelings about privacy invasion, data loss, and related technology concerns. Our Sofihub experience has shown that our emotion-oriented approach to this aspect of technology can be captured, designed into the solution, and evaluated with target end users.

5.2.6. Other Views on using SofiHub

In addition to the key emotional goals evaluated in previous subsections, we also measured four other emotions; namely, feeling excited about having SofiHub, feeling confident about using SofiHub, feeling that SofiHub increases their comfort, and feeling that SofiHub runs smoothly.

These were measured using four questionnaire items, using the Likert scale range 1 to 5. For measuring feeling excited, level 1 of the Likert scale was “I feel worried about having SofiHub around my house” and level 5 was “I feel excited about having SofiHub around”. At the start of the trial only one participant out of ten reported a value of 3 (the minimum value reported), and at the end of the trial also only one participant reported a minimum value of 3. For measuring feeling confident, level 1 of the Likert scale was “I feel scared about using SofiHub” and level 5 was “I feel confident about using SofiHub”. At the start of the trial, all of the ten participant reported values of 4 or higher, and this was repeated at the end of the trial as well. For measuring feeling that SofiHub increases comfort, level 1 of the Likert scale was “I feel that SofiHub increases my discomfort” and level 5 was “I feel that SofiHub increases my comfort”. At the start of the trial three out of the ten participant reported a value of 3 (the minimum value reported), and at the end of the trial only one participant reported a minimum value of 3. For measuring feeling that SofiHub runs smoothly, level 1 of the Likert scale was “I feel that SofiHub is a complicated system” and level 5 was “I feel that SofiHub runs smoothly”. At the start of the trial only one participant out of ten reported a value of 3 (the minimum value reported), and at the end of the trial all of the participants reported values of 4 or higher.

These findings show that in general, the participants felt excited to have SofiHub installed in their homes, were confident in their ability to use it, felt that SofiHub increased their comfort, and that SofiHub operated smoothly.

More generally, as discussed in Section 2, these are also important goals for both smart homes and elderly-oriented software solutions in general such as pendants, apps, portals and others. In fact, any Internet of Things-based system with user interaction with non-technical end users will have emotional expectations around addressing emotional concerns around complexity, discomfort, and reliability.

5.2.7. Emotional Threats

The data collected during the interviews also revealed some emotional threats experienced by the participants during the trial. These concerns were mainly linked to issues with functionalities. Given that the technology was plugged in to a power socket and relied on electricity, a couple of incidents linked to power failure or accidental dislodgement of the power supply were noted during the trials. Users raised concerns about the system being disrupted and the delay in playing the messages. In some cases, the users were worried that they might have 'upset' or 'confused' the system.

Again as in the previous subsection, these are likely to be common emotional threats in any non-technical end user system relying on sensors, power connections, natural language or gesture based interactions and so on. Using our emotion-oriented requirements engineering and evaluation approaches for these systems is likely to inform developers of these concerns and help them to try and mitigate them in their designs and implementations.

5.3. Implications of Findings on the Next Generation of SofiHub

The findings from these trials are being used to refine the tool and research methodology. The next generation of the tool will be trialled in the homes of 13 older adults, out of which 3 participants had participated in the recent trials and the remaining 10 have never used SofiHub before.

Based on our findings, we identified two new emotional goals namely, *'feeling less lonely'* and *'feeling cared about'* which were addressed by the *'issue messages'* functional goal. During the interviews, most of the participants talked about how they waited for the morning messages to play. They were mostly pleased with the variation in the messages and some of them queried about the possibility of having night messages. While the next generation of SofiHub will maintain most of its functional goals, two new emotional goals (*'less lonely'* and *'cared about'*) and a quality goal *'chatty'* has been included in the refined goal model as shown in Figure 7.

We will also expand our research to study the extent to which smart home technologies are successful in alleviating loneliness. Our updated questionnaire and interviews will include statements and questions, respectively, to address the emotional goal of *'feeling less lonely'*. We will also make use of a well established UCLA loneliness scale to assess the level of loneliness at different time periods: (a) prior to the installation of SofiHub in their homes, (b) in the middle of the trial and (c) after SofiHub is removed from their homes.

These findings are important for a wide range of other smart home solutions and software or devices aimed at elderly or users with mental and/or physical challenges. Assisting to address lonliness amoung the elderly has become a major mental health challenge and representing these emotional goals in requirements, addressing them in functional features and their realization, and evaluating how well the goals are met are likely to be important for many other smart home solutions.

6. Threats to Validity

Emotional goals: The emotional goals that we have developed represent a good starting point to emotional-goals for smart home technologies. However, these goals are based on the state-of-the-art in the literature as well as our findings from the initial workshops and trials on our solution. This explains why in our trials we learned about two missing goals in our original model – as reported above – which will be integrated with the initial model and used in phase 2 SofiHub development and trialling.

Target systems: We do not have access (and have not done trials) with other leading edge smart home solutions to conduct concrete pain point analysis in order to be able to derive different emotional goals, different priorities, and evaluate them with competing systems and approaches.

Emotional goals during System Design: There is no formal process to communicate and make sure that the system is being designed following the identified emotional goals e.g. when designing a user interface, implementing interaction features and feedback in the software. In our case, we have been involved with the development team on regular basis, and we have worked on the design and roll out of the trials, as well as the evaluation of the findings. The analysis conducted was mainly qualitative and subjective based on participants feedback. Hence we are looking to extend the size of our next trials to include more participants, which would help us to assess if our analysis and findings are significant or not.

Findings from the trials: Even though user emotional expectations is a subjective concept, the data analysis process was conducted objectively using the process of content analysis to eliminate subjectivity as much as possible. Each interview script and questionnaire was analysed by more than one researcher and the compilation of the synthesised notes was conducted by a group of 3 researchers. Hence in terms of reliability, the findings of this study were not dependent on any specific researcher. We are working on a more quantitative technique that maps emotional goals to a set of computable metrics that can be calculated over time to reflect goals like connected, loneliness, etc. using interactions between SofiHub and residents. Another threat to validity is the duration of the trials. Although our trials took three months, we are planning to extend this to longer

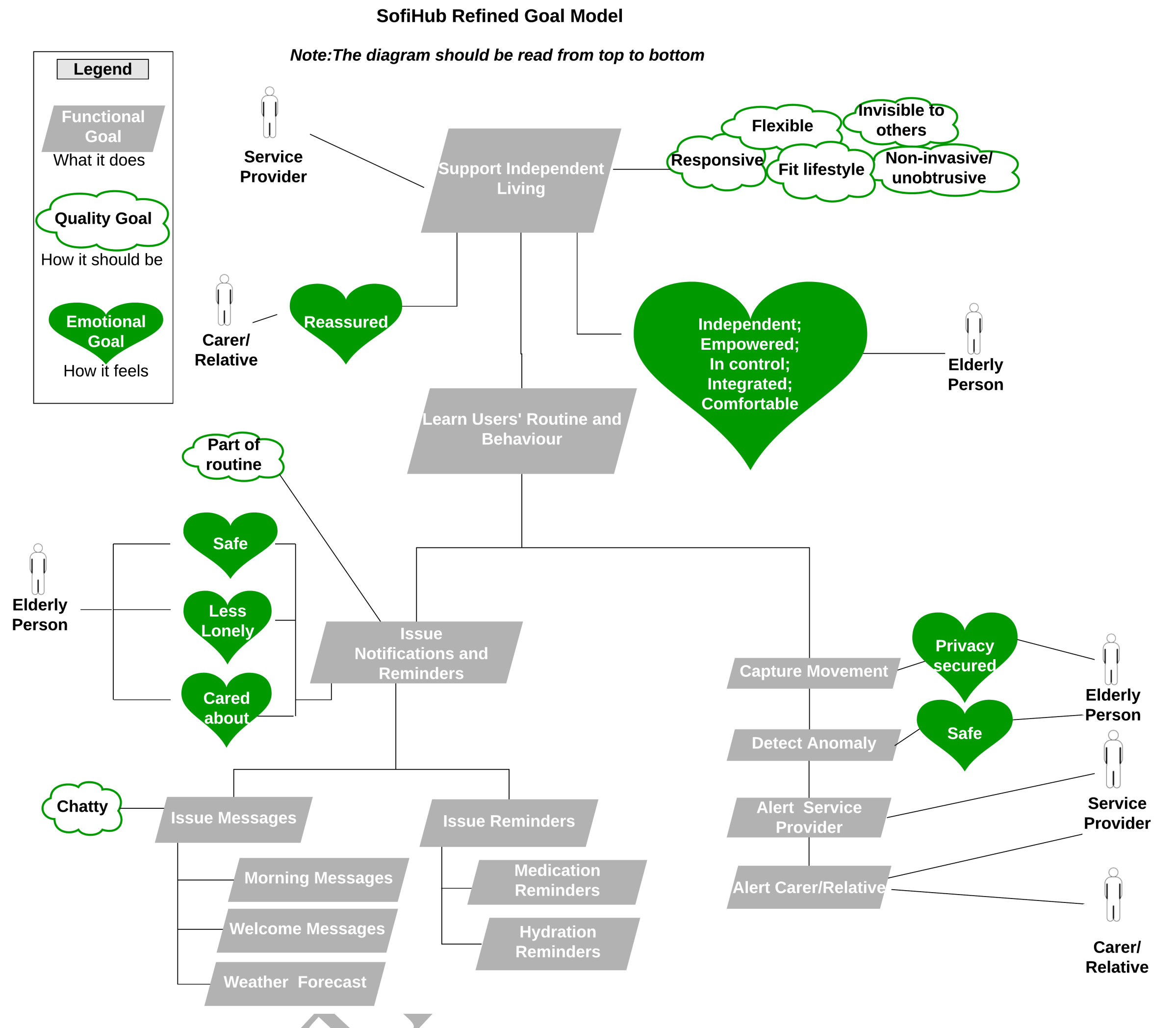

Figure 7: Refined Goal Model

period and introduce monthly interviews & surveys in addition to interaction metrics as mentioned above.

Even though this study was conducted with only 10 older adults, we argue that this study can be extended to other people. The participants involved in our case study were representative of the population of elderly adults and, therefore, if this study was extended to more participants, similar results would be anticipated. We are planning to increase the number of participants in the next trials.

7. Discussion

In this work, we presented a set of emotion-oriented requirements engineering and evaluation techniques, which we applied to design and evaluate our new Smart Home Technology- SofiHub. Designing systems with an emotion-oriented approach entails a number of challenges. First of all, emotion-oriented techniques are not mature enough. For example, our technique has been trialled on four real-world scenarios until now. Second, given the subjective nature of emotions, it is hard to develop a solution that satisfies everyone. Third, incorporating users' emotional goals without a well-established methodology is not only challenging but also daunting for software engineers. Based on our findings, we argue that our emotion-oriented techniques used to design SofiHub were successful in capturing users' goals, in particular, their emotional needs given that, most of the participants responded positively to SofiHub and even expressed their willingness to adopt the technology. Their only concerns with adopting this technology were linked to (i) cost and (ii) response time to generate an alert in case of an emergency. SofiHub not only addressed the set of emotional goals identified at the beginning of the trial but also helped in alleviating loneliness and making its users feel cared about.

We therefore reiterate that our proposed techniques are valuable tools that can be used to capture, model and evaluate users' emotional expectations. The elicitation and modelling techniques can be integrated within existing requirements engineering processes, thus adding value to the overall set of requirements. Furthermore, they can be applied and extended to other projects with a user-centered focus, within different domains. Applying the emotion-oriented elicitation technique within such systems, can help in identifying potential concerns related to the way users feel about the system at a very early stage in the software development cycle. In addition, project managers and requirement analysts can use these emotion-oriented models, in particular, the goal model, to develop an additional layer to identify how well emotional goals have been captured and to uncover any hidden requirement. These elicitation and modelling techniques can hence contribute towards the completeness of the set of requirements, improving the quality of the software and reducing the redesign costs and development time, as project managers and engineers have a clearer picture of what end-users want. Knowing what users want can also help in improving the productivity of the development team as they do not have to guess or imagine what would satisfy the users.

Our proposed emotion-informed questionnaire can be used to evaluate solutions where emotional goals are important and that they are being suitably addressed in the software solution. It is worth noting that emotion being subjective and complex, the proposed tool might not provide adequate information regarding the extent to which emotional goals have been achieved. They are, however, simple to use and provide a quick insight into the extent to which emotional goals have been achieved. Our recommendation is to use this emotional assessment tool along with some other existing qualitative data gathering tool such as interviews like we did in this case study.

Based on our observations from the workshops with the development teams, we determined that even though the models provided the developers with a clearer picture of the end-users and their needs, they were insufficient in self guiding them throughout the design and implementation processes to ensure emotional goals are met. Interestingly, in the area of game design, designers are adept at developing games which are meant to be 'fun', 'interactive' and 'engaging'. These designers use design patterns and follow design guidelines to create games [81]. Unfortunately, this wealth of knowledge has not fully permeated in the software engineering field. The models, presented in this work, could be applied and further extended to create a set of design guidelines and heuristics to guide designers in their task. Similarly, a set of software development guidelines or checklists can be created such that developers can be provided with specific guidance to ensure that emotional aspects are accurately considered/implemented. Additionally, further goal representational enhancements e.g. annotations, stereotypes, constraints, links could be added to UML and other design-level software artifacts.

According to some researchers, the acceptance and adoption of a technology depend mainly on the technology's benefits, cost and relative advantage over other alternatives as well as the complexity of use [82, 83, 84, 85]. Others identify user emotional expectations as a critical determinant for the adoption and acceptance of a technology [1, 2, 5, 4]. Our findings show that when it comes to adopting and accepting a technology, many factors other than the users' emotional goals also come into play, such as the cost of the technology and the response time to generate an alert in case of an emergency.

8. Conclusion

Capturing, modeling and realizing emotional goals is a key enabler to the adoption of socio-technical or people-oriented systems. This work contributes towards emphasising the importance of such emotional goals during system design and provides a set of emotion-oriented techniques to engineer a smart home technology.

In this paper, we have applied emotion-oriented techniques to develop SofiHub, a smart home technology for elderly people. We have presented a Smart home emotion and goal model that represent key goals that should be taken into consideration when building a smart home solution. We presented SofiHub that was designed following emotion-oriented requirements modeling approach. Finally, we have presented details of our trials in 10 houses. Our findings show that the SofiHub solution has met the emotional goals we have identified earlier. We also have identified two goals that we did not consider in the initial design: alleviating loneliness and cared-about. Furthermore, our findings and study show that user emotional expectations are a critical determinant to the success of a technology. As part of our future work, we intend to formalise the approach used to bridge the gap between the requirements and design phases.

Acknowledgements

We would like to thank the SofiHub team who allowed us to use their technology to acquire the trial data for this work. We would also like to acknowledge the efforts put forward by the DSTIL team at Deakin University to develop the smart home technology.

References

References

[1] G. Demiris, M. J. Rantz, M. A. Aud, K. D. Marek, H. W. Tyrer, M. Skubic, A. A. Hussam, Older adults' attitudes towards and perceptions of 'smart home' technologies: a pilot study, Informatics for Health and Social Care 29 (2004) 87–94.

[2] S. Pedell, L. Sterling, A. Keirnan, G. Dobson, Emotions around emergency alarm use: A field study with older adults, Technical Report, Report for smart services CRC, Swinburne University of Technology, 2013.

[3] A. Mendoza, T. Miller, S. Pedell, L. Sterling, The role of users' emotions and associated quality goals on appropriation of systems: two case studies, 24th Australasian Conference on Information Systems (2013).

[4] I. Ramos, D. M. Berry, J. Á. Carvalho, Requirements engineering for organizational transformation, Information and Software Technology 47 (2005) 479–495.

[5] T. Miller, S. Pedell, A. A. Lopez-Lorca, A. Mendoza, L. Sterling, A. Keirnan, Emotion-led modelling for people-oriented requirements engineering: the case study of emergency systems, Journal of Systems and Software 105 (2015) 54–71.

[6] D. A. Norman, Emotional design: Why we love (or hate) everyday things, Basic books, New York, 2005.

[7] A. Mendoza, J. Carroll, L. Stern, Software appropriation over time: from adoption to stabilization and beyond, Australasian Journal of Information Systems 16 (2010).

[8] G. Baxter, I. Sommerville, Socio-technical systems: From design methods to systems engineering, Interacting with Computers 23 (2011) 4–17.

[9] J. Paay, L. Sterling, F. Vetere, S. Howard, A. Boettcher, Engineering the social: The role of shared artifacts, International Journal of Human-Computer Studies 67 (2009) 437–454.

[10] M. Kissoon Curumsing, Emotion-Oriented Requirements Engineering, PhD dissertation, Swinburne University of Technology, 2017.

[11] M. Kissoon-Curumsing, S. Pedell, R. Vasa, Designing of an evaluation tool to measure emotional goals, IJPOP: Special Issue on Emotions and People-Oriented Programming 3 (2014) 22–43.

[12] M. Kissoon-Curumsing, A. Lorca-Lopez, T. Miller, L. Sterling, R. Vasa, Viewpoint modelling with emotions: A case study, IJPOP: Special Issue on Emotions and People-Oriented Programming 4 (2014) 25–53.

[13] N. Fernando, F. Tan, R. Vasa, K. Mouzakis, I. Aitken, S. Australia, Examining digital assisted living: Towards a case study of smart homes for the elderly, in: ECIS, Research-in-Progress Papers. 70.

[14] R. Harper, Inside the smart home, Springer Science and Business Media, 2006.

[15] D. J. Cook, J. C. Augusto, V. R. Jakkula, Ambient intelligence: Technologies, applications, and opportunities, Pervasive and Mobile Computing 5 (2009) 277–298.

[16] D. J. Cook, A. S. Crandall, B. L. Thomas, N. C. Krishnan, Casas: A smart home in a box, Computer 46 (2013) 62–69.

[17] R. Steele, A. Lo, C. Secombe, Y. K. Wong, Elderly persons perception and acceptance of using wireless sensor networks to assist healthcare, International journal of medical informatics 78 (2009) 788–801.

[18] J. Van Hoof, H. Kort, P. Rutten, M. Duijnstee, Ageing-in-place with the use of ambient intelligence technology: Perspectives of older users, International journal of medical informatics 80 (2011) 310–331.

[19] J. A. Kientz, S. N. Patel, B. Jones, E. Price, E. D. Mynatt, G. D. Abowd, The georgia tech aware home, in: CHI'08 extended abstracts on Human factors in computing systems, ACM, 2008, pp. 3675–3680.

[20] N. K. Suryadevara, S. C. Mukhopadhyay, R. Wang, R. Rayudu, Forecasting the behavior of an elderly using wireless sensors data in a smart home, Engineering Applications of Artificial Intelligence 26 (2013) 2641–2652.

[21] Tunstall ivi intelligent pendant, `http://www.tunstall.co.uk/solutions/ivi`, 2017. Accessed: 2017-06-26.

[22] LiveLife personal mobile alarm, `https://livelifealarms.com.au/`, 2017. Accessed: 2017-06-26.

[23] Tunstall wall-mount help button, `http://www.tunstallhealthcare.com.au/products/helpbutton`, 2017. Accessed: 2017-06-26.

[24] Tunstall flood detector, `http://www.tunstall.co.uk/solutions/flood-detector`, 2017. Accessed: 2017-06-26.

[25] Quell smoke alarms, `https://www.quell.com.au/collections/smoke-alarms`, 2017. Accessed: 2017-06-26.

[26] Swann anti-flood and water leakage alarm, `http://www.swann.com/au/sw351-wla`, 2017. Accessed: 2017-06-26.

[27] Stove guard motion sensor, `http://ilcaustralia.org.au/products/18761`, 2017. Accessed: 2017-06-26.

[28] i-pot helps elders feel less lonely, `https://www.engadget.com/2005/04/15/i-pot-helps-elders-feel-less-lonely/`, 2005. Accessed: 2017-06-27.

[29] Mobile device to revolutionize care for world's growing ageing population, `https://ollomobile.prezly.com/mobile-device-to-revolutionize-care-for-worlds-growing-ageing-population`, 2017. Accessed: 2017-06-27.

[30] Tricella smart pillbox, `http://www.tricella.com/`, 2017. Accessed: 2017-06-27.

[31] Mandown app, `http://www.mandownapp.com/`, 2017. Accessed: 2017-06-27.

[32] C. P. Ltd, Anna cares, `https://itunes.apple.com/au/app/anna-cares/id920271792?mt=8`, 2017. Accessed: 2017-06-27.

[33] grandCARE, `https://www.grandcare.com/`, 2017. Accessed: 2017-06-27.

[34] Healthsense, `http://healthsense.com/healthsense-dashboard/`, 2017. Accessed: 2017-06-27.

[35] Independa, `https://independa.com/`, 2017. Accessed: 2017-06-27.

[36] Lively, `http://www.mylively.com/how-it-works`, 2017. Accessed: 2017-06-27.

[37] F. Portet, M. Vacher, C. Golanski, C. Roux, B. Meillon, Design and evaluation of a smart home voice interface for the elderly: acceptability and objection aspects, Personal and Ubiquitous Computing 17 (2013) 127–144.

[38] S. Mallett, Understanding home: a critical review of the literature, The sociological review 52 (2004) 62–89.
[39] K. L. Courtney, G. Demeris, M. Rantz, M. Skubic, Needing smart home technologies: the perspectives of older adults in continuing care retirement communities (2008).
[40] G. Demiris, B. K. Hensel, M. Skubic, M. Rantz, Senior residents perceived need of and preferences for smart home sensor technologies, International journal of technology assessment in health care 24 (2008) 120–124.
[41] M. L. Meuter, M. J. Bitner, A. L. Ostrom, S. W. Brown, Choosing among alternative service delivery modes: an investigation of customer trial of self-service technologies, Journal of Marketing (2005) 61–83.
[42] D. P. Lorence, H. Park, New technology and old habits: the role of age as a technology chasm, Technology Health Care 14 (2006) 91–96.
[43] S. L. Wood, C. P. Moreau, From fear to loathing? how emotion influences the evaluation and early use of innovations, Journal of Marketing (2006) 44–57.
[44] M. Hassenzahl, The interplay of beauty, goodness, and usability in interactive products, Human Computer Interaction 19 (2008) 319–349.
[45] T. Miller, S. Pedell, L. Sterling, F. Vetere, S. Howard, Understanding socially oriented roles and goals through motivational modelling, J. Syst. Softw. 85 (2012) 2160–2170.
[46] E. Cambria, A. Livingstone, A. Hussain, The Hourglass of Emotions, volume 7403 of *Lecture Notes in Computer Science*, Springer Berlin Heidelberg, pp. 144–157.
[47] R. Colomo-Palacios, A. Hernàndez-López, Á. García-Crespo, P. Soto-Acosta, A study of emotions in requirements engineering, in: Organizational, Business, and Technological Aspects of the Knowledge Society: Third World Summit on the Knowledge Society, WSKS 2010, Corfu, Greece, September 22-24, 2010. Proceedings, Part II, volume 112 of *Communications in Computer and Information Science*, Springer Berlin Heidelberg, Berlin, Heidelberg, 2010, pp. 1–7.
[48] I. Ramos, D. M. Berry, Is emotion relevant to requirements engineering?, Requirements Engineering 10 (2005) 238–242.
[49] S. Thew, A. Sutcliffe, Investigating the Role of 'Soft Issues' in the RE Process, in: 16th IEEE International Requirements Engineering, 2008. RE '08, pp. 63–66.
[50] A. Sutcliffe, S. Thew, Analysing "people" problems in requirements engineering, in: 32nd International Conference on Software Engineering, volume 2, IEEE, pp. 469–470.
[51] A. Sutcliffe, Emotional requirements engineering, in: 19th IEEE International Requirements Engineering Conference (RE), pp. 321–322.
[52] R. Proynova, B. Paech, S. H. Koch, A. Wicht, T. Wetter, Investigating the influence of personal values on requirements for health care information systems, in: Proceedings of the 3rd Workshop on Software Engineering in Health Care, ACM, pp. 48–55.
[53] S. Y. Eric, Social modeling and i, in: Conceptual Modeling: Foundations and Applications, Springer, 2009, pp. 99–121.
[54] A. A. Lopez-Lorca, T. Miller, S. Pedell, L. Sterling, M. K. Curumsing, Modelling emotional requirements, http://people.eng.unimelb.edu.au/tmiller/pubs/modelling-emotional-requirements.pdf, 2014. Viewed 1 February 2015.
[55] J. Marshall, Using goal models for project management in teaching, Flash Talk at OZCHI, 2012.
[56] R. Plutchik, The nature of emotions, American Scientist 89 (2001) 344+.
[57] M. B. Arnold, Emotion and personality, volume 1, Columbia University Press, 1960.
[58] P. Ekman, W. Friesen, P. Ellsworth, What emotion categories or dimensions can observers judge from facial behaviour? In, P. Ekman, Emotion in the Human Face (1982).
[59] N. H. Frijda, The emotions, Cambridge University Press, New York, 1986.
[60] J. A. Gray, The whole and its parts: Behaviour, the brain, cognition and emotion, Bulletin of the British Psychological Society 38 (1985) 99–112.
[61] J. William, What is an emotion?, Mind 9 (1884) 188–205.
[62] K. Matsumoto, J. Minato, F. Ren, S. Kuroiwa, Estimating human emotions using wording and sentence patterns, in: IEEE International Conference on Information Acquisition, IEEE, p. 6 pp.
[63] W. McDougall, An introduction to social psychology, Luce, Boston, 1926.
[64] O. H. Mowrer, Learning theory and behavior, Wiley, New York, 1960.
[65] K. Oatley, N. Johnson-laird, P., Towards a cognitive theory of emotions, Cognition & Emotion 1 (1987) 29–50.
[66] J. Panksepp, Toward a general psychobiological theory of emotions, Behavioral and Brain sciences 5 (1982) 407–422.
[67] W. Parrott, Emotions in Social Psychology, Psychology Press, Philadelphia, 2001.
[68] S. S. Tomkins, Affect theory, Approaches to emotion 163 (1984) 195.
[69] J. B. Watson, R. Rayner, Conditioned emotional reactions, Journal of experimental Psychology 3 (1920) 1.
[70] B. Weiner, S. Graham, An attributional approach to emotional development, Emotions, cognition, and behavior (1984) 167–191.
[71] M. Q. Patton, Designing qualitative studies, Qualitative research and evaluation methods 3 (2002) 230–246.
[72] K. Baxter, C. Courage, K. Caine, Understanding Your Users: A Practical Guide to User Research Methods, Morgan Kaufmann, 2015.
[73] A. Dix, Human-computer interaction, Harlow : Pearson, 3rd edition, 2004.
[74] E. R. Tufte, Envisioning information., Optometry & Vision Science 68 (1991) 322–324.
[75] M. Hassenzahl, Attrakdiff (tm), http://www.attrakdiff.de, 2007. Viewed 16 July 2016.
[76] A. P. Dickens, S. H. Richards, C. J. Greaves, J. L. Campbell, Interventions targeting social isolation in older people: a systematic review, BMC public health 11 (2011) 647.
[77] M. Cattan, M. White, J. Bond, A. Learmouth, Preventing social isolation and loneliness among older people: a systematic review of health promotion interventions, Ageing and society 25 (2005) 41–67.
[78] J. Petersen, D. Austin, J. A. Kaye, M. Pavel, T. L. Hayes, Unobtrusive in-home detection of time spent out-of-home with applications to loneliness and physical activity, IEEE journal of biomedical and health informatics 18 (2014) 1590–1596.
[79] C. Alcock, L. Burgess, H. Hasan, Connecting isolated senior citizens: illustrating the complexity of social information systems development, in: H. Hasan (Eds.), Being Practical with Theory: A Window into Business Research, Wollongong, Australia: THEORI, 2014, pp. 126–130.
[80] N. Balta-Ozkan, R. Davidson, M. Bicket, L. Whitmarsh, Social barriers to the adoption of smart homes, Energy Policy 63 (2013) 363–374.
[81] S. Bjork, J. Holopainen, Patterns in game design (game development series), Hingham: Charles River Media, 2004.
[82] F. D. Davis, Perceived usefulness, perceived ease of use, and user acceptance of information technology, MIS Quarterly 13 (1989) 319–340.
[83] E. Karahanna, D. W. Straub, N. L. Chervany, Information

technology adoption across time: a cross-sectional comparison of pre-adoption and post-adoption beliefs, MIS Quarterly 23 (1999) 183–213.

[84] V. Venkatesh, Determinants of perceived ease of use: Integrating control, intrinsic motivation, and emotion into the technology acceptance model, Information systems research 11 (2000) 342–365.

[85] V. Venkatesh, M. G. Morris, G. B. Davis, F. D. Davis, User acceptance of information technology: toward a unified view, MIS Quarterly 27 (2003) 425–478.

Appendix

An additional set of supporting documents, relevant to this work, have been added to the appendices, which has been submitted with this document. The table below provides a description of the contents of each appendix.

No.	Name	Contents
A	`AppendixA`	Contains the questionnaires and the daily checklist used during the trial.
B	`AppendixB`	Contains a set of interview questions used during the trial.
C	`AppendixC`	Contains the Affinity Diagram derived from the analysis of the interview transcripts.
D	`AppendixD`	Contains the questionnaire data (in charts)