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A Smart, Caring, Interactive Chair Designed for Improving Emotional Support and Parent-Child Interactions to Promote Sustainable Relationships Between Elderly and Other Family Members

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Abstract: In this study, we implemented a four-stage service design process to analyze the home-based interaction behavior between elderly and other family members to identify hidden needs for strengthening inter-generational relationships and creating harmony as a turning point for new product innovations in home-based interactive devices. In the demand exploration stage and demand definition stage, context inquiry and service modeling were applied to understand the intergenerational relationship between the elderly and other family members and the potential needs and expectations of family interactions. The overall demand mainly includes four points: (1) the improvement in inter-generational relationships requires the active care of family members, (2) the improvement in inter-generational emotional interactions requires accurate mastery of parental responsibilities, (3) the chairing design of the living room can be used to understand and document parental life practice, and (4) big data parental lifestyle records can be analyzed. Based on hidden demands, a smart care interactive system (SCIS) with a chair was designed for improving emotional interactions and parent-child interaction between the elderly and other family members. The results of the verification experiment show that the smart care interactive chair (SCIC) can significantly help the elderly with intergenerational relationships in terms of emotional support and parent-child interactions. The family emotional support and parent-child interactions are the foundation of the sustainability of family relationships and the cornerstone of social stability.

Keywords: service design; home caring devices for elderly; emotional interactions between elderly and family members; Internet of Things (IoT)

1. Introduction

Due to rapid growth of the industrial era, industries have transformed and the economic development gap between rural and urban areas has widened. Rapid urbanization has shifted the traditional family structure and function [1]. With the progress of society and the development of medical science and technology, the social population structure is ageing, and the living pattern of the elderly population in Taiwan has changed. The proportion of elderly people living with their children (including spouses) is close to 68%. The proportion of people living separately from their children (including spouses) is 32% [2]. Connidis [3] thought that, despite the changes in family life caused by social changes, the elderly ethnic group may be separated from their adult children. However, the importance of family relationships is more valued and expected by the elderly, including emotional support from family members. Communication and interactions with family members are most valued by the elderly community [4,5]. However, previous studies have shown that interpersonal interactions

are an important issue for the elderly, since about 25% of 70- to 85-year-olds remain at their homes. Even at the age of 56–69 years old, 14% remain at home [6]. Having more time at home causes a relatively high frequency of interactions with loved ones, and since the elderly have twice as much free time as other age groups, many scholars suggest that proper interpersonal interactions can maintain the mental health of the elderly [7,8] and can reduce psychological social isolation and loneliness [9], further reducing the risk of death and of Alzheimer's disease [10].

Although society has changed, family emotional support and parent-child interactions are the most important factor in maintaining family relationships [11], being the foundation of the sustainability of family relationships and the cornerstone of social stability. However, the ageing society is facing a problem with care. Adult children feel pressure to care for their elderly parents, which generates contradicting feelings in terms of emotions, roles, and self [12], and 39% of adults are in a pattern of self-sacrifice when taking care of older parents [13]. Conflicts occur between the personal interest of caring for parents and adult children, and the strength of the parent-child relationship affects the intergenerational caring by adult children [14]. This pressure can lead to alienation among family members and can even divide the family [15].

Therefore, we considered elderly parents as core users, and adult children, family members, and caregivers as service providers for caring their elderly parients. Through the viewpoint and method of service design centered on user experience, contextual observations were recorded to investigate the experience before, during, and after service contact and to discover the shortcomings during the experience and the unsatisfied potential needs. This study explores the potential needs of improving parent-child relationship between generations. The scope of observation is not only dialogue, but also the difficulty of simply describing and analyzing the dynamic course of activities through words. Therefore, context exploration [16] is used as a tool to explore the context based on user's activities in order to build the potential needs of the elderly. Via field interviews, field surveys, and analysis, the user's overall working mode is obtained, and the process of obstacles in activities is then analyzed and further highlighted. For example, Duan [17] used the contextual inquiry observation method and conducted an analysis of elderly remote health care services to understand the users' lifestyle, behavior patterns, needs, and obstacles. Kuoa et al. [18] used contextual inquiry to identify potential needs for long-distance health care. When cultural context was added, conflicts between service providers and patients could be reduced. Xiao et al. [19] investigated the hidden service needs for the use of the E-care professional care management system. By improving the quality of existing contact points and experiences, processes, and family interactions, we propose a new product and services to improve intergenerational relationships [20,21].

The purpose of this study was to explore the characteristics, needs, and expectations of the interactions between elderly parents and their children through the service design method, and to determine the real contact behavior and experience gap of adult parents. According to the environment, activities, objects, and contact experience of various family members, the interactions and communication behavior between the elderly and their children at home were analyzed to identify the hidden need of harmonious intergenerational relationships. Innovative home interaction devices are proposed to improve these intergenerational relationships. Based on the environment, activities, objects, and contact with various people, we analyzed the home-based interaction behavior between the elderly and their children to determine how to strengthen the relationships between the generations, and a home interactive device is proposed to improve the intergenerational relationships.

2. Literature Review

2.1. Parent-child Relationship between Generations

The interactions between elderly parents and their families is the most important relationship in life. It is the most common, basic, and earliest relationship, lasting from life to death, and is the closest and least numerous type of intimate relationship with the most far-reaching impact [22]. The

core interpersonal relationships of the elderly include intimate relationships between spouses and children, whereas peripheral relationships include those with friends, relatives, and neighbors. The interactions and intimacy of the elderly with others are not as great as those of the central family members [23]. Seventy percent of the elderly in Taiwan said that their ideal mode of living is to live with their children, 13% stated that they want to live only with their spouse, and 6.3% stated that they want to live alone [2]. Due to the development of society and the economy, family life has changed. The family lifestyle of three generations in Taiwan has gradually disappeared, replaced by the core family (two generations). Connidis [3] argued that although social changes have altered family life and the retired elderly may be separated from their adult children, the importance of family relationships is more valued and expected by the elderly. Therefore, intergenerational relationships are interpersonal relationships based on kinship and are a kind of parent-child relationship of mutual respect and communication [6]. However, intergenerational relationships change gradually over time, from authoritative and submissive top-down relationships between parents and children to equal and mutually supportive adult-to-adult relationships. Therefore, the interactions between the two generations are bidirectional, which produces certain norms in interactions and emotional communication [7], among which family emotional support and family communication interactions are the most important factors for the elderly and their families [4,5].

Different interpersonal relationships exist between the two generations. Close relationships may involve love and care, but also include the possibility of conflict, jealousy, and anger. In the experience of adult children in caring for their parents, there is the phenomenon of parent-child power reversal. Whether the parent-child relationship is good or not also affects the intergenerational care of adult children. In regard to sex and marriage, unmarried daughters and daughters-in-law seem to be more likely to be taken for granted as caregivers. Additionally, women worry that entering marriage will mean taking care of their parents-in-law and losing themselves [14], which affects the harmony of emotions and interactions between generations. These stressors cause more alienation among family members and can even lead to family divisions [15]. Emotional connection and interactions are important indicators of an intergenerational relationship. Most of the elderly actively find someone to talk with when they are in a bad mood. Most mainly focus on friends and neighbors, followed by children and spouses. Therefore, if children are actively concerned with their parents and allow their parents to be dependent, they are more likely to ease their mood than provide money [24]. Older people want to actively maintain close interactions with their families. Positive interactions with family members enable them to gain satisfaction, pleasure, intimacy, and emotional support, and allow them to maintain their self-worth [25].

2.2. Intergenerational Emotional Connection and Family Interaction Device

The interactions between the elderly and other family members is an important issue in society. Relationships between the elderly and other family members are weakening due to social changes. Although social changes have led to changes in family life, the elderly may be separated from their children, but family relationships are more valued and expected by the elderly [10]. For families with elderly members, the emotional support of family members and family communication and interactions are two of the most important issues [3]. The emotional connections and interactions between the elderly and their children is an important indicator of inter-generational relationships. Improvement in interpersonal relationships is helpful for the mental health of the elderly [8], effectively reduces the risk of Alzheimer's disease [10], and is as effective as fitness activities in this regard [26].

The design of intelligent living spaces is mainly focused on supporting and monitoring the basic activities of daily living (ADLs), including eating, bathing, toileting, dressing, and food preparation. For example, the European Union promotes the ambient assisted living (AAL) research program [27] by employing a variety of sensing technologies and electronic products to create a smart home living environment, assisting the elderly to maintain independent living and personal privacy [28]. In another example, by embedding an optical fiber sensor or a piezoelectric sensor in a wooden floor, a

communication system was used to transmit various types of interactive information within a home environment [29].

2.3. Service Design

Service design applies service as the core to satisfy user expectations of experiential economy. The development of design specialty has changed from focusing on the substantive aspects of products [30] to the expectation and experience of caring about the intangible aspects of users. Emphasizing the interactions and experiences between the service delivery process and consumers, the focus of design development has changed from tangible objects to the intangible world [21]. Therefore, the service design focuses on users' comprehensive experience, including their experience before, during, and after the service, providing users with usable, useful, and desirable products and efficient services [31]. Service design should be used as a strategy in production and consumption systems and should provide opportunities for sustainable development of the environment and society [31].

2.3.1. Service Design Process and Method

The process of service design is not linear but convergent and divergent. Each stage is a process of rethinking and revising [32,33]. Mager [20] pointed out that by observing and interpreting customers' needs and behavior patterns, designers can describe specific service content and operation functions through visual presentation and transform these functions into feasible service design schemes. All decisions in the process affect the final design results. Designers must constantly reflect to clarify each design process. Having a good service design process has become the key to determining the quality of products.

For example, in 2001, faced with the Internet bubble, IDEO, a well-known design company based in Palo Alto, California, USA, immediately decided to adjust their service and operation modes. In addition to continuing to introduce innovative products, the main resources of the company were invested in the service innovation and design process. The main concept of the IDEO's design process is to build products from a user standpoint, design products from the perspective of users, and find out the real needs of people by observing user behavior and placing themselves in the context of the user [34]. IDEO defines the service design process as [35] (1) developing insights about the market, (2) creating radical value propositions, (3) exploring creative service models, (4) bending the rules of delivery, and (5) iteratively piloting and refining the new service.

The British reformed the Design Council, which was originally in charge of industrial design, which then became a new British service-based economy think-tank and nonprofit organizer. At the end of July 2008, it published a three-year development strategy called "The Good Design Plan." Its overall goal was to inspire and make the best use of design to make the U.K. a more competitive, creative, and sustainable country. The Design Council (2005) proposed the use of a double diamond design process (4Ds) for representative enterprises. This process divides the service design process into four main stages according to the order of divergence and convergence: discover, define, develop, and deliver [36].

Sung [37], in an integration service design-related study, proposed a general purpose service design process, called the idea service design process (referred to as IDEA SDP). The IDEA SDP is divided into four main phases with six execution steps and corresponding methods and tools, including five important milestones. The four main phases of IDEA are (1) the inquiry phase, which contains two execution steps, "exploration" and "interpretation"; (2) the design phase, in which the implementation steps are "claims" and the key activities involve establishing excellent value propositions and to clearly define services; (3) the execution phase, in which the execution step is "prototype"; and (4) the evaluation phase, which consists of two execution steps: "validation" and "delivery."

The Institute of Information Industry (III), a Taiwan government organization, cooperated with the German Fraunhofer IAO to propose a service design method called service experience engineering (SEE), which defines service as a commodity to introduce the management and research

and development of industrial engineering, and to simultaneously match the industrial manufacturing process of goods to the service construction process [38]. SEE is divided into three phases: (1) the find phase, including consumer demand surveys and technology observing research; (2) the innovation net, including two research focuses on the specific service-related industrial value chain and service modeling; and (3) the design lab, including proof of concept (PoC), proof of service (PoS), and proof of business (PoB).

Although there are some differences in the number of steps in the four service design processes mentioned above, each is derived from the same theoretical logic [39], and most of the tools used are similar. The steps involved in the IDEA SDP integration service design process proposed by Sung [37] emphasize value co-creation, an outside-in process, value in use, multidisciplinary, and holistic as the core concepts. The contextual inquiry method and service modeling in service experience engineering regard all stakeholders as co-designers in the process of development [38], facilitating the development of user-oriented innovative service products [40]. The use of contextual inquiry rules out the idea that traditional qualitative research uses only one method of data collection and has subjective shortcomings [16]. This use also complements the shortcomings of quantitative research that cannot deeply understand the research objects. Duan used the service experience observation method and conducted an analysis of elderly remote health care services to understand the users' lifestyles, behavior patterns, needs, and obstacles [17]. The service design requirements and specifications that best met the long-term healthcare needs of the elderly were summarized. The use of contextual inquiry can eliminate the use of traditional qualitative research, which uses only one method of data collection and has subjective shortcomings, but also complements the quantitative research and does not provide an in-depth understanding of the shortcomings of the research object.

Therefore, the design process in this study combined contextual inquiry and service modeling in service experience engineering [40] and IDEA SDP's service design structure [37]. The design process involves four stages: demand exploration, demand definition, design execution, and product verification. In the demand exploration and demand definition stages, we applied context inquiry and service modeling to understand the intergenerational relationships between the elderly and the potential needs and expectations of the family. Based on the potential demand, a product design policy was proposed, and the prototype was designed and produced accordingly.

3. Research Methods

We explored the potential needs and expectations of the intergenerational relationships between elderly parents and their adult children using the service design process as a research method. The research design was divided into four stages. The first step, demand exploration, has two steps. The first step is to establish the persona through observations and semi-structured interviews, select representatives, and define the main target groups of this study. The second step is to observe the household behavior of the elderly with a method of contextual inquiry. Through five aspects—activities, the environment, interactions, objects, and users—we identified the behaviors and real situations, needs, and expectations of the elderly people in their daily lives and interactions with their parents and children. The survey data were analyzed using five models [16–19]: the interaction model, sequence model, cultural model, object model, and entity environment model. These five models were used to explore the problems with and information about the home care of elderly people. The second stage is demand definition, where the affinity diagram was used as the method to transform complicated preliminary data into comprehensible information. Finally, user needs and design opportunities were obtained, and design guidelines and development specifications were listed. We executed the design in the third stage, in which a cross-disciplinary team was recruited according to the design guidelines and hardware and software specifications, prototype design, and functional model making. The fourth is product verification, which includes specific empirical evidence for improving intergeneration relationships, user participation in experiential activities, and user evaluation (Figure 1).

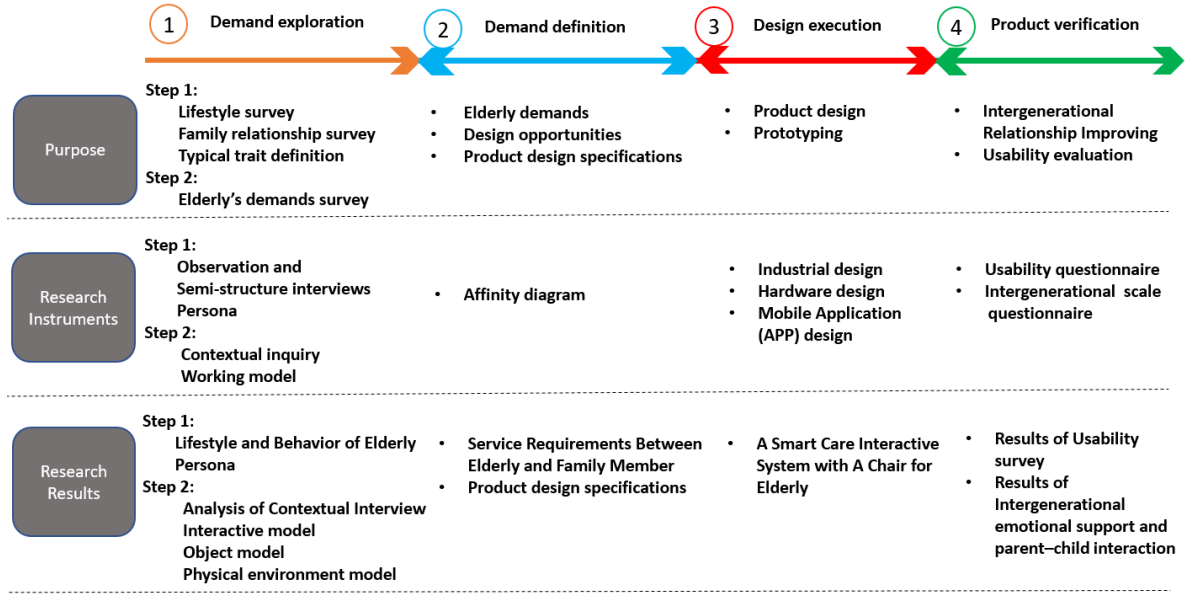

Figure 1. The research design process.

3.1. The Demand Exploration Stage

3.1.1. Observation and Semi-Structured Interviews

In the preliminary interview stage, the aim was to have the elderly describe their lifestyles and relationships with their children through interviews and observations. A total of 15 participants, including six children and nine elderly people over 65 years of age, from Douliu City, Kaohsiung City, and Changhua County participated in the interview at this stage. Each interview lasted about 40 min. We hoped to learn about the lifestyles of the elderly, their intergenerational relationships with their children, and their expectations and needs for intergenerational relationships. The interview outline was adjusted according to the participants' responses. Six elderly people were interviewed in Douliu City, Yunlin County, and the other four elderly people were interviewed at home.

3.1.2. Persona

According to the observations and semi-structured interviews, the typical characteristics and behaviors of the elderly were summarized using the affinity graph method, and the representative figures of the group were identified, which was defined as the main target group in this study.

3.1.3. Contextual Inquiry

In this study, six participants, three senior citizens and three children, representing the target population persona, were recruited as the subjects for observations and interviews in the context survey experiment. The goal of the interviews was to collect information about the real behavior of participants in their interactions with their children in daily life through five aspects—activities, the environment, interactions, objects, and users [18]—and to explore the unsatisfied needs of participants in their lifestyles and relationships with their children.

3.1.4. The Working Model

In this study, three working models—the interaction model, object model, and entity model [41]—were used to collect the contextual data and summarize the participants' various lifestyle behaviors and their relationships with their children. (1) The interaction model was used to describe the environment, people, things, and interaction modes that the elderly people encountered in their lives in order to investigate the parent-child interactions. (2) Tool models recorded participants' daily

living, contact, and use of various tools in their interactions with their children and presented problems and obstacles to actual use. (3) The entity model described the participants' living environments where their children interact with each other, the overall layout, structure, facilities, and the placement and use of various tools and appliances. The participants' movements were recorded in the entity model and it was used to confirm the restrictions and constraints that exist in the physical environment and to grasp the relative position and scope of activities of participants.

3.2. The Demand Definition Stage

In this study, an affinity diagram was used to summarize user data, identify users' real potential needs, and transform abstract thinking into concrete solutions. A focus group of three design experts, each with 10 years of professional design experience, was recruited for the affinity diagram meeting in order to summarize the potential demands between the elderly and their children. According to the results of the observations, semi-structured interviews, and the work model, the interaction needs between the elderly and their children were summarized using an affinity graph. This stage summarized the users' behavior patterns in contextual inquiry research and the potential demand for products or services, and defined the design principles of innovative services to improve intergenerational relationships.

3.3. The Design Execution Stage

Based on the product design guidelines derived from the demand exploration and demand definition stages, we recruited a cross-disciplinary team to design new interactive furniture that meets the potential needs and expectations of the eldery and children. We divided product prototyping into hardware and software phases. The hardware was divided into two parts, furniture design and sensor construction, and the software used was a mobile application (App) programming.

3.4. The Product Verification Stage

This product verification stage was mainly used to test the interactive chair designed to improve the understandings of emotions between generations. User experience with the smart care interactive chair (SCIC) suggests that it impacts the understanding of emotions between generations. The verification stage of the experimental prototype was designed in two parts: pre-test and post-test of the Intergenerational Relations Scale (IRS) and the experiment prototype test. We used the IRS to test two aspects: emotional support and family interactions [42]. We hypothesized that the mean scores on emotional support and parent-child interactions produced by the participants would be higher after experiencing the SCIC than the mean score of participants who did not experience the chair.

3.4.1. Participants

The participants were recruited based on the characteristics of the personas. Three groups were invited to participate in the experiments to use the prototype. Each group consisted of 2 people: one elderly parent and one adult child, and the participating elders were over 65 years old and were all retired (Table 1). All participating children were working people who owned smartphones.

Table 1. Participants in the interactive furniture evaluation.

Group	Sex	Age	Category	Labeling
1	Male	68	Elderly	E1
	Male	36	Children	C1
2	Female	81	Elderly	E2
	Male	55	Children	C2
3	Female	71	Elderly	E3
	Female	46	Children	C3

3.4.2. The Intergenerational Relationship Scale Questionnaire

The Intergenerational Relationship Scale (IRS) was mainly used in this study to investigate the emotional support of the family members and parent-child interactions that the elderly and adult children value most [3]. The IRS questionnaire is based on Wang's elderly family relationship and life satisfaction questionnaire [42]. We only adopted two aspects of Wang's questionnaire: emotional support and parent-child interactions. The former refers to emotional support and care between elderly people and their children; the latter refers to the normal operation of children's assistance to their parents with respect to their bodies and minds. There were 8 items of emotional support and 6 items of parent-child interactions, for a total of 14 items in the questionnaire. IRS uses the Likert five-point scale, which is divided into five different degrees, from 5, completely agree, to 1, completely disagree (completely agree, agree, fair, disagree, and completely disagree), to measure the emotional support and parent-child interactions (Table 7). The higher the score, the better the intergenerational relationship between the elderly and their adult children. The experimental process involves performing a pre-test of the questionnaire before the experiential prototype test. The experimental procedure involved the performance of IRS before and after the SCIC had been used, and the analysis of the scores produced by the participants.

3.4.3. The Apparatus, Material, and Procedure

This experiment was conducted in two parts: (1) the pre-test and post-test of the IRS questionnaire and (2) the experiential prototype questionnaire. The interactive chair experiment was conducted for one week with the chair being placed in the living room of a participant's home. Before the experiment, the participants, including parents and children, were asked to fill out the IRS questionnaire. After the completion of the questionnaire, the participants were taught how to use the interactive chair and the App software. This study provided the smartphone Zenfone 5, made by Taiwan company ASUS, for the App experiment. The whole process, including questionnaires, usage commentary, mobile phone, and the App trial, was completed in about one hour. After one week of using the interactive chair, the participants were asked to fill out the post-test IRS questionnaire and the usability questionnaire for the interactive chair and App software.

3.4.4. The Prototype

The experimental stimuli were the smart care interactive chair prototype, which included a chair and the App software. Each group used the chair for 7 days. The chair was equipped in the living room for the elderly to use. A smartphone (Zenfone 5) with the SCSI App APK interactive system was offered by the experimenter to the adult children. The following is a brief description of the App function evaluation methods:

(a) Sitting record: This functional test enabled users to quickly retrieve the sitting record of the App, and the form of data expression is easy to understand.
(b) Weight recording: This functional test enables users to quickly access the weight records of the App, and the form of data expression is easy to understand.
(c) Abnormal notification: This functional test aims to enable users to quickly determine abnormal times for receiving notifications from the App to trigger concern.
(d) Seat settings: This functional test enables users to quickly complete the data settings of seats.
(e) User and elderly settings: This functional test is designed to enable users to quickly complete the data settings of the elderly.

3.4.5. Usability Questionnaire

The purpose of this study was to evaluate the prototype design in terms of usefulness and ease of use [43]. After experiencing the intelligent interactive chair, the functions of the software and hardware were evaluated by an open-closed questionnaire. The hardware was used by the elderly, whereas

the software App was used by the children. In order to ensure that each evaluator's assessment was independent, fair, and unbiased, the participants were asked to write down their opinions, or their oral reactions were observed and recorded during the assessment.

4. Results

We explored the potential needs and expectations of the intergenerational relationships between elderly people and their adult children using the service design method, and developed an intelligent interactive care chair to improve the emotional support and parent-child relationship between the elderly and their adult children. The results are presented in four stages: (1) the demand exploration stage, (2) the demand definition stage, (3) the design execution stage, and (4) the product verification stage.

4.1. The Results of Demand Exploration

In order to understand the lifestyle and communication issues of elderly people, a direct interview was conducted to collect relevant information. During the visit, living, interaction, and caring were the three core issues. Further questions were raised with respect to related issues that developed. In addition to interviews with seniors, interviews with children were arranged. The environment in which each interview was conducted was a place where the respondent felt comfortable, and the researchers conducted semi-structured interviews based on pre-designed questions. Through interviews about the elderly's living conditions, habits, needs, expectations, and their interactions and problems with their family members, data were collected. We described the typical characteristics of elderly people's lifestyles and family relations, which were analyzed through a behavioral model.

4.1.1. Analysis of Lifestyle and Behavior of the Elderly

The objectives of the interview were two-fold. The first objective was to understand the current lifestyle habits of the elderly and their daily behavior patterns. We aimed to understand the lifestyles of the elderly as well as the people with whom they often interact. The second objective was to understand the communicative interactions between the elderly and their family members. We interviewed 15 respondents, consisting of six children of nine elderly people aged 65 years old and above. One-on-one individual interviews and group interviews with two or three people (e.g., friends and relatives) were conducted in which other respondents were allowed to express their opinions. According to the interviews and observations, the areas and events of the elderly person's regular activities were identified, referred to Table 2. From the observations, we found that the in-depth interactions between the elderly and their children usually occur in a private residence.

The behaviors, events, objects, and relationships in the home activity environment were analyzed from the lifestyle patterns. The interactions between the elderly and the children mostly occurred in the living room, and the living room was the area where they spent most of their time. Only the living room served more than one function, and this was where the elderly and family members emotionally interact. The rest of the areas, such as the kitchen, bathroom, and courtyard rarely served as locations for emotional interactions. Table 1 summarizes the activities, places, behavioral events, objects, and behaviors of related people based on observations and interviews.

Table 2. Analysis of elderly behavior at home.

Place	Behavior/Event	Object	State	Relationship	Time
Living Room	Watching TV	Remote control, TV, chair, monitor, book, table and chair, storage cabinet, monitor	Spend time, care about current events, self-study	Family, spouse, friend	Morning, afternoon, evening
	Family Interactions	Cell phone, phone, chair, monitor	Caring for children, children caring for parents, boring and find people to chat with, having something to ask for help with	Family, spouse, friend	Morning, afternoon, evening
Kitchen	Cooking	Kitchenware, tableware, dining table, chair	Cooking three meals, boiling water, and processing the purchased ingredients	Family, spouse	Morning, afternoon, evening
	Dining	Tableware, dining table, chair	Eat, communicate with friends or children	Family, spouse, friend	Morning, afternoon, evening
Courtyard	Organize Flower, Rest	Gardening equipment, monitor chair	Get up early, tend to the flower gardens, arrange the flowers in the afternoon, water the flowers, pull the vegetables, plant new plants, occasionally sit in the sun, socialize with friends and neighbors	Family, spouse, friend	Morning, evening
Room	Sleeping	Bed, bedding	Most of the elderly go to bed at 9:00–11:00 p.m., and their wake-up time is 5:00–7:00 a.m.	Spouse	Morning, at night
Bathroom	Toiletries, Toilet Sinks, Toilets	Toiletry, toilet sink	Morning, wash at night before going to bed, bathing	Spouse	Morning, at night

4.1.2. Persona

Based on the respondents' lifestyles and their children's living patterns, four categories were derived with the help of an affinity diagram: (1) living together with their children; (2) staying together, but children have their own life; (3) children live in a different city; and (4) children live separately but in the same community. Based on the above categories, six representatives were selected from the nine elderly respondents, and four representatives were selected from the six children. Table 3 shows their basic data, education levels, daily activities, interactions, personalities, and living conditions.

Table 3. The personas of the four lifestyle living patterns.

Living Together		**Stay Together, but Children Have Their Own Life**	
AFemale	**BMale**	**CFemale**	**DFemale**
Age: 81 Sex: Female Living status: living together Health status: chronic disease Economic status: good	Age: 60 Sex: Male Living status: living together Economic status: good	Age: 67 Sex: Female Living status: living together Health status: no chronic diseases Economic status: middle class	Age: 32 Sex: Female Living status: living together Economic status: middle class
Like lively family, expecting children and grandchildren to come back. Minor dementia, but can basically cook by herself. There is a monitor in the home, but she did not feel like being watched.	Because her mother is not well, after retirement, he returned to her hometown to take care of her mother. He often uses smart electronic products, and often cares about the state of her mother in terms of high technology acceptance.	Normal lifestyle, joined the dancing community, lives with children, communication with children is not smooth, but feels that her children still practice filial piety, responsible for cooking dinner.	Stable work, single, living at home. Dinner with parents and they interact with each other, and then do their own thing, does not like her parents to manage everything, understands her parents' lifestyle.
Living Separately		**Living Separately at the Same Community**	
EMale	**FMale**	**GMale**	**HFemale**
Age: 71 Sex: Male Living status: living alone Health status: chronic disease Economic status: good	Age: 35 Sex: Male Living status: outside Economic status: middle class	Age: 66 Sex: Male Living status: living together Health status: no chronic diseases Economic status: good	Age: 55 Sex: Female Living status: living near parents Economic status: good
Normal life and work, occasionally goes to the park to exercise or chats with neighbors, likes to live apart from his children, feels that meeting every day would be annoying, approachable.	Stable office worker, spends less time with his parents but wants to care more about his parents. His work is stable and he needs to take care of family and work, but wants to learn more about his parents' lifestyle. Usually contact is by telephone, sometimes he says too much and feels that parents are tired.	Everyday routine is fixed. Good financial situation, participates in community activities. Learns new knowledge, interacts with children at dinner time, often does not know what the children are doing.	Successful career, busy work, back to see her parents on holidays. Spends holidays with parents, lives in the same community as parents. There is a surveillance care system in the home. Wants to know more about her parents' lifestyle. Hopes that technology can help solve the problem.

4.1.3. Focus Person Contextual Interview

We conducted in-depth interviews with selected focus persons identified by the persona assessment. These interviews mainly explored the family life and interaction patterns of retired seniors. Through in-depth interviews, observations, and cultural probes, more in-depth data collection occurred. The data were sorted using the affinity diagram method, as shown in Table 4, and added to the analysis of demand points.

Table 4. The analysis of the focus persons' contextual interviews.

Issue	Description	Overview
Communication problem	1. Elderly self-esteem is very strong, they do not like others to treat them with the mentality of compassion or concern. 2. They are happy with other people's care, but at the same time, they do not like family care and do not think they need to care about their mentality. 3. The communication with children has changed, and smartphone App software, such as LINE and FB, has become the communication medium. 4. The difference in living habits leads to a gap in communication.	1. How do children really understand their parents' lives? 2. How do children understand parents' situation and pay attention over time? 3. Easy interactive understanding of communication mode.
Physical deterioration	Degeneration of body function leads to knee deterioration, vision also deteriorates with age, and memory degradation is an important issue.	
Increased dependency on familiar transactions	1. A reduction in the willingness to accept new things and a link to emotions or memories of the item. 2. The elderly has fixed items and a familiar space.	Exclusive elderly items and comfortable space design.
Thought problem	1. Retirement without planning will affect the psychological state of the elderly. 2. Chronically ill elderly people cause psychological problems. 3. Gaps of thought and practices with children can easily lead to negative thoughts.	Understand each other's lives and work and communicate smoothly.
Expecting interaction	1. The elderly generally want the family to be chattering. 2. Expects family reunion during the holidays. 3. They also want to know the current situation of their children. 4. The feeling that the child cares too much will produce boredom, but they feel happy that there are still interactions.	Always understand each other's lives and work and let the communication flow smoothly.
Interaction time difference	1. The life of the children is different from that of the elderly. There are no immediate interactions. When the children go to work, this is the resting time of the elderly. 2. After the children get off work, some of the seniors have rest time. Interactions most happen during dinner and holidays.	Lifestyles are different, but this allows them to interact and move instantly.
Way of caring	1. Children often say that they do not know how to express their concern. Every time they repeat the same conversation, they get bored with their parents, and eventually, they do not know what to say. 2. In the face of chronic diseases or older elders in their homes, they choose to install monitors or a home security phone. However, the elderly are not accustomed to the existence of the monitor and will eventually be disgruntled, indirectly causing unpleasantness on both sides.	Monitoring and interaction should be more friendly and user-friendly without disruption.
LINE: An integrated platform of instant messaging software developed by LINE Company of Naver Group.		
FB: Facebook (FB) is a social network service and social media website that originated in the United States.		

4.1.4. Working Model

According to the data collected from the context visits and cultural probes, we analyzed the interaction model, object model, and physical environment model in the five behavioral models, and the results are as follows.

Interactive Model

This model shows the people around the elderly. Figure 2 shows that the elderly spend most of their time at a specific place, and the living room is where the elderly are more active. There are issues with interactions between the elderly and family members caused by poor methods of caring and communication. These issues were observed.

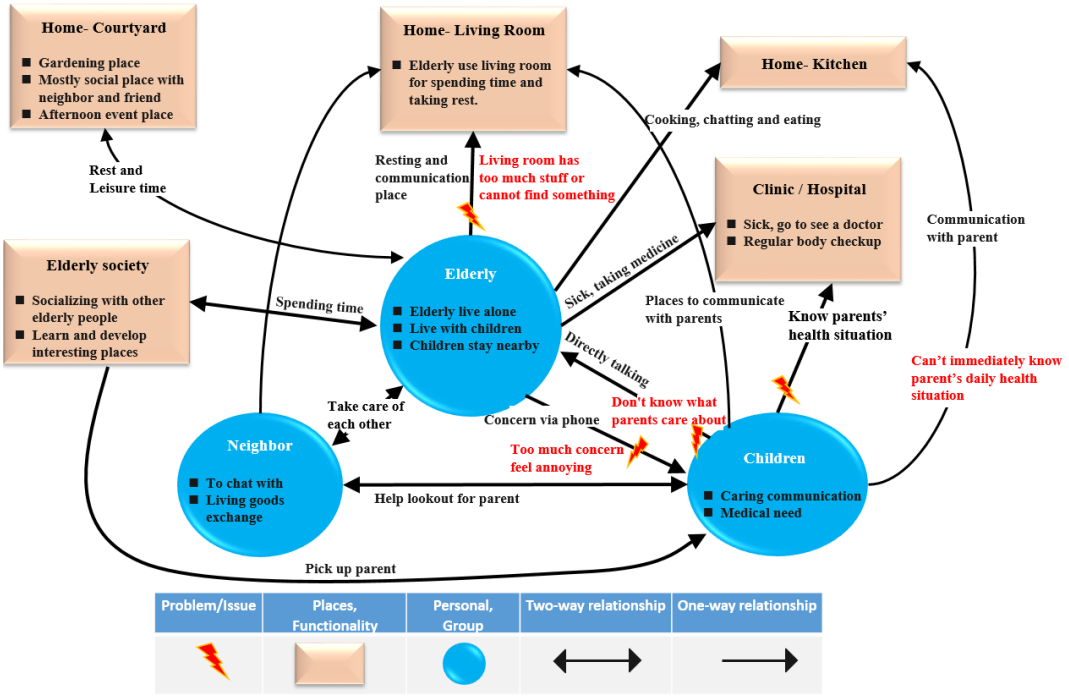

Figure 2. Interactive model showing the integration of people and events that elderly people encounter in their lives.

Object Model

Through visiting and observing, we identified the living room objects that are often used by the elderly, as listed in Figure 3. Seats and the television could be used to promote intergenerational emotional interactions. We found that the elderly use seats most of the time in the morning and evening, and the elderly tend to use seats as a habitual behavior. Based on this issue, we integrated the Internet of Things (IoT) with everyday objects to promote emotional interactions between generations.

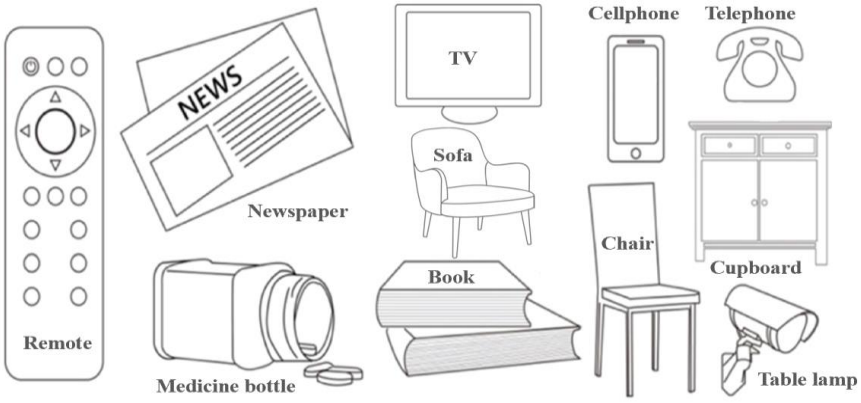

Figure 3. The working object model shows the items that are often used by elderly people in their daily lives in the living room.

Physical Environment Model

Figure 4 shows a house plan of an elderly family. The figure shows that elderly people tend to have their own places and the everyday objects they often use are placed in exclusive locations.

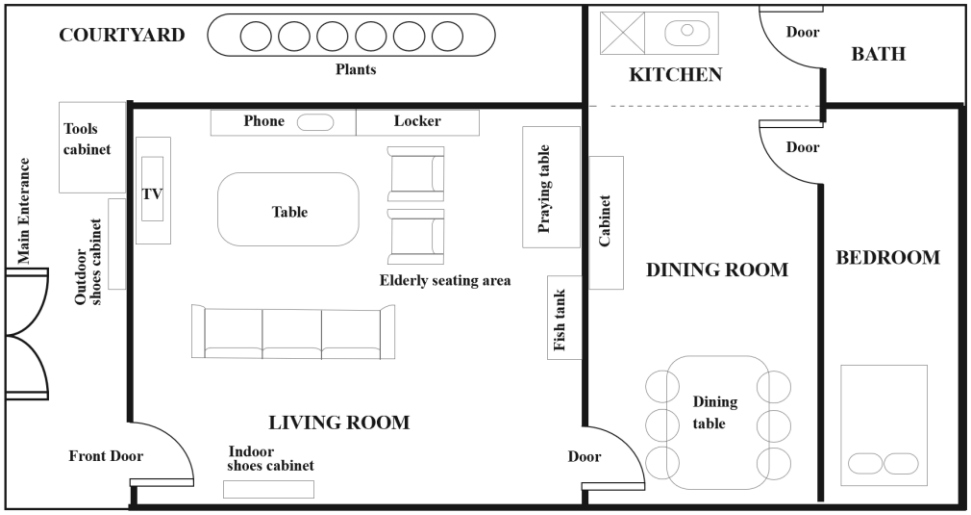

Figure 4. A physical environment model of a house plan of an elderly family.

4.2. The Results of Demand Definition

4.2.1. Potential Demands between the Elderly and other Family Members

In this study, after observations, interviews, and data collection, the respondents' behavior patterns were summarized in an affinity diagram. We identified the issues with intergeneration interactions and the everyday objects with which the elderly interact in their daily lives. From the model data above, the behavioral patterns and potential needs of parents and children in terms of intergenerational emotional interactions were summarized. The final four-point potential demands are summarized as follows:

(1) The improvement in intergenerational relationships requires the active care of children. As identified from interviews and interaction modules, even children living with their parents do not know how to express their concerns, and repeating the same dialogue does not solve the physical and mental problems of the elderly. After the adult children have their own family, their relationship with their parents changes from caretaker to caregiver. Because there is still room for interaction between the two groups, the children's attitude toward their parents shifts to active care for retired parents, and the intergenerational relationships are not well established.

(2) The improvement in intergenerational relationships requires caring for the elderly's daily activity routines. In the interviews, retired parents complained that children care and interact with careless attitudes, and the same interactive discourse is repeated. The elderly are happy to take care of their children, but they simultaneously require children to understand them in order to have good quality interactions. Therefore, it is necessary to provide a product that is useful for the elderly that is able to record the elderly's basic physiological information and daily routines, and lets the elderly communicate with their children at any time, even when the children live in a different city.

(3) A chair placed in the living room could be designed to enable understanding and record parents' life practices. Retired people or the elderly spend four to six hours in the living room early in the evening, whereas the bedroom is where they spend the longest amount of time each day. The living room is the area where they spend most of their time interacting with their children. According to the observations, the elderly have a habit of using the same chair in the living room

every day, and family members respect each other when they use the chair. Therefore, a chair could be designed to record daily routines. Physiological information, such as weight, heartbeat, and blood pressure of the elderly, could be transmitted to the children through the IoT. Even if they live in different cities, they can monitor and care about their parents' daily routines.

(4) To analyze parental lifestyle data, a smartphone application program could be designed to check daily routines and physiological information, such as weight, heart rate, and blood pressure, collected through the chair. The data could be recorded on a cloud database system, and if users' physiological data show unusual conditions, such as a change in weight of 5% within a week, unusual timing of using the chair, and abnormal heartbeats, this could be reported to the children. By providing parental information to children as basic data for interacting with parents, their concern would not only be limited to superficial greetings, but also to the understanding of their daily routines of interest and interactions to promote intergenerational caring interactions.

4.2.2. Product Design Requirements for the Smart Caring System

After considering the requirements for enhancing mutual caring interaction and harmony, this study presents the specifications for the design of this interactive home device as a new product innovation opportunity. The development of this interaction device for the elderly will be implemented with the IoT technology concept, as shown in Table 5. The technology is divided into hardware and software. The hardware part includes the furniture design with embedded sensors, and the software part is an application designed for smartphones. A smart chair suitable for the elderly can be designed to fit their habits. Through the sensors embedded in the chair, data are transmitted to family members' mobile phones via the Internet; from the display data, children are able to understand the status and condition of their parents. Caring for elderly people is not entirely about health, but also about feelings of isolation. Older people look forward to interacting with their distant children and loved ones and strengthening their family relationships based on care and mutual respect. A smart chair could be an answer to this concern. The system's framework is shown in Figure 5.

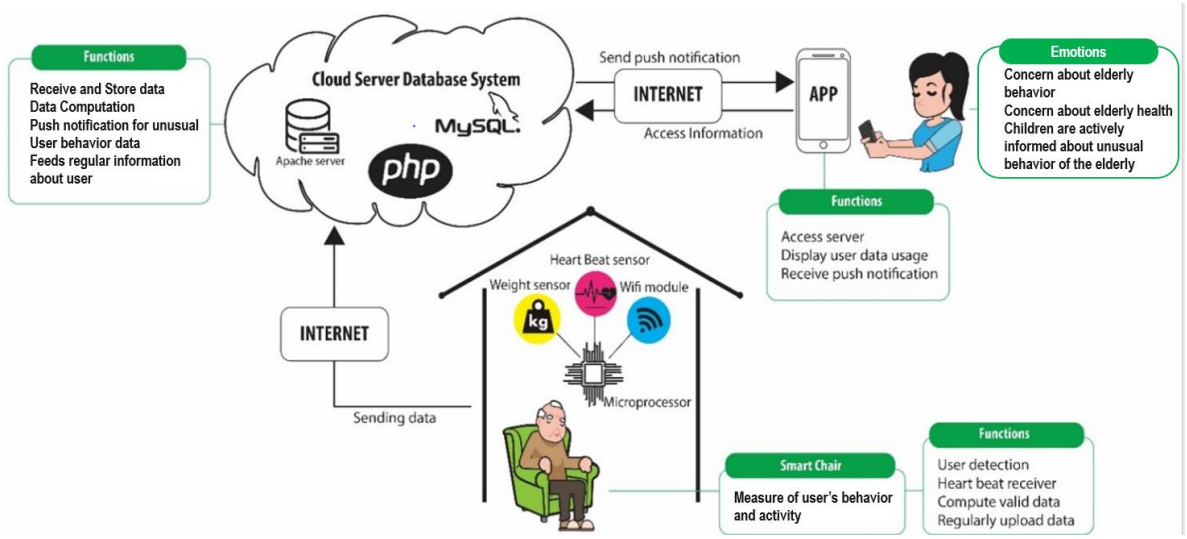

Figure 5. A framework of an SCIS.

Table 5. Design requirements for building a smart care interactive system (SCIS).

Design Target		Feature	Demand	Observation
User	**Elderly**	A comfortable and user-friendly chair space	Comfortable, sitting and lying down	Parents sit on chairs for long periods of time and need a comfortable chair
			Lighting facilities	Sitting in a chair reading a newspaper, but the light does not seem enough, turning on a big light wastes electricity
			Simple storage space	Often put things near the chair, it is chaotic and there is no place to put things, and sometimes they cannot find things.
	Children	Understand parents' lifestyles at home, and can effectively interact with parents	Transfer parental usage records and analyze usage status via a cellphone app, as the basis for caring and interactions	Always understand each other's lives and work, make communication smooth.
			The chair is equipped with sensors to detect and record parents' activities	
Property Design	**Sofa chair**	A comfortable chair for personal use by a private person	Comfortable chair	Parents sit on chairs for long periods of time and need a comfortable chair
			Will not cause backache	
			Good place for sitting	Fear the chair will be too soft, making it difficult to rise because their arms are weak
			Simple admission of personal newspapers	I read books and newspapers in my chair, storage for glasses and pens
			With lighting equipment	Read books and newspapers in chair
		Sensor device design	Use pressure sensor to record time	Make children aware of their parents' lifestyles
			Use pressure sensor to detect user's weight	Children need accurate understanding of their health
			Use pulse sensor to record heartbeat and blood pressure	
	Parent-child interaction App	User interface design	Time of chair use	Children can use this information to interact with their parents and care about their health
			Change in body weight	
			Heart beat and blood pressure information	
			Unusual use of chair time is presented	
			Unusual change in body weight	
			Unusual physiological information presented	
			Emergency notification	Children need immediate notification if parental condition gets unusual
Cloud Server		Record, analyze, and send events to smart devices	Record, analyze, transmit usage time, weight changes, physiological information	

4.3. The Results of Design Execution

4.3.1. The Prototype Design of a Smart Care Interactive System with a Chair for the Elderly

Based on the potential need to improve the intergenerational emotional relationship summarized in the above survey, we developed a home-based intelligent interaction system. The smart care interactive system (SCIS) designed for elderly includes a smart chair with the following functions.

(1) Smart sensing interactive system: Integrates a chair, smart sensors, Internet of Things features, wireless transmission of daily activities of a user, and their physiological conditions to a cloud server.
(2) Signal analysis system: Storage and analysis of the data of daily activities and physiological conditions of a user, e.g., weight, heartbeat rate, and blood pressure. These data can be viewed on a smartphone so that family members can understand the physical conditions of an elderly member.
(3) Abnormal notification system: By analyzing and comparing the currently sensed data to the stored data of healthy conditions, the system can diagnose ill conditions or emergency conditions of an elderly member. In such cases, the system will alert the caring family members to take appropriate actions.
(4) The smartphone App software can visualize and enable interaction with the daily activity and physiological data to reflect the condition of an elderly person and actively notify the caring family members of the current conditions of the elderly person.

According to these concepts, the design framework was constructed, including software and hardware parts, as shown in Figure 6. The hardware part includes seat design and sensor construction, and the software part includes App design and database design.

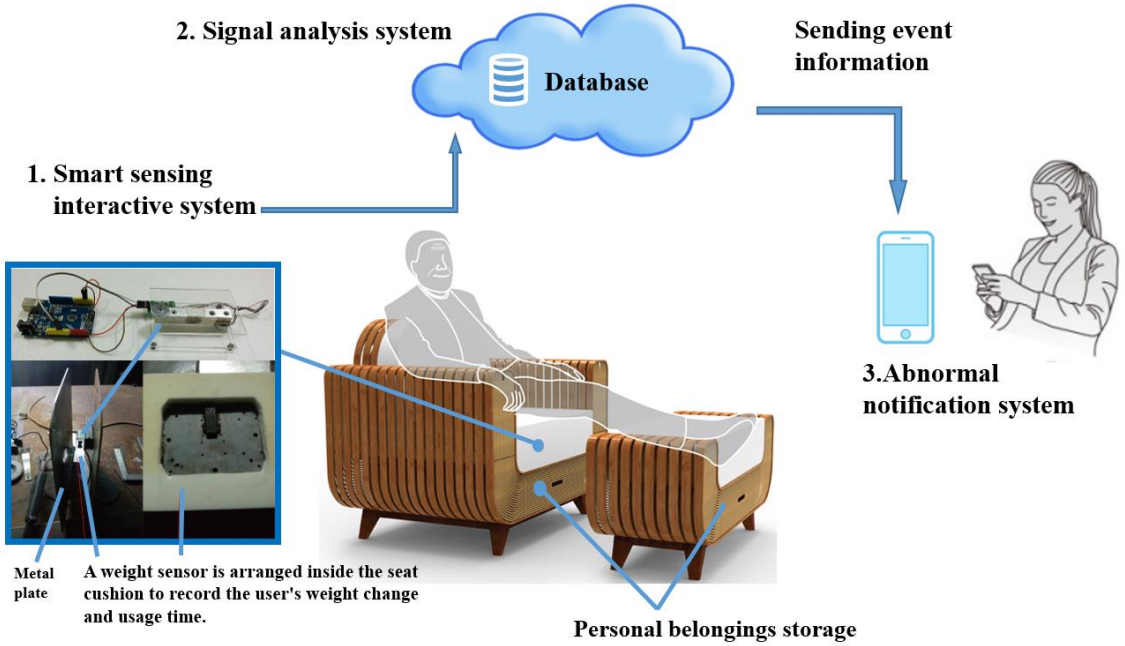

Figure 6. The prototype of an SCIS with a chair.

4.3.2. Chair Hardware Design

For the seat design, professionals in furniture design, electronics, and programming were invited to design the prototype and sensor.

(1) Seat design concept: Taiwan is located in the subtropical region, and its southern part has close to a tropical climate. The average temperature in summer is ~28–29 °C. Even in winter, Kaohsiung can

still reach ~19–20 °C. Therefore, the seat design used bamboo as a material, which has a cool feeling in the summer, and a curved shape with a simple form was used. The space created by the bending of the bamboo piece has a storage function. The chair was equipped with a velvet cushion and a footstool, which also function as storage (Figure 6). After the appearance, material, and function design of the chair were confirmed, the bamboo body part of the chair was fabricated by a bamboo furniture expert, and the chair foot and cushion were completed by woodworking professionals. The pressure sensing module was then set up and placed in the chair cushion to measure the weight of the elderly person and their chair usage time.

(2) Sensor construction: In this study, a pressure sensing module used in this study can measure body weight. The sensing weight is limited to 100 kg, and it provides quick responses and is resistant to interference. In order to allow the body weight to be evenly distributed on the sensor, the sensor was designed to be installed in the middle of a metal plate and buried in the cushion foam so that the user's weight could be stably sensed, as shown in Figure 6.

4.3.3. Smartphone App Design

Based on the above design concepts, we defined the time interval for sensing and recording information as the time interval for the elderly person sitting on their seat. By recording time intervals, we tried to understand the daily work and rest status of the elderly, so the interface design could be preliminarily classified to align the App with the interactive needs. In building the App, we collaborated with people who had a background in computer science. We divided App design into the functional design, interface flow design, and interface design and programming.

4.3.4. App Functional Design

Based on the above design concepts, we defined the time interval for sensing and recording information as the time interval that the elderly people were sitting on their seats. By recording time intervals, we tried to understand the daily work and rest status of the elderly people, so the interface design could be preliminarily classified to better align the App with their interactive needs. In building the App, we collaborated with people who had a background in computer science. We divided App design into functional design, interface flow design, and interface design and programming.

The main purpose of interactive furniture regarding the intergenerational relationship is to record elderly people's behavior through sensing devices and display it to their family members via an App. This recording informs children about the lives and behaviors of the elderly. When there are abnormal conditions, the app notifies their children through a message. This could conveniently and efficiently allow children to care for and interact with their parents to improve the intergenerational relationship. The main functions include seat pairing, personal information, usage record, weight record, and abnormal usage notification, as shown in Table 6.

Table 6. The list of App functions.

Function	Description
Seat pairing	Name the chair and code it, and pair the chair with the database.
Personal information	Enter the pre-recorded information about an elderly person, including their personal information, photo, name, height, weight, and schedule.
Usage record	Using the daily, weekly, monthly, and yearly recordings, the children can watch the life of an elderly person and take time to understand their behavior and condition.
Weight record	From the daily, weekly, monthly, and yearly records, the children can monitor the behavior of an elderly person, and the weight data will be used to understand the life and condition of the elderly person.
Abnormal usage notification	When the elderly person's schedule is different from usual or their weight changes, the system considers this abnormal, and, in a short period of time, the child will be notified through the mobile phone, and the child can immediately respond.

4.3.5. App Interface Design

Before designing the App interface, an interface flow diagram was drawn to clarify the connections between interfaces, improve the accuracy of the interface architecture in the early stages, and help the programmer understand the method and structure of the App implementation (Figure A1).

Based on the definition of the App function setting and interface process, we developed the elderly interactive furniture App interface, and each function page is introduced here:

1. Seat setting pairing: Seat settings are entered by the user and named. By matching the corresponding data storage space with serial numbers, the first login and the database are matched (Figure A2).
2. User settings: The children input their own basic data and help to input the data of the elderly. The user data settings include the name, email, telephone, and sex. The data settings of the elderly include personal photos, sex, name, height, weight, active and rest time, and so on (Figures A3 and A4).
3. Sitting information record: In this interface, weekly, monthly, and yearly data about active and resting times are recorded. This interface structure is divided into three parts. The first part is the daily, weekly, monthly, and yearly data display selection; the second part is the date selection; and the third part is the sitting and resting data display. The following text describes the interface design for the daily, weekly, monthly, and yearly data display (Figure A5).

    (a) Sitting information record—days: The user's sitting time is used as the data record. This page uses a direct timeline to record data, so the user obviously and instantly can see the sitting and rest conditions. Points and pages are followed by a data representation of the day's active and rest states.

    (b) Record of rest—week, month: All weekly, monthly, and yearly information is recorded. The data record mode is presented in a graph. In the lower selection area, the user can jump directly to a day or week and view the daily or weekly record. As such, they can clearly see the time when the elderly person in the family sits on the chair every day, and the data can be used to observe whether the elderly's living habits have changed.

    (c) Active and rest record—year: Records all yearly rest information. The record mode of this page is presented in a bar chart. In the lower selection area, you can jump directly to the month to view the current month's record.

4. Weight record: The interface is roughly the same as the seat record. The weight record is divided into four parts: day, week, month, and year. The interface structure is divided into three main parts. The first part is the data display selection for the day, week, month, and year; the second part is the date selection; and the third part is the weight data display (Figure A6).
5. Abnormal notification: After the establishment of basic data, the program determines whether the recorded data are in line with the user's daily life and rest intervals. If the sensor is triggered during the normal working hours, it shows abnormal actions through vibration and sound effects to remind children to take the initiative to monitor the life status of an elderly person. Notice information appears in the emergency notification window, and other abnormal status information is logged in tabular form after clicking on the notification (Figure A7).

The application programming part of this research involved a cross-disciplinary collaboration with professionals with a background in computer science. Through discussion, design and implementation were completed. The programming part includes the App interface design, a cloud database, an Android connection interface program, and an Arduino sensing device. The program architecture is shown in Figure A8. The development environment, language, tools, and details of each programming step are listed in Table A1.

4.4. The Results of Product Verification

This experiment was mainly completed to test the interactive chair designed to improve the communication of emotions between generations. The verification stage of the experimental prototype was divided into two parts: the pre-test and post-test of IRS, and the experiment prototype test. This study used the IRS to test two aspects: emotional support and family interactions [24]. We hypothesized that the mean emotional support and parent-child interaction scores produced by participants would be higher after experiencing the SCIC compared with the mean score produced by those who did not experience the chair.

4.4.1. The Results of Intergenerational Relations Scale

The reliability of the 14 items in the pre-test and post-test of the IRS was also analyzed. The results showed that the internal consistency coefficients of Cronbach's alpha were 0.891 and 0.893, respectively, demonstrating acceptable reliability.

On average, the mean pre-test and post-test IRS scores were 1.82 and 3.34, respectively, and the difference between them was 1.52. The post-test and pre-test IRS scores were strongly and positively correlated ($R = 0.75$). There was a significant average difference between the post-test and pre-test IRS scores ($t = 11.54$, $p < 0.001$), referred to Table 7.

Table 7. The t-test for the differences between the mean pre-test and post-test scores regarding the smart care interactive chair (SCIC).

Emotional Support	**Pre-Test**	**Post-Test**	**Std. Deviation**	**t**	**Sig. (Two-Tailed)**
	Mean	**Mean**			
1. When I am in a bad mood, I take the initiative to talk to my children.	1.67	3.67	1.00	3.4	0.070
2. I take the initiative to talk with my children about my thoughts.	1.3	3	0.58	5.0	0.038
3. When I am in a bad mood, my children take the initiative to comfort me.	2.3	4	0.58	5.0	0.038
4. When children are under pressure in life, they tell me first.	1.3	3	0.58	5.0	0.038
5. My children greet me.	2.67	4.3	0.58	5.0	0.038
6. I often think of my children.	3	4.3	0.58	4.0	0.050
7. When I am not feeling well, I initiatively tell my children.	2.3	3.3	0	-	-
8. My children take the initiative to ask about my physical condition.	1.67	3.67	1.00	3.4	0.070
Sub-Total	2.03	3.66	1.01	13.7	0.00
Parent-child Interactions					
9. My children share the joys of life with me.	1.67	3	0.58	4.0	0.050
10. My children listen to my complaints.	1.67	3.67	1.00	3.4	0.070
11. My children help me to measure by blood pressure, blood sugar and so on.	1	1.3	0.58	5.0	0.038
12. Children often take the initiative to greet.	1.3	3.3	0.58	5.0	0.038
13. I often take the initiative to contact my children	1.67	3.3	0.58	5.0	0.038
14. I take the initiative to care for the health of my children	2	3	0	-	-
Sub-Total	1.55	2.93	0.94	5.14	0.00
TOTAL	1.82	3.34	1.05	11.5	0.00

For the emotional support part (Questions 1–8 of Table 7), the average pre-test score was 2.03, and the average post-test score was 3.66. The difference between them was 1.63. The emotional support scores of post-test and pre-test were strongly and positively correlated ($R = 0.85$). There was a significant average difference between the post-test and pre-test emotional support scores ($t = 13.68$, $p < 0.001$). This shows that, after using the interactive chair, users' intergenerational emotional support significantly improved. Except for Questions 1, 7, and 8, there were significant differences between pre-test and post-test scores on the other emotional support questions. Although Questions 1 and 8 were not significant, they showed close to significant differences ($t = 3.4$, $p < 0.07$).

In terms of emotional support, in the parent-child interaction part (Questions 9–14 of Table 7), the average score for the pre-test was 1.55, and the average score for the post-test was 2.93. The difference between them was 1.38. The parent-child post-test and pre-test interaction scores were strongly and positively correlated ($r = 0.67$). There was a significant average difference between the parent-child post-test and pre-test interaction scores ($t = 5.14$, $p < 0.001$). This shows that, after using the interactive chair, parent-child interactions significantly improved. Except for Questions 10 and 14, there were significant differences between pre-test and post-test scores for the other parent-child interaction questions, but Question 10 showed a close to significant difference. The hypothesis of this study is accepted. The average scores for emotional support and parent-child interaction of participants who experienced the SCIC were higher than the average scores compared with those who had not experienced the chair. The SCIC is clearly an aid in providing emotional support and improving parent-child interactions.

4.4.2. Results of the Usability Questionnaire

This system uses a heuristic usability evaluation as feedback and monitors two aspects, usability and ease of use, as shown in Table 8. Based on feedback, these results will be used for future revisions and to improve the usability of the App system. This usability assessment was used for six participants, three seniors and three children, and feedback opinions were collected and summarized into furniture revision suggestions and interactive suggestions, as shown in Table 8.

Table 8. Suggestions for furniture revisions and interactions for the seat and App.

Furniture Revision Suggestions		
Category	Component	Opinions
Functions	Seat	Add storage function under the seat Adjustable cushion
	Back of the Chair	The back of the chair needs to be longer Increase the adjustability Headrest needs to be expanded A waist section is required
	Foot rest	It can be lightweight or integrated into the chair body
Interactive Suggestions		
Category	Component	Opinions
Seat	Emergency rescue	Add SOS button that dials 110 (the emergency number of Taiwan)
	Health status	Add relevant medical detection to let the family know the user's status
App	Health status	Add related medical detection to let the family know the user's status
	Multi-connection	Let family members have room for communication

Based on the evaluation opinions, we found the following key points: (1) The design of the furniture part is not perfect—the design of the back is not long enough, and the elderly users are dissatisfied with the neck support part. (2) The design of the footrest is very comfortable; however, contrary to the function of the living room storage space, the elderly participants said that (a) it is very difficult to move the footrest, and (b) the living room space is very small. The footrest sometimes hinders the movement of elderly people in the living room. The rear footrest must be re-designed to solve the above two problems. (3) In the children's section, through the App, they are able to effectively understand the elderly's active and rest status. Through the visual information display and warning messages, they can immediately understand the current situation of the elderly, which increased their desire to interact with the elderly. Some medical or health functions need to be added to the system in the future.

5. Discussion

We used the research-design-verification research structure to explore the changes in the structure and function of traditional families caused by the transformation of industries and the gap between urban and rural economic development [1], resulting in changes in the residential patterns of the elderly population in Taiwan. Due to the alterations in family life caused by social changes, the retired elderly may also be separated from their adult children, but family relationships are more valued and expected by the elderly. Within these relationships, the emotional support of family members and family communication and interactions [3] are most valued by the elderly and their families [4,5].

In the face of the rapidly ageing population structure and the changes in family structure caused by the development of industry and commerce, the cohabitation of three generations of the family—grandparents, parents, and unmarried children—that occurred in the past is decreasing. Even if children live with their parents, they live at a different pace, which leads to tension in intergenerational relations due to poor understanding and communication. In order to promote the development of harmonious relationships between the elderly and their families, the interactions and communication behavior between elderly parents and adult children at home based on the service experience insight framework were analyzed. The lifestyle, habits, behaviors, needs, and expectations of the elderly were identified through observations and interviews. During the interviews, by observing the daily necessities and lifestyles of the elderly, and classifying their behaviors with an affinity graph, the target population was defined into certain personas after compiling the data. The target participants were asked to record their daily lifestyles and emotions by means of cultural probes, and behavioral models of retired parents and adult children were then developed using interactions, tools, and entities. The potential needs for home interactions between elderly parents and adult children were analyzed to improve the interactions between the elderly and their adult children. The design framework of the home interaction device and the architecture of the Internet of Things was divided into hardware and software parts. The hardware part includes a home interactive sofa chair with a sensor device, and the software part is App programming, which further improves the home-based interpersonal and emotional interactions of the elderly.

5.1. Potential Demands for Elderly and Family Member Interactions

After observing and interviewing, summarizing and analyzing, collecting user data, and drawing behavioral models, we summarized the potential demands of parents and children for intergenerational emotional interactions: (1) Improving intergenerational relations requires active care from children, (2) improving intergenerational emotional interactions requires precise control of parents' active and rest times, (3) understanding and documenting parents' life practices can be completed using a sitting equipment design in the living room, and (4) big data can be used to analyze parents' life practice records.

The improvement in the intergenerational relationship involves children's active care (referring to Section 4.2.1., Demand 1), because the intergenerational relationship between parents and adult

children has gradually changed from an authoritative and obedient top-down relationship to an equal and mutually supportive adult relationship with the evolution of time. Therefore, the interactions between the two generations are bidirectional, not a short-term single project, and should involve long-term support and interactions [44]. However, different interpersonal relationships exist between the two generations. Intimate relationships may bring love and care, but they can also include the possibility of conflict, embarrassment, and anger. Various sources of stress and tension alienate family members and can even divide families [15]. The children's active concern for their parents gives elderly parents a sense of dependence, which can relieve their economic pressure better than the provision of money [24]. The improvement in family relationships is more helpful to the mental health of the elderly [45] and effectively reduces the risk of Alzheimer's disease [11], which has the same effect as leisure sports [27].

The emotional interactions between generations need to be understood (referring to Section 4.2.1., Demands 2 and 3). Through the analysis of the lifestyles and behaviors of the elderly at home, we identified that the living room is the most frequent area for interactions between the children and the elderly parents, and elderly people also spend the most time in the living room during the day. Other areas, such as the kitchen, bathroom, bedroom, and courtyard have their own unique functions. Only the living room has multiple functions, and parents and children have the space for emotional interactions. This echoes Senger et al.'s finding that retired older people often stay at home [6]. Therefore, through the design of a seat suitable for elderly parents, we recorded their daily activities and physiological information and used big data to analyze their parents' life practice records (referring to Section 4.2.1., Demand 4). If their weight changed 10–20% more or less than the previous week or if the seat is used at an abnormal time for three days in a week, such as 12:00–3:00 p.m., the abnormal notification system will inform the children to pay special attention and the records will provide children with basic data for interaction with their elderly parent. Their concern would then not only include superficial greetings but also an accurate grasp of information related to care interactions to promote emotional interactions between generations. Through the Internet of Things, even if they live in different cities, they can grasp their parents' active and rest times. Reducing the conflicts, jealousy, anger, and pressure brought about by parents and adult children because of love and care can reduce the alienation of family members and prevent the splitting families [15].

5.2. Improvement in Intergenerational Relationships

Through the experiments, the SCIC was shown to significantly improve the emotional support and parent-child interactions with the elderly as well as the intergenerational relationships. In the emotional support part of the questionnaire (Questions 1–8 of Table 7), the average scores of Questions 2, 3, 4, 5, and 6 were significantly higher in participants after the experience, compared with before the experience. Among them, Questions 2 and 6 showed an improvement in elderly parents' attitudes toward their children. They regarded adult children as equal friends and actively shared their thoughts with their children. Questions 3, 4, and 5 showed that, after experiencing this product, children actively talked with their parents, comforted their parents (Question 3), greeted their parents (Question 5), and shared information about their lives and work pressure with their parents (Question 4).

In the parent-child interaction part of the questionnaire (Questions 9–14 of Table 7), the participants showed a significant difference in parent-child interactions after using the SCIC. Among them, Questions 9, 11, 12, and 13 all showed significant differences. Questions 9, 11, and 12 showed improved attitudes of the children toward their parents. They actively shared the joy of life with their parents (Question 9), cared for their health, and took the initiative to measure blood pressure and blood sugar (Question 11). They also actively greeted their parents (Question 12), and parents actively contacted their children (Question 13). This also shows that, after experiencing the SCIC, the parent-child interactions in the intergenerational relationship significantly improved, especially regarding the active care of the elderly by their children. These improvements in emotional support and parent-child interactions showed that collecting information on the daily lives of the elderly

through the SCIC allows remote family members to understand each other's lives and health, which is an important function for improving intergenerational relationships.

5.3. Improving Intergenerational Relations for Sustainable Development of Family and Society

This paper began stating that the gap between urban and rural areas is caused by the development of industry and commerce and that population migration in rural areas indirectly changes the family structure [1], resulting in problems with family care that are commonly faced by the ageing society. Intergenerational relations are impacted by this social phenomenon, which causes adult children to gradually feel the pressure to take care of their elderly parents. There are various contradictory emotions between family, parent-child interactions, and personal career growth [12]. In terms of caring for older parents, 39% of adults respond in a self-sacrificing way [13]. Whether the parent-child relationship is good or not affects the intergenerational care by adult children, and unmarried daughters seem to be more likely to be taken for granted as caregivers. After the marriage of adult children, the daughter-in-law also fears losing herself because she assumes the role of caring for her parents-in-law, while the son bears family and economic expectations [14]. This kind of pressure can cause alienation among family members and even split the family [15].

However, older parents are most concerned with the emotional connection and interactions between parents and children. Li and Chang [14] found that older parents care about companionship rather than care from their adult children. Instead, older parents provide them with various kinds of assistance. The children's active concern for their parents makes the elderly parents depend upon them, which can relieve the subjective economic pressure of elderly parents more than the provision of money [24]. The improvement in family relationships is more helpful to the mental health of the elderly [45] and effectively reduces the risk of Alzheimer's disease [26], which has the same effect as leisure sports [27]. Through this study, the potential needs were explored through contextual inquiry, and the SCIC developed in this study was shown to help children understand their parents' daily behavior at home through the smart sensor.

The abnormal state notification can be used to immediately provide information about the parents' physical and mental health to adult children. Through experiential verification, the chair was found improve emotional support among generations and promote parent-child interactions. It also enables older parents and adult children to actively share their thoughts, and positive interactions within families can enable older people to obtain satisfaction, pleasure, intimacy, appropriate self-disclosure, emotional support, and maintenance of self-worth [25]. Although family and society change with economic development and different values, family emotional support and good family interactions are the most important factors for maintaining family relations [11]; they are the basis for the sustainability of family relations and the cornerstone of social stability. This is the most important contribution of this study.

5.4. Limitations of Research

In this paper, the interactions between older parents and adult children at home were analyzed within a service experience insight framework, and the need to improve emotional interactions between generations was summarized. Accordingly, an SCIS with a chair was designed. Through experiential verification, this system was shown to effectively improve the emotional support and parent-child interactions in intergenerational relationships. However, due to financial support, it is impossible to conduct a large-scale experience experiment. In addition, older parents may be reluctant to use the chair, which is also the limitation of this study. However, this chair is bought by adult children for their parents to use, so the users of the chair do not know that their use status is recorded and transmitted to their children. In the future, we expect more senior citizens to participate in studies and experience this product over a longer period of time to allow the design of a product that has both theoretical and practical benefits.

6. Conclusions

We explored the potential needs and expectations of the intergenerational relationship between elderly parents and their adult children using the service design process as a research method. This involved four stages: demand exploration, demand definition, design execution, and product verification. In the demand exploration and demand definition stages, we applied contextual inquiry and service modeling to understand the intergenerational relationships of the elderly and the potential needs and expectations of family interactions. By shaping the user's contact points through an interaction model, tool model, and environment model, we identified the obstacles and opportunities for stakeholders, such as adults, children, relatives, neighbors, caregivers, and elderly people, in their daily activities. Through shaping the cultural context of these activities, we identified the hidden needs for strengthening the harmony between generations. We applied design criteria for interactive home care furniture for the elderly to meet these potential demands and strengthen the family relationships based on emotions, mutual respect, and understanding. The main results of this study were as follows: first, we determined the potential needs in terms of home interactions of the elderly; second, we established design solutions to meet these needs; third, we validated the design solutions.

6.1. Applying Services Design for the Developing the Smart Care Interactive Chair

This research process combined the contextual inquiry of SEE [40] and the service process architecture of IDEA SDP (IDEA Service Design Process) [37] to develop the SCIC in four product development stages: demand exploration, demand definition, design execution, and product verification. In the process of implementation, demand exploration and demand definition were the two most important stages in the design process. In the stages of demand exploration and demand definition, we easily discovered the unsatisfied needs of users by applying the contextual inquiry method and service modeling [16–19]. The focus of service design is co-creation [37], so in the context insight method, stakeholders should be regarded as co-designers in the development process because users contact and interact with these people, creating obstacles and opportunities. The second focus was on contact points. Attention should be paid to the service providers' (or stakeholders') environments, activities, interactions, use of objects, and contact points with users. When providing services, service modeling can be used to identify barriers and opportunities for contact. In implementing the demand definition stage, obstacles and opportunities can be identified and exposed through integration. In the design phase, the barriers to these contact points naturally become the focus of design improvement and service points. For example, children working outside do not know the physical condition of their parents, which is a barrier to contact. Big data from the daily activities of their parents can be collected through the smart chair, so that they can grasp the health status of their parents at any time through the smartphone App. Therefore, the focus is not on science and technology, but on how to establish a mechanism for parents and children to care about each other, to develop service products to promote emotional interactions between generations. This is an important contribution of this study.

6.2. Potential Demands

After the observations, interviews, induction, and analysis, the behavioral patterns and potential needs of emotional interaction between parents and children can be summarized as follows:

(1) Children's active care can improve intergenerational relationships. Therefore, the adult children's mentality toward their parents should change from passive to active care for retired parents, so that good intergenerational relationships and interactions are created and maintained.
(2) An accurate understanding of parents' daily activities can effectively improve the emotional interactions between generations; even if parents and children are separated from each other, there will be no communication gap.
(3) The design of the seat in the living room can be used to understand and record the daily lives of the parents, and care can be based on the information collected.

(4) A large data analysis was used to collect information about parents' daily lives and physical activities at home. Through the smart action device software, adult children can be provided with the basic data for interactions with older parents. Their concern is not only superficial greetings but also a precise grasp of the care interaction of their information to promote emotional interactions between generations.

6.3. Design Solutions

Based on the need to improve intergenerational emotional relationships that were summarized in the context survey, we developed a home-based SCIS that aims at improving intergenerational emotional interactions to meet the potential needs of the elderly and their children. This SCIS consists of a chair and App software. The SCIC provides a comfortable sitting and personal storage space for the elderly, with sensors inside to collect information on the daily routines of the elderly users. The smart sensing interactive system wirelessly transmits the daily activities of a user and their physiological conditions to a cloud server. The signal analysis system can store and analyze the data regarding the daily activities and physiological condition of a user, e.g., weight, heart rate, and blood pressure. These data can be viewed on a smartphone so that family members can understand the physical conditions of an elderly member. Finally, the abnormal notification system can analyze and compare the currently sensed data to the stored data based on healthy and usage conditions, and the mobile device software (App) presents the data including any abnormalities. In such cases, the system will notify the remotely working children or caretakers to take appropriate actions.

6.4. Validating the Design Solutions

The purpose of the final verification experiment was to investigate whether the SCIC can improve the emotional needs of the elderly. We used the Intergenerational Relations Scale (IRS) to test two aspects of emotional support and family interactions in intergenerational relationships [41]. Paired t-tests were used to test the differences in average scores of emotional support and parent-child interactions before and after using the chair. The experimental results showed that the interactive chair can significantly help the elderly in terms of emotional support and parent-child interactions. After experiencing this product, in terms of emotional support, parents regard adult children as equal friends and will actively share their thoughts with their children. Children talk more actively with their parents, comfort their parents, and share life and work stress after experiencing this product. In terms of parent-child interactions, after experiencing this product, children's attitudes toward their parents were more active. For example, they are more likely to share the joy of life with their parents and care about their parents' health, and take the initiative to greet their parents, and parents can also take the initiative to contact their children.

Finally, the experiment with the SCIC identified that there are many areas that need to be improved in the future, such as seat comfort, the addition of physiological measurements, such as blood pressure, heart rate, and blood sugar, and the addition of an emergency notification button. With respect to the use of the App interface, children should be able to immediately understand the status of the elderly through a dynamic visual information display and warning information, and a function for direct interaction between children and the elderly should be added. However, although this product is mainly used at home, it can also be used in caring institutes.

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Appendix A

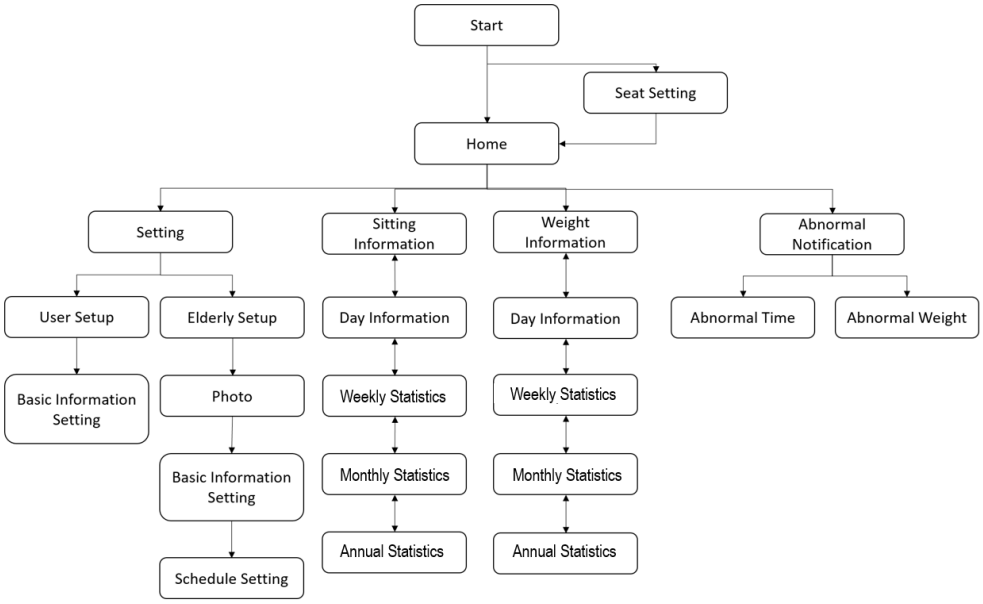


Figure A1. Interface flow design of the App.

Figure A2. Seating pairing interface.

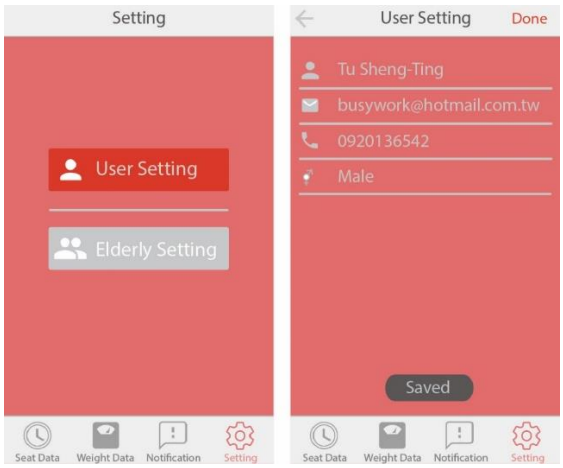
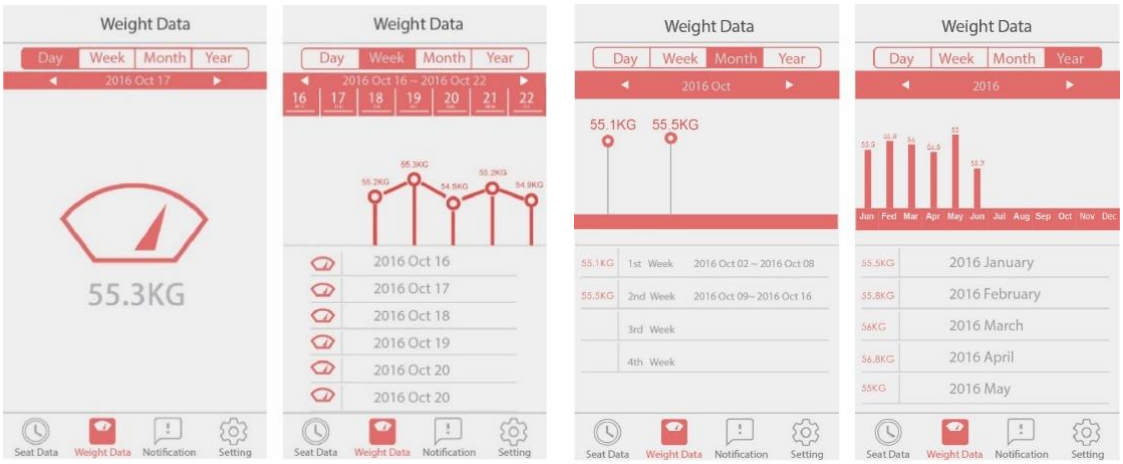


Figure A3. User setting interface of the App.

Figure A4. Elderly image setting interface on the App.

(**a**) (**b**)

Figure A5. Interface of the active daily, weekly, monthly, and yearly data recorded on the App.



(**a**) (**b**)

Figure A6. App interface showing the daily and weekly, monthly, and yearly weight records.

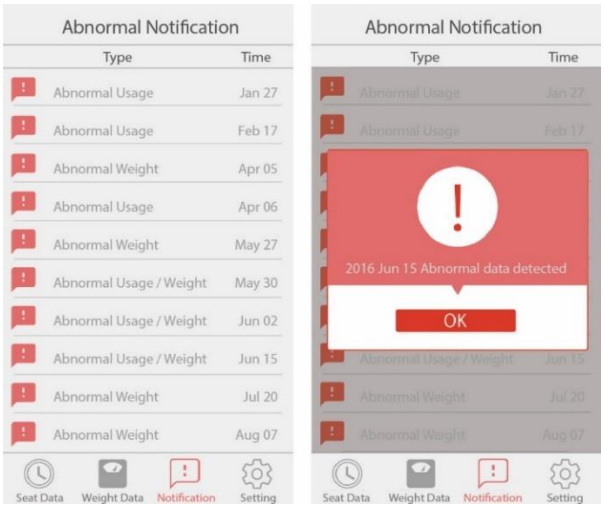


Figure A7. Abnormal notification interface (drawn in this study).

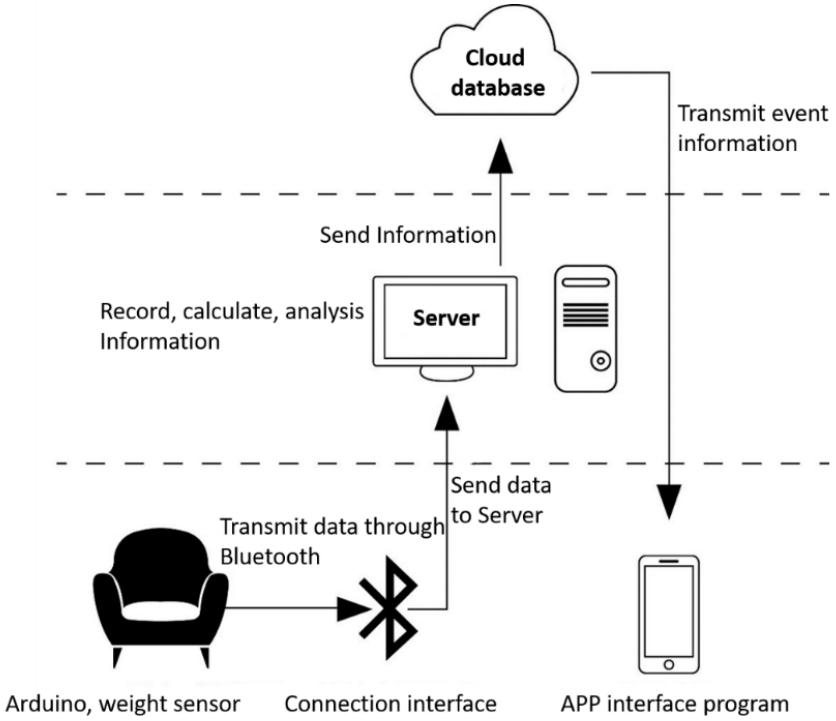


Figure A8. The programing logic architecture.

Table A1. The development of the environment, language, tools, and details of each programming task.

	App Uses Interface Programming:	Cloud-based database—user weight and active and rest data	Android connection interface program	Arduino weight sensing device
Environment	Android Studio	phpMyAdmin, XAMPP	Android Studio	Arduino IDE
Language	Java (Android)	php, MySQL	Java (Android)	Java (Arduino)
Functions	1. Load screen 2. User account login 3. SQLite Embedded Data Inventory Retrieval 4. Multilayer Fragment Dynamic Interface Design (Sliding, Label, Paging, and Composite Interfaces) 5. Adapt dynamic table design 6. MP Android Chart—Data collation of charts 7. Immediate downloading and display of cloud-based data 8. Cloud-side data real-time updates and debugging	1. Establishment of Xampp Work Platform 2. Establishment of MySQL tables 3. Establishment of PHP communication data location 4. PHP upload table content 5. PHP modification of table content 6. PHP update table content 7. PHP download table content 8. PHP search table content	1. Bluetooth permission setting 2. Bluetooth connection device data sheet 3. SQLite internal data inventory 4. Bluetooth and Arduino connection, data reception 5. Instant update and debugging of cloud data 6. Instant upload and display of cloud data	1. Weight sensor settings 2. Bluetooth connection device settings 3. Weight sensor grabs the sensing weight 4. Judging the weight unit and the importance of the data 5. Bluetooth connection to the App, data transfer

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