

# Finding the Expectations of Smart Home and Designing the Meaningful Technology for Delivering Customers' Satisfaction

Yaliang Chuang, Eindhoven University of Technology, Eindhoven, Netherlands, [y.chuang@tue.nl](mailto:y.chuang@tue.nl)

Lin-Lin Chen, Eindhoven University of Technology, Eindhoven, Netherlands/  
National Taiwan University of Science and Technology, Taipei, Taiwan,  
[l.chen@tue.nl](mailto:l.chen@tue.nl)

Yu-Shan Athena Chen, Eindhoven University of Technology, Eindhoven, Netherlands, [y.s.chen@tue.nl](mailto:y.s.chen@tue.nl)

## Abstract

Smart home is becoming a focus in both literature and product development practices. The current study employed a human-centered design approach to understand users desires and expectations from their living context. Six critical themes were developed via in-deep interview, field observation, and data analysis. They are *house as a supportive friend*, *atmosphere generator*, *theme songs for every moment*, *coordinator and reminder*, *life memory collector*, and *routine builder for young generations*. Those concepts were partially integrated to define the value proposition for the target user group of parents with young children. This guides the design ideation and video prototyping to illustrate the user experiences. Through a focus group discussion, the design concepts were validated with six potential customers. The results also show that the design concept has the potential to motivate children's behaviors, help to build their routine, and has the flexibility to fulfill different needs toward the changes of the family's life cycle.

*Keywords: Smart home; human-computer interaction; Internet of Things; contextual inquiry; concept design.*

## Introduction

In the past decade, we have seen the connected technology became an important material and feature of many products. It transforms and upgrades the mundane objects as a kinds of smart things. With the maturing infrastructure of internet and computing capabilities, we are surrounded by enormous services that provide needed information or assistance to support our activities in the virtual spaces and/or physical world. One of the application areas is the smart home. The discussion has attracted much attention in the public press (Manjoo, 2011), marketing media (Higginbotham, n.d.), and academic research (e.g., Brush, et al., 2011; Costanza, et. al., 2014; Dixon, et. al., 2010; Yang & Newman, 2013). However, it did not become a field of research until related technology emerged in recent years (Mennicken, Vermeulen, & Huang, 2014), especially the *Internet of Things* (IoT). The smart home is no longer merely prototypes under evaluation in laboratories; on the contrary, we have recently seen more and more systems and products demonstrated at the Consumer Electronics Show and sold on the market. However, it was found that very few of products were ready for customers to enjoy the benefits of the innovations in many consumers' review (such as Higginbotham, n.d.; Mennicken et al., 2014). Even for the people who understand the general sense of a novel

technology, they still encountered many frustrations and questioned the advertised benefits to their lives after using the products for a while (Rodden, et al., 2004; Takayama, Pantofaru, Robson, Soto, & Barry, 2012). Mennicken et al. (2014) thought that this gap was due to the tech-centered approach applied by the majority of designers and researchers. There were very few studies investigating meaningful technologies that translate into a sense of satisfaction (Rodden, et al., 2004).

In this research, we utilized the human-centered design approach to investigate different users' needs and desires in their everyday lives and understand their expectations of smart home. We started with the contextual interviews and home visiting with ten families to understand their daily rituals and unmet needs, including two design students who live in a shared apartment. We also asked the two designers using cultural probes to collect meaningful objects from their living environments and imagine the smartness they want to added to the artefacts. Through analyzing the observations with theme analysis (Braun & Clarke, 2006), we identified six main insights from their expectations, including *House as a Supportive Friend*, *Room Atmosphere Creator*, *Give me Theme Songs for Every Moment*, *Coordinator and Reminder*, *Life Memory Collector*, and *Routine Builder for Young Generations*. We then compared those ideas with the available products on the market and chose the family with small children as the targeted user because it implies distinct users' needs and potential marketing opportunities. In the follow-up design process, we used sketches, acting out, and storyboards to develop the product and system. The final concept was the young children's companion that could guide them to build their routines synced with the family members through their daily activities, such as role playing or bedtime story telling, etc. The tangible doll could also collect the child's data for helping parents diagnose the problems (such as nightmare) and adjust the environment or day activities to solve the troubles. Finally, we used the video prototyping to illustrate the possible future scenarios for a small family with a young child and recruited six parents to evaluate the concept through a focus group discussion. The result shows that our design concept could not only facilitate the parenting tasks with synchronized routines, but also help to initiate much more intimate interactions with their children. This feature also opens up the possibilities to release the tensions in dealing with the children's irregular routine and promote harmonious relationships afterward. The main contributions of this study are two folds. First, we demonstrated how to conduct the contextual inquiry (Holtzblatt, 2005) to explore people's living experiences and understand their expectations of smart home. Second, we showed how to illustrate the user experiences of future technologies with video prototyping (Greenberg, Carpendale, Marquardt, & Buxton, 2012) and use the result to gather target customers' feedbacks on functionalities and marketing strategies. That new knowledge and methods could lead designers to define and validate meaningful value propositions at the beginning of product development. This will guide them to generate ideations that could deliver specific benefits for the customers.

## **Related Works**

Since Jim Sutherland built the home system (Echo IV) for helping him and his family manage their daily expense in the 1960s (Spicer, 2016), there have been many concepts of smart home developed. One of the important applications is the home security. In average, a burglary takes place every

14.1 seconds in the U.S. (iControl, 2015). The connected devices and cameras could help to monitor the house and provided the inhabitant's peace of mind. Energy saving and comforts are

the other two common topics related to smart home.

Besides those developments in technology, there also are several design studies that used interviewing and anthropology approaches to understand people's real experiences of living within a smart home (e.g., Brush et al., 2011; Rodden et al., 2004). Overall, there still are several gaps between customers' expectations and the smartness of the home system. For example, in the House\_n project developed by MIT (2006), there were more than 300 hundred devices embedded in the environment. Although it was a research prototype, the ubiquitous computing concept has been evolved as the main design pattern for system development. In nowadays, it is common to see dozens of tiny devices disturbed around the house in many smart home systems. Gartner (2014) even predicted that a typical family home could contain more than 500 smart devices by 2022. As the number of devices increases, it brings several usability issues of manageability and the user experience challenges in providing flexibility to fit the interactions to their activities.

Beyond those above-mentioned considerations on the system aspects, there also are several design challenges that the design researchers could make contributions. First, regarding the historical development of technology, the majority of the researchers adopted a tech-centered approach (Mennicken, Vermeulen, & Huang, 2014). On the contrary, the user-center design approach could guide the development team to investigate user needs and use the findings to define meaningful technologies that could provide a sense of satisfaction (Rodden et al., 2004). For instance, Lee, Davidoff, Dey, & Zimmerman (2008) focused on the dual-income family with children. They used contextual methodology to understand the inhabitants' routines and daily activities. Through the qualitative investigations, they pinpointed the frustrations in having the control on their lives, especially the planned tasks related to their children, such as the preparation of school activity or the arrangement of whom to pick up the children. As a result, a smart home that could facilitate the communications among the family members and provides solutions for unexpected situations was proposed in their research. In this case, it was demonstrated that design researchers could play an important role in gaining the better understanding on users' real problems and provide potential solutions without informational complexity (Yang & Newman, 2013). The most important one is to define clear value proposition from the users' perspectives and promote its benefits toward the customers' lives (iControl, 2015; Osterwalder, Pigneur, Bernarda, Smith, & Papadacos, 2014).

## **Methods and Participants**

In order to get various inspirations from different compositions of family, generations, and life styles, we recruited diverse user groups for conducting the contextual studies through sampling the participants from the mailing list of a cooperative organization of homemakers in Taiwan. We also used a screening questionnaire to find diverse candidates living with their family members or friends. Finally, three males and seven females who agreed to our home visit were recruited. Eight of the total ten participants were parents, while the other two interviewees were students lived in a rental apartment shared with the other students who majored in different disciplines. The interviewees' ages ranged from 20 to 60. Their family members or friends were encouraged to join in the conversation when we were interviewing the participants. All of the participants' housing type was apartment, which is the most common housing type in Asia. The floor space was between 712 and 1300 square feet.

During every home visit, we carried out a semi-structured interview with the participant

(sometimes together with their family members or roommates), and took a home tour with them (Holtzblatt, 2005). In the interview, we followed a script that is focused on understanding 1) basic information about the inhabitants, 2) their daily routines, activities and rituals, 3) some interesting events in the most recent three months, 4) their parenting experience, 5) social interactions, especially the differences or conflicts among them with the other inhabitants, and 6) their opinions and wishes of smart home. In the home tour, we asked the participants to show us the most valuable things (especially electronic devices) and tell us the stories behind their selections. Through asking and discussing the details of the stories with them in the living context, we identified several values that were essential for the customers. The interviewed were transcribed and accompanied with observation notes and photo images for later analysis and discussions in the research group.

Family	Residents	Ages	Interviewee's Occupation	Grandparents
A*	4	6~38	House-husband	Another town
B	6	1~80	House-wife	Together
C	3	22~56	House-wife	Nearby
D	6	14~85	House-wife	Together
E	5	10~48	House-wife	Another town
F	4	3~47	House-wife	Another town
G	4	13~52	House-wife	Nearby
H*	3	6~40	House-husband	Nearby
I	2	22-28	Design Students	Another town
J*	2	20-28	Design Students	Another town

**Table 1. Basic information of the participants.**

The \* indicates the male interviewee, the others are female.

## Findings

By using the theme analysis (Braun & Clarke, 2006) approach to analyze the data collected from the user interviews and visits, we identified six themes that imply important user values and unmet needs. In this section, we will explain those topics individually and envision some ideas with smart technologies; however, some of the themes overlap and should be taken into account together. The six themes are as follows:

- **House as a Supportive Friend:** When people are lonely or ill, they often feel helpless and desire to receive warming caring or greetings. We found this need strongest for the two students who share the department with the other roommates. Although they live together, however, because they are not as close as family members, they rarely share personal annoyance with the other people. To fill the gaps, the house might be able to act like a friend or mediator in providing caring interactions or asking helps from the other users when the inhabitants show some cues. How might we add emotional intelligences to enable the house fulfill people's social needs?
- **Room Atmosphere Creator:** It has been found that a pleasant setting of the environment

could help to improve users' productivities and engagements. In three of the eight families we visited in our study, we found that many participants tend to use the lighting and music to create specific atmospheres for different activities when they have the equipment. But the selection process was time-consuming and sometimes likes trial and error. By utilizing the new IoT technology, the smart home might be able to learn the users' preferences for doing specific activities and create proper atmospheres for enhancing their experiences, such as reading, entertainment, or enjoying the social interactions of a party.

- **Theme Songs for Every Moment:** In our field study, we noticed that the teenage generations liked to collect the CD or posters of their favorite artists and sing the songs to express their emotions at the moment or as a daily reflection, especially while taking a shower. The two design students mentioned that when they were thinking design ideas, they usually played specific music for inspiring their ideas. Through the connectivity of the home enchantment system and the abilities in activities detection, the smart home can be an implicit company that could facilitate the inhabitants to express their emotions or to inspire new designs.
- **Coordinator and Reminder:** The chaos was another topic we found from the field study, especially in the double-income families. Although most of the families we visited had a family calendar to schedule shared activities, they still had quarrels about some events that the other member forgot to do what they promised before. This might be because the group planning was not synced with their personal schedule or was interrupted by unexpected events or important tasks. With the continuous monitoring technology, the smart home could help to synchronize the inhabitants' schedules, remind them to do specific tasks, and coordinate with each other. This will help people to manage the complexities and have control of their lives (Lee et al., 2008).

In addition to those desires for emotional caring and living scene generator, we also noticed two other interesting themes from the participants' parenting experiences:

- **Life Memory Collector:** In our visiting, it was found that there were plenty of photos or souvenirs displayed in the participants living spaces. One special category is the handicrafts made by the children for special events. Although those artifacts are implicit triggers to recall many happy memories in their daily lives, the parents were shouldering the burdens of keeping those handicrafts. Very often they struggled on keeping or throwing the old or imperfect pieces when they clean up the house before the Chinese New Year. In addition, three participants who lived in the rental apartment mentioned that they moved several times in their childhood. Every time they moved, they lost invaluable memories marked on the walls or created within the interactions of specific artifacts. Since the digital technology is advanced in data recording and storage, the future smart home could help people to save the memories and recall the happiness in a more economical and interesting way.
- **Routine Builder for Young Generations:** In five of the six families with toddlers (between 2 to 8 years old), the parents encountered similar frustrations in educating their kids to build their daily routine, especially the bed time and morning rituals. Some parents tried to set the goal with their children and motivate them to achieve it with rewards. However, they said it

did not work all the time and they still have not found the effective solutions. With the ubiquitous technology of smart home, we might be able to create interactive activities that could attract children's attentions and assist them to create the rituals from children's perspectives.

**Figure 1. Some of the photos collected in the field studies.**



## Concept Design Development

In comparison above mentioned findings with the related works (e.g. Brush et al., 2011; Chan et al., 2017; Lee et al., 2008; Manjoo, 2011; Takayama et al., 2012; Yang & Newman, 2013), we identified parenting and choose family with young children as the target users for design. We then organized two workshops to extract the high-level values and generate design concepts on smart homes. As a result, we created an <Apps4Home> concept and formulated the following value proposition:

<Apps4Home> is an extensible smart home system like the modern mobile phone. The advanced feature is the alternative packages designed for specific user needs. For instance, in the <Kids' Edition>, there are an interactive storybook, a multiple function table lamp, and a sheep doll that could detect the child's activities and change the environment settings automatically. Through incorporating the standard communication protocols, the system could collaborate with the other smart devices, such as Philips Hue, to deliver rich user experience. When the parent uses the storybook for the bedtime, the bed room could be augmented like the summer or winter with the assistance of the lighting and air condition or radiator. Some visual images could be projected on the ceiling. At night, the doll could also detect the child's sleeping and cooperate with the other appliances to calm her down if he/she waked up from a nightmare. In this case, the system will notify the parent in the next morning

and suggest a better time to wake the child up by analyzing the sleeping data, checking the parents' schedule, and the traffic status. With the supports of smart home, parents and children could synchronize their activities and build a shared routine together.

The <Apps4Home> also provides an App ecology platform. Developers could utilize the IoT technologies to build bundled applications of tangible devices and software to solve specific users' needs and provide excellent customer experiences.

In the second workshop, we invited three engineers and six designers to generate ideas that can fulfill those high-level requirements. To guide the brainstorming, we first identified three personas of the double-income family from our first user study. The parents are 35-45 years old and the children are aged from newborn infant to seven years old. During the ideation process, some photos selected from those collected from the home visits were used to help them focus on user needs and inspire interesting concepts. We then used the storyboard to visualize how could those designs be used in their daily lives. In the scenario shown in Figure 2, the doll played as an avatar to be played with the child and detect his/her activities. It also communicated with other machines to provide dynamic services. For example, during storytelling time, the avatar would help to enhance the ambiance by selectively collaborating with the air condition, spray, projector, and speakers to simulate the world of the story. This could enhance the storytelling and initiate the communications between parents and the kids. Since in most of the families, the story time is highly demanded by the children, we assumed that the integrations of interactivity and intelligence could effectively trigger the young generations to follow the parents' requests in time. For instance, the parent could restrict the storytelling to a specific time. If the children delayed triggering the function, they would miss the new story or unable to experience the augmented versions.

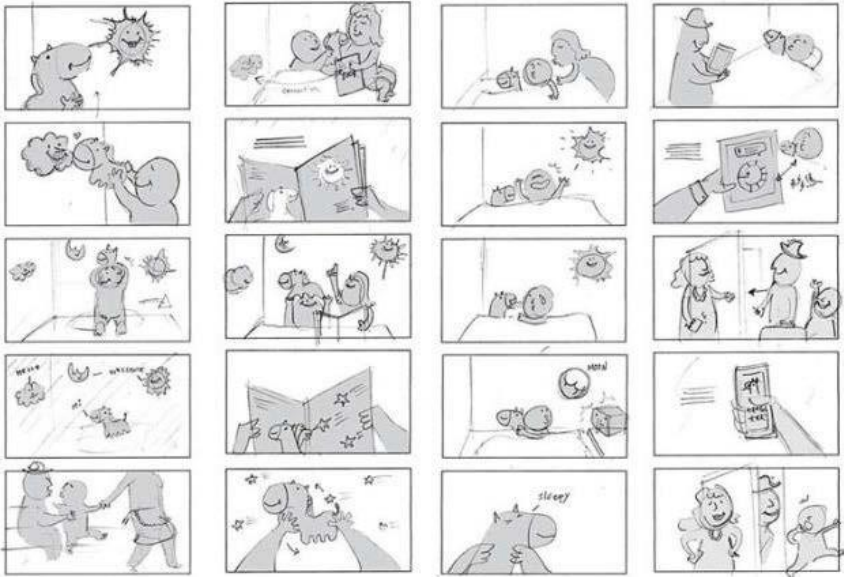


Figure 2. The Bedtime Ritual for Kids scenario.

### Concept Video

To evaluate the concept in advance, we used video prototyping (Greenberg, Carpendale, Marquardt, & Buxton, 2012) to illustrate the interactions and user experiences. This is not only a design activity that turned the conceptual idea into a visual demonstration. It is also an ideation process in developing the details of designs during the film making. For example, we not only created the

tangible prototypes specified in the storyboard but also made a simulation system on the mobile phone. The concept video can be accessed via <https://youtu.be/I7VrsyqMnkU>.

Comparing to physical prototyping, the use of video prototyping enabled us to demonstrate the designs of user experience with an easily understandable format. It also assisted designers to explore the various possibilities in creating the human-system interactions. One example was in the nightmare scene (shown in Figure 3). The avatar was able to sense and monitor the child sleeping. When he/she unexpectedly woke up from a nightmare, the avatar could trigger specific lighting and sound (e.g. parents' voices or soft music) to comfort him/her. This could probably help to guide him/her into sleeping again.



**Figure 3. The concept of calming down children in midnight.**

## Design Evaluation

In order to understand the customers' feedback toward our design concept, a focus group discussion was organized. Six parents (one male and five females, aged 36 to 44) who have children younger than 8 years old were recruited from the authors' social network. During the discussion, we first led them to talk about their parenting experiences and challenges or frustrations, including morning rituals, daily routines, bed time story, and sharing home chores. Although none of them participated our first contextual study, their experiences were consistent with the observations reported in the *Findings* section. Three of the participants shared their frustrations in synchronizing the children's routine to the parents' when they were younger.

The concept video was then presented and the facilitators introduced the concept of smart home and the four main functions of this concept, including: (1) storytelling, (2) atmosphere generated along with the storytelling, (3) accompanying and comforting children during sleeping, and (4) dynamically waking the kid up based on his/her sleeping in the night. Overall, the participants appreciated the user experience and its abilities in facilitating the parenting. Since the kit provides many interactions between the children and the environment, they could learn to have good behaviors in order to get good response from the system. The integration of storytelling could also provide a mechanism to have the children keeping on the schedule in a playful way. Although only two parents shared the experience about their children's nightmare, they found it would be a useful application if the system could detect it and bring them to dreams automatically.

In addition, we also discussed the marketing settings with the participants. They thought that US\$100 could be the reasonable price for a doll and storybook. Two parents thought that the products could be modularized and sold with alternative packages to fit the different life cycle of

the families. When the novice parents has a newborn infant, the physiological monitoring function might be most desirable. However, parents with a toddler would expect divers experiences on storytelling. This suggestion also opens up a possibility in creating long-term customer relationship through the extensible platform. The firm could provide subscription services to customize the functions for parents whose children are in different developmental stages. The <Apps4Home>(Kids' Edition) could even play as a companion to capture the growth of their children, save their memories and recall the happy moments for some specific events in the family. Together with the participants' ideas, we envision that this design could not only facilitate the parenting tasks and enhance children's learning experience, but also lead to more intimate parent-children interactions and harmonious relationships.

## Conclusions

Research on the smart home presents several challenges to both design and the innovation of technology. To explore possible opportunities, we conducted a series of contextual inquiries to learn about domestic routines, user needs, and important values. We identified six themes and integrated some of the expectations to define the value propositions. Systematic design approaches were used to generate a hundred ideas with multidisciplinary brainstorming workshops. A concept video was produced to envision the user experience, system functions, and customer benefits. The film was also served as an effective validation tool used in the focus group discussion with six target customers. Through the discussion, we confirmed the design concept and identified advanced features that could help to create a sustainable business model and deliver customer satisfactions.

## Acknowledgement

This research was supported in part by the Ministry of Science and Technology of Taiwan (MOST 106-2633-E-002-001), National Taiwan University (NTU-106R104045), and Intel Corporation.

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## Author Biography

### Yaliang Chuang

Yaliang Chuang is an assistant professor in the faculty of Industrial Design at Eindhoven University of Technology (TU/e). Before joining the department, he worked as the doctoral fellow in the Intel- NTU research center on the design studies for the IoT era. His research focuses relate to the Human- Computer interaction, user experience, and need findings. He also serves as the Managing Editor of the *International Journal of Design*. Currently, he teaches design innovation methods and conducts researches on designing the natural interactions between users and intelligent products & systems in an environment shared by multiple people.

### Lin-Lin Chen

*Prof.dr. Lin-Lin Chen* is chair of Design Innovation Strategies and a vice dean of the faculty of

Industrial Design at Eindhoven University of Technology. She is also professor in the department of Design at National Taiwan University of Science and Technology (NTUST). She received her B.S. degree from National Cheng Kung University in Taiwan and Ph.D. from the University of Michigan at Ann Arbor, USA. She was dean of the College of Design at NTUST from 2004 to 2010, president of the Chinese Institute of Design from 2007 to 2008, and convener for the arts (and design) area committee of Taiwan's National Science Council from 2009 to 2011. She is the founding editor-in- chief of the International Journal of Design (SCI, SSCI, AHCI), vice president of the International Association of Societies of Design Research (IASDR), and fellow of the Design Research Society. Her research focuses on user-IoT interface, design innovation, and product aesthetics.

### Yu-Shan Athena Chen

Yu-Shan Athena Chen is an assistant professor in the Department of Industrial Design at Eindhoven University of Technology. After having the MS degrees in Psychology and Business Administration, she obtained her Ph.D. degree in Department of Administration at National Chengchi University in Taiwan. Her research focuses on consumer behavior, neuromarketing, and design psychology. More specifically, she investigates how people react to marketing communications and commercial designs.