Is Smart Home a Necessity or a Fantasy for the Mainstream User? *A Study on Users' Expectations of Smart Household Appliances*

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Despite the various benefits that smart home technologies offer, they are not widely adopted by mainstream users. Understanding the expectations of future users is fundamental to facilitate the widespread adoption of these technologies. With a focus on smart household appliances, this paper presents 1) mainstream users' preference for smart product features, 2) perceived benefits of these features and potential use cases in which these benefits are prominent, 3) users' expectations of smart household appliances as well as differences in the expectations of different user types, and 4) design recommendations derived from synthesizing the results with previous work. Twenty in-depth interviews were conducted to elicit users' expectations. Participants comprised single living individuals, people living with friends or relatives, housewives and dual income families who represent early adopter and early majority technology adoption categories. The results indicated that flexible autonomy and remote control have great potential for facilitating the widespread use of smart household appliances when they are combined with the ability to increase users' competence in household activities through providing guidance.

Keywords **–** Design Recommendations, Household Appliances, Smart Home, User Expectations.

Relevance to Design Practice **–** This paper proposes four design recommendations derived from analyzing prospective users' expectations of smart household appliances. Design practitioners can use these recommendations when designing smart household appliances desirable for mainstream users.

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Introduction

Smart home technologies have not been widely adopted by mainstream users despite their availability and the benefits they can offer (e.g., better energy management, improved security and assisted living). Based on an extensive review of smart home research, Wilson, Hargreaves and Hauxwell-Baldwin (2015) argue that the reason for this slow adoption is the technology-centered approach used in their development and propose that following a user-centered approach would be a solution.

A user-centered approach to smart homes technologies requires exploration of users' expectations of future homes. An important step in this exploration is deciding on the user group, i.e., whose expectations will be examined. Selecting individuals from appropriate technology adoption categories (Rogers, 2003) is key to produce knowledge that can be used to design technologies desirable for a wider audience. This is because consumers from different technology adoption categories usually have different characteristics influencing their expectations. Consumers can be categorized into five groups according to their adoption of new technologies. These are *innovators (technology enthusiasts), early adopters (visionaries), early majority (pragmatists), late majority (conservatives) and laggards (skeptics)* (Rogers, 2003; Moore, 2014). Early adopters and early majority, who represent almost 50% of the consumer market, are the main drivers of early and mainstream consumer markets. This study aimed at eliciting the expectations of future users from these groups to better understand how smart home technologies can be designed to meet the expectations of a wider audience.

Another important step in this exploration is deciding on the focus of the smart home, i.e., which components will be examined. Smart homes have four main components: 1) a network of appliances and devices (household appliances, sensors, multimedia devices and control devices), 2) communication network, 3) algorithms and data processing methods and 4) services and utilities (Alam, Reaz, & Ali, 2012). This study focused on smart household appliances in terms of these four components and people's expectations of these appliances in the future home. Several reasons motivated this choice. First, when household appliances are augmented with sensing, processing and networking capabilities, they can serve as the building blocks of smart homes (Kortuem, Kawsar, Sundramoorthy, & Fitton, 2010). Second, from the user's perspective, these appliances have

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a central role in the home as they help inhabitants to perform daily activities. Third, users do not need to have prior technical knowledge in programing and automation to use these appliances. Fourth, the high cost of ownership is a major barrier to home automation adoption (Brush et al., 2011). As mainstream users might be unwilling to invest in an expensive smart home, smart household appliances could serve as a middle ground between traditional homes and smart homes. Fifth, major household appliance companies are increasingly investing in internet connected household appliances and services to facilitate the transition towards smart homes (e.g., BSH Home-connect, LG SmartThinQ), indicating an important area for design.

The study contributes to previous work on smart homes in providing an account of users' expectations of smart household appliances and four design recommendations that can guide designers in making these appliances desirable for mainstream users. In-depth interviews were conducted with 20 prospective users who could be categorized as either early adopter or early majority in terms of individual innovativeness. The interviews probed the daily activities that the participants wished smart household appliances could help them with, smart features they wished these appliances could have, the way they wanted to interact with these appliances as well as the underlying reasons for their preferences and expectations.

The following sections present the previous work on smart homes, the study method and the results revealing preferred product features along with their perceived benefits and potential use cases, preferred interaction styles, the expectations of future household appliances as well as the differences in these expectations. Finally, the paper presents design recommendations derived from analyzing the results and previous work.

Background and Related Work

Design researchers have been investigating smart homes for almost 20 years. Recent developments in RFID, smart sensors, communication technologies and internet protocols, the emergence of the internet of things (Evans, 2011) and people's integration of connected devices into their household practices (Harper, 2011) have provided the technological basis for companies to fully realize the concept of the smart home. Despite this long history and its recent developments, smart home technologies have not been widely adopted by mainstream users. Researchers considered the technology-centered approach to their development as the primary reason for this slow adoption rate (Wilson et al., 2015; Zhai, Liu, Yang, Long, & Virkki, 2014) and proposed a user-centered approach as a way to deliver tangible value to people's lives (Evans, 2011; Koreshoff, Robertson, & Leong, 2013; Shin, 2014).

Previous user-centered research on smart homes can be classified into three categories. One line of studies focused on developing living laboratories and exploring users' interaction with smart home technologies to better understand how these technologies could evolve to meet changing user needs (Intille, 2002; Kientz et al., 2008). These studies helped researchers identify problems related to feasibility, usability and functionality of smart home technologies and encouraged the research community to explore these issues further.

Another line of studies investigated existing users of various home automation systems to better understand what it means to live with home automation and to identify challenges and opportunities for the adoption of such systems (Brush et al., 2011; Jakobi, Ogonowski, Castelli, Stevens, & Wulf, 2017; Mennicken & Huang, 2012; Takayama, Pantofaru, Robson, Soto, & Barry, 2012). These studies helped researchers understand the benefits of smart homes, motivations to invest in home automation as well as barriers to their adoption.

The last line of studies explored the needs, goals and desires of prospective users through following an ethnographic approach to understand how smart home technologies can support people's daily lives (Davidoff, Lee, Yiu, Zimmerman, & Dey, 2006; Eggen, Hollemans, & Van De Sluis, 2003; Lee, Davidoff, Zimmerman, & Dey, 2006). These studies allowed researchers to understand users' expectations of future homes and contributed design principles that could be used to design technologies enhancing the home experience.

Table 1 summarizes the insights derived from previous work. It combines the motivations for and benefits of owning smart home technologies, challenges and barriers to their adoption and principles proposed for designing them in a way to meet user expectations.

As it can be seen from Table 1, previous studies provided valuable insights for designing better smart home technologies. Principles, benefits and barriers can be used to design technologies which are well-integrated within the home environment and offer direct benefits to end users without raising significant concerns. This study differs from and advances on these studies in addressing three gaps.

First, from the systems perspective, previous studies mainly focused on home automation systems (e.g., Mennicken & Huang, 2012) and identified benefits as well as problems related to their use. However, smart homes do not only consist of home automation systems and barriers such as the high cost of ownership which might prevent mainstream users from installing these systems (Brush et al., 2011). Exploring other components of the smart home would expand current knowledge about ways of facilitating users' transition towards living in smart homes. In this respect, this study complements previous work by focusing specifically on smart household appliances and identifying their perceived benefits, smart product features contributing to these benefits and the cases in which these benefits can provide tangible value to users.

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Table 1. Design principles, motivations, and challenges as identified by previous work.

Design Principles	*Motivations/Benefits*	*Challenges/Barriers*
Principles by Davidoff et al. (2006) • Allow for the organic evolution of routines and plans. • Easily construct new behaviors and modify existing behaviors. • Understand periodic changes, exceptions and improvisation. • Design for breakdowns. • Account for multiple, overlapping and conflicting goals. • Participate in the construction of family identity. • The home is more than a location. Principles by Eggen et al. (2003) • People want to create their own preferred home experience. • People want technology to move into the background. • Interaction with the home should become easier and more natural. • The home should respect the preferences of the user. • The home should adapt to the physical and social situation at hand. • The home should anticipate user needs and desires as far as possible without conscious mediation. • The home should be trustworthy. • People always want to be in control. • Hello Life	• *Having a peace of mind*: knowing that everything is fine at home (Brush et al., 2011; Mennicken & Huang, 2012; Takayama et al., 2012) • *Convenience*: managing daily activities with minimum effort (Brush et al., 2011) • *Control*: overseeing what's happening at home (Brush et al., 2011) • *Optimization*: being ecologically conscious and saving money (Mennicken & Huang, 2012; Takayama et al., 2012) • *Experimentation*: tinkering to learn and touch (Takayama et al., 2012; Mennicken & Huang, 2012) • *Entertaining and impressing others* (Takayama et al., 2012) • *Personalizing the home*: making a home more like one's own (Takayama et al., 2012) • *Being modern*: living in a home equipped with advanced technologies (Mennicken & Huang, 2012)	• *Control*: the distribution of power in decision making between the home and the user (Mennicken & Huang, 2012) • *Costs*: costs related to purchase, installation and maintenance (Brush et al., 2011) • *Fitness to current and changing lifestyles*: ability to integrate into user' lifestyle (Jakobi et al., 2017) • *Flexibility*: the level of freedom provided for installing, modifying and extending the smart home (Brush et al., 2011; Jakobi et al., 2017) • *Interoperability*: ability to communicate with other technologies and devices (Jakobi et al., 2017) • *Manageability*: the convenience provided for maintenance (Brush et al., 2011) • *Privacy and security*: ability to provide risk-free use and data protection (Brush et al., 2011) • *Predictability of benefits*: knowing the potential benefits before installation • *Usefulness*: providing direct benefits to user's life (Mennicken & Huang, 2012)

Second, studies investigating existing users mainly gather insights from technology enthusiasts (Brush et al., 2011; Mennicken & Huang, 2012). However, gathering insights from early adopters and early majority is essential to facilitating the widespread adoption of smart home technologies since these adoption categories are regarded as the main drivers of the consumer market (Moore, 2014). So far, only one study has involved early adopters and early majority in their sample (Takayama et al., 2012), but the ratio of early majority users was very low (2 out of 12). This study complements this work by exploring the benefits of smart household appliances for a more balanced sample of early adopters (n = 12) and early majority (n = 8).

Third, studies examining prospective users' expectations of future homes mainly gathered insights from dual income families with children, arguing that they have sufficient resources and interest in the benefits of smart homes compared to other user groups (Davidoff et al., 2006; Eggen et al., 2003). However, due to the diversity in household types, it is very challenging for designers to develop solutions that meet the expectations of different households (Mennicken, Vermeulen, Huang, 2014). Understanding the differences in expectations of different user types could be the first step to overcoming this challenge. The study complements previous work in exploring the expectations of individuals representing different household types, e.g., housewives, single living individuals, people who share a flat with friends and dual income families.

User Study

Participants

The study aimed at eliciting early adopter and early majority users' expectations of future household appliances to produce recommendations to be used in their design. Identifying early adopter and early majority users is a not a trivial task. This is because consumers in different technology adoption categories have many different personal characteristics (Moore, 2014; Rogers, 2003) and the factors influencing their adoption decisions can change over time (Waartz, Everdingen, & Hillegersberg, 2002). In this study, an individual innovativeness scale—widely employed to identify consumers from different adoption categories—was used to identify early adopters and early majority. Other criteria used during recruitment included that a participant had to be at least 18 years old, had to have an intention to change at least one of the household appliances within the next six months, had to have internet access at home and had to be classified as either A or B in terms of socio-economic status (SES).

A professional marketing research firm handled the participant recruitment. A recruitment questionnaire was prepared including questions about gender, age, occupation, income, educational level, marital status, other household members, intention to change household appliances within six months, internet access and individual innovativeness. A translated version

(Kılıçer & Odabaşı, 2010) of the scale (Hurt, Joseph, & Cook, 1977) was used to measure innovativeness. In total, ten women and ten men participated in the study. Six were housewives, three were students and 11 were employed. Ten were classified as A and ten were classified as B in terms of SES. Twelve were early adopters and eight were early majority (Table 2). All participants were Turkish and living in Istanbul, representing urban dwellers in a developing country and an emerging market.

Data Collection Method

Semi-structured interview was used as a data collection method due to the access it provides for learning about people's experience, opinions, attitudes and perceptions. Each interview included several pre-determined questions (see Appendix) followed by extra questions probing the reasons behind participants' answers to establish an in-depth understanding of their expectations and preferences.

A 100 × 100 cm wide white canvas and a set of 8 × 8 cm cards were used during the interviews to motivate participants to easily articulate their thoughts and to provide them with an engaging interview session. The canvas included a pictogram representing a day along with a statement saying "Could you tell us about a regular day of yours?" The cards were grouped into five categories. These were activities, household appliances, features, interaction styles and control devices. Each card had a symbol and a title explaining its content. There was also a sixth category of cards that was intentionally left blank so that the participants could add any activity, appliance, feature, interaction style or control device (Figure 1).

Four pilot interviews were conducted to assess whether this method elicited in-depth user data and to refine the items in the categories. Before the pilot, a list of items for each category was created through a literature survey and a brainstorming session with the participation of each author. Five of the appliance features (autonomy, adaptability, ability to co-operate, human like interaction and multi-functionality) were adapted from Rijsdijk and Hultink (2009). Ability to be controlled remotely was added to the list during the brainstorming session with the intention of emphasizing the connectedness of the home (Harper, 2011). The features identified by the pilot participants (i.e., ability to provide guidance, ability to learn and upgradability) were added to this feature list (Table 3).

Table 2. Participant characteristics.

P	*Sex*	*Age*	*SES*[a]	*Occupation*	*Marital St.*	*Child*	*Household type*	*Innovativeness*
P1	F	37	B	Housewife	Married	2	Couple with children	Early Adopter
P2	M	34	A	Army officer	Married	1	Couple with children	Early Adopter
P3	M	26	A	Mechanical Engr.	Single	-	Lives with friends	Early Adopter
P4	F	37	B	Housewife	Married	2	Couple with children	Early Adopter
P5	F	37	B	Housewife	Married	2	Couple with children	Early Majority
P6	F	22	A	Student	Single	-	Lives with grandma	Early Majority
P7	M	49	B	Consultant	Married	2	Couple with children	Early Adopter
P8	F	30	B	Housewife	Married	2	Couple with children	Early Adopter
P09	M	31	B	Project manager	Married	2	Couple with children	Early Majority
P10	M	33	B	E-commerce dir.	Single	-	Lives with cousin	Early Adopter
P11	F	30	A	Interior Designer	Married	1	Couple with children	Early Majority
P12	M	33	B	Project Manager	Single	-	Lives alone	Early Majority
P13	M	26	A	Industrial Engr.	Single	-	Lives with friends	Early Majority
P14	F	30	A	Housewife	Married	2	Couple with children	Early Majority
P15	F	29	B	Housewife	Married	2	Couple with children	Early Adopter
P16	M	22	A	Student	Single	-	Lives alone	Early Adopter
P17	M	28	B	Project manager	Single	-	Lives with siblings	Early Majority
P18	F	20	A	Student	Single	-	Lives with friends	Early Adopter
P19	F	29	A	Financial advisor	Single	-	Lives alone	Early Adopter
P20	M	55	A	School principal	Married	1	Couple with children	Early Adopter

NOTE: [a] There are six socio-economic groups in Turkey: A, B, C1, C2, D and E. These groups were identified by looking at the SES matrix developed by the Turkish National Researchers Association (TUAD, 2012). This matrix uses household income and educational level for determining the SES groups.

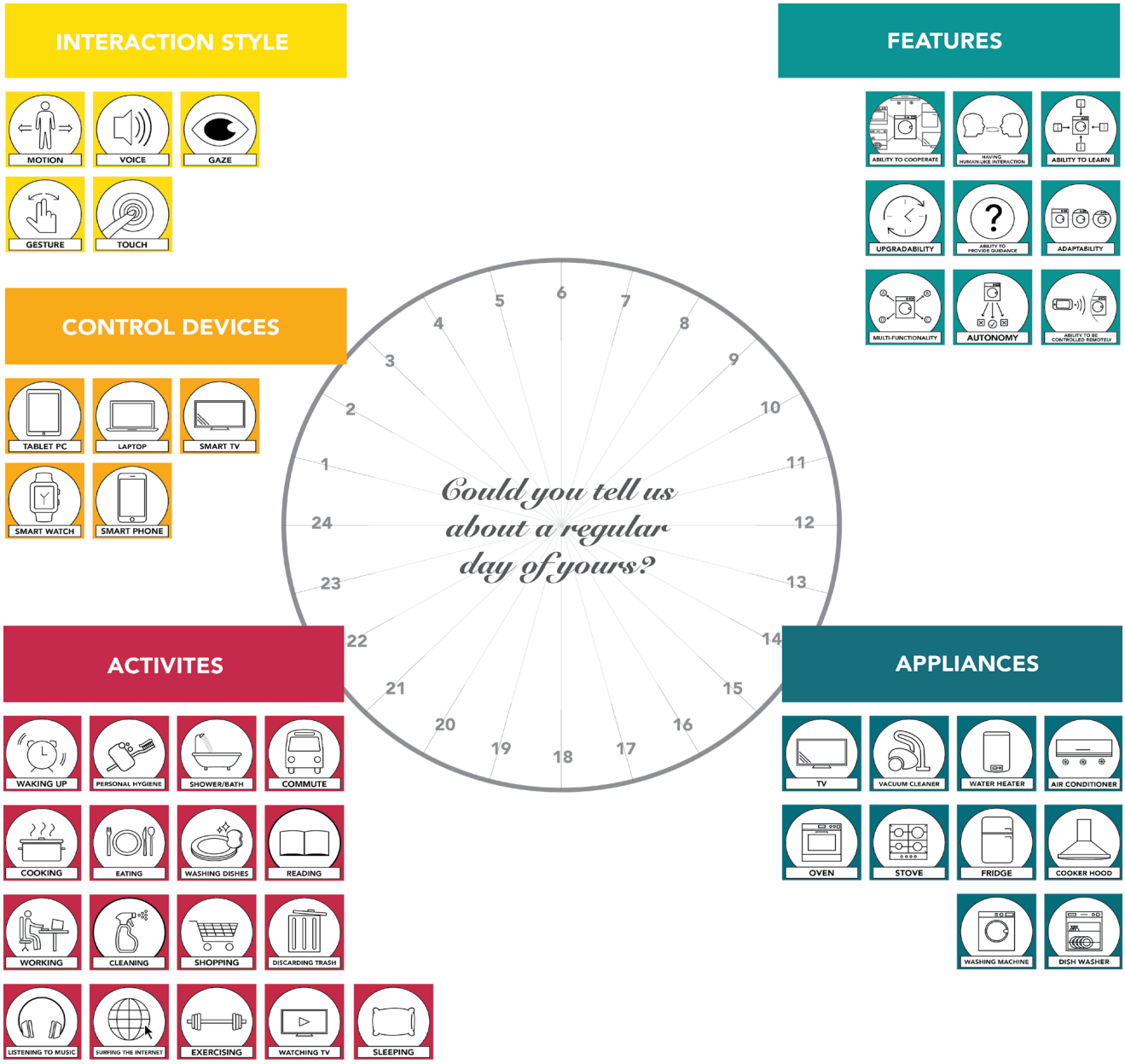

Figure 1. Materials used during the interviews.

Table 3. The list of activities, appliances, features, interaction styles, and control devices in the cards.

Activities	*Appliances*	*Features*	*Interaction style*	*Control device*
• Cleaning • Commuting • Cooking • Discarding trash • Eating • Exercising • Listening to music • Personal hygiene • Reading Shower/ Bath • Shopping • Sleeping • Surfing the internet • Washing dishes • Working • Waking up • Watching TV	• Air conditioner • Cooking Hood • Dish Washer • Fridge • Oven • Stove • TV • Vacuum cleaner • Washing Machine • Water Heater	• Ability to be controlled remotely • Ability to cooperate • Ability to learn • Adaptability • Autonomy • Ability to provide guidance • Having human-like interaction • Multi-functionality • Upgradability	• Gaze • Gesture • Motion • Touch • Voice	• Laptop • Smart phone • Smart TV • Smart watch • Tablet PC

Study Procedure

Interviews were conducted between 17 February 2017 and 13 March 2017 in the focus group room of the market research firm (Figure 2). Each session was video recorded. The average session duration was 90 minutes. After the interview procedure was explained to the participants, they signed a consent form.

Figure 2. A snapshot from one of the interview sessions.

In the first part of the session, participants were asked to talk about the activities they performed during a weekday and the household appliances they used during these activities. They were also asked to indicate any change that might occur during holidays. After placing all the cards on the canvas, the participants were asked to talk about the activities they love and hate and the appliances they use the most. Then, they were requested to share their expectations of future household appliances if they could renew their appliances without any technology and budget constraints. During this phase, they were encouraged to share their ideas even if they perceived an idea to be meaningless or technologically infeasible.

In the second part of the session, the appliance features (Table 3) were introduced to the participants and they were asked to allocate the desired features to appliances. During this phase, there was no limit to the number of features that a participant could assign to an appliance. The participants were also free to leave an appliance without adding a new feature. Later, they were asked to select one feature per appliance. The purpose was to identify the most desired features. Then, they were asked to assign the type of interaction style that they prefer. During this phase, they were free to keep on-appliance controls (e.g., buttons, knobs) instead of selecting any of the interaction styles provided. Lastly, they were asked to select the control devices for those appliances that they wanted to control remotely.

Analysis

The sessions were analyzed through qualitative coding (Miles & Huberman, 1994). The recordings were transcribed into text (60 pages). Each author read these transcripts to familiarize themselves with the data. Transcripts were coded by following a deductive approach, using activities, appliances, features, interaction styles and control devices as categories. Each author then re-coded each category following an inductive approach, with codes derived from the data. New sub-categories were identified with this approach, for instance, chores versus pleasurable moments and novice householders versus experts for the activity category. After coding the first three transcripts separately, the authors came together and discussed the compatibility of the codes. They then continued coding the remaining transcripts with agreed upon codes. In addition to the qualitative analysis, the number of features wanted by each participant was counted for when participants had no constraints and when they were asked to select the most desired feature for each appliance.

Results

The findings are grouped into four parts. The first part includes the most preferred features along with their perceived benefits and potential use cases. The second part includes the most preferred interaction styles and control devices. The third part includes the expectations of future household appliances discussed in relation to previous work. The last part presents the differences in expectations of different user types.

User Preference of Features

When participants were free to assign as many features as they wanted to an appliance, the range of preferred features included the ability to be controlled remotely, autonomy, ability to cooperate, ability to provide guidance and multi-functionality (Figure 3a). When they were asked to select a single desired feature for an appliance, autonomy rose to first place (Figure 3b).

When selecting these features, participants mentioned various benefits that they would offer and concerns that they would raise. The majority of the benefits were in line with previous work (Table 1). Convenience, having a peace of mind, optimization, personalizing the home and impressing others were found to be the major benefits of owning a household appliance with smart features. Two new benefits were also identified. These were creating a feeling of fulfillment in providing guidance and creating time for pleasurable activities by taking over household chores. Control was a major concern as it was in the previous work. Two new concerns were also identified. These were users' reluctance to share the credit of success with appliances and distrust of appliances' abilities in adapting to the complexity of daily life (Table 4).

Participants also commented on the cases and the appliances these benefits and concerns were related to prominent (Table 4). Looking at Figure 3 and Table 4, the most noticeable outcomes relate to autonomy and the ability to be controlled remotely. Autonomy was mainly preferred for washing machines and stoves. Although participants mentioned various use-cases and benefits of this feature (e.g., taking over household chores and creating time for pleasurable activities), it was the one which raised the most concerns. Participants worried about whether autonomous household appliances would make the right choices and believed that these appliances would take control of their lives. The ability

Feature/Appliance	Washing machine	Stove	Oven	Fridge	Dish washer	TV	Vacuum cleaner	Heater	Cooking hood
Ability to be controlled remotely	9	8	7	6	10	7	3	7	3
Autonomy	10	9	5	5	6	3	6	4	6
Ability to cooperate	3	10	8	5	4	3	3	3	6
Ability to provide guidance	7	4	6	7	2	2	3	1	1
Multi-functionality	9	2	3	4	3	2	4	1	2
Ability to learn	5	1	1	0	1	5	1	3	0
Upgradability	2	2	1	1	2	5	1	1	1
Adaptability	2	2	2	2	2	1	1	2	2
Having human-like interaction	2	3	0	3	1	0	1	1	0

(a)

Feature/Appliance	Stove	Fridge	Washing machine	TV	Heater	Oven	Dishwasher	Cooking hood	Vacuum cleaner
Autonomy	8	4	5	2	2	5	4	4	2
Ability to be controlled remotely	4	2	2	2	9	0	4	1	0
Ability to cooperate	2	3	1	1	0	3	1	4	2
Multi-functionality	0	3	6	2	0	1	0	1	3
Ability to provide guidance	4	4	3	0	1	0	1	0	0
Upgradability	0	2	1	4	0	0	2	0	0
Ability to learn	0	0	1	2	1	2	0	0	1
Having human-like interaction	1	2	0	2	0	2	0	0	0
Adaptability	1	0	0	0	0	0	1	0	0

(b)

Figure 3. The distribution of preferred features: (a) no limitation and (b) maximum one feature per appliance.

Table 4. Smart features, benefits they provided, concerns they raised and suggested use cases.

Features	*Suggested Cases*	*Perceived Benefits/Challenges*
Ability to be controlled remotely	• A mobile app to turn off stove or oven remotely in case of emergencies • Helping household members who are not knowledgeable with the appliances remotely though a mobile app • Avoiding crises due to schedule changes by controlling the dishwasher and the washing machine through an app • Adjusting the heater before coming home	• Having a peace of mind • Convenience by better planning of daily activities
Autonomy	• Self-functioning vacuum cleaner because cleaning is a burden for most participants • Stove and oven turning themselves off when left on or in case of over-heating • Dishwasher and washing machine selecting the appropriate program to work based on the type of dishes or laundry	• Having a peace of mind • Convenience by taking over chores • Optimization in energy, time and money • Creating time for pleasurable activities • Feeling under control of technology • Distrust in autonomous appliances' decisions
Ability to Cooperate	• Fridge, oven, stove and cooking hood working together as cooking is an ongoing process among these appliances	• Convenience in facilitating the transition between different household activities
Ability to Provide Guidance	• Washing machine, fridge and oven providing guidance on cooking, storing and doing laundry	• Feeling of fulfilment • Reluctance to share the credit with appliances
Multi-functionality	• Washing machine also functioning as a dryer and doing the ironing, or a vacuum cleaner cleaning the carpets and the walls	• Optimization of space • Convenience by taking over chores • Creating time for pleasurable activities
Ability to Learn	• A heater adjusting the water temperature depending on the person using it	• Personalizing the home • Distrust in technology's abilities
Upgradability	• TV with channel and software upgrades	• Increasing usefulness through new features
Adaptability	• Addition of an anti-allergenic washing program for the baby's laundry	• Having a peace of mind • Flexibility to deal with new situations in home
Human like Interaction	• Stove, oven and fridge providing cooking tips and recipes	• Convenience • Entertaining and impressing others

to be controlled remotely was preferred mainly for washing machines, dishwashers, stoves and heaters. This feature raised no concerns while providing several benefits such as having peace of mind and convenience in avoiding issues due to schedule changes.

Ability to provide guidance was preferred for washing machines, fridges and stoves. This feature was generally received well by participants because it would eventually lead to increased ability in undertaking household activities (e.g., cooking like a chef), although a few participants did not want to share the credit for their achievements with appliances. Ability to cooperate and human-like interaction were mainly preferred for kitchen appliances and for cooking as they would help provide a convenient, uninterrupted and technologically advanced cooking experience. Multi-functionality was mainly preferred for washing machines and it was believed to provide efficient use of space in the home and create time for pleasurable activities by combining two functions into one appliance. Ability to learn and adaptability, although their benefits were not essential for the participants, were seen to enhance their daily lives in providing a more personalized experience and flexibility to deal with new situations around the house (e.g., guests staying over). However, participants indicated their concerns about appliances' ability to know the diversity of everyday life, which was considered to be very complex, interwoven and unpredictable. Lastly, upgradability was mainly preferred for TVs because participants associated these with a computer in terms of its interface and functions and believed that the newer versions of its software would provide new features.

User Preferences of Interaction Styles

All of the participants preferred smart phones for controlling the appliances that they wanted to control remotely. They did not want to be overwhelmed by the addition of new appliances at home as they already owned many. Participants also did not want to be overwhelmed by constant feedback coming from the appliances to their smart phones. Even though they wanted to be informed about the things going on at home, they wanted this information to be limited. Some expressed concern that when there is too much information, it would be ignored among the stream of notifications coming to their smart phone.

As for controlling the appliances from inside the home, none of the participants wanted to replace the on-appliance controls like buttons and knobs. They thought about other interaction styles as an addition to these controls; voice control was the most common addition, followed by controlling through touch screen. Participants stated that it would be most convenient to voice the commands directly to an appliance rather than searching for them within a menu. Voice commands would also allow appliances to be controlled when the user's hands were full and provide personalized control, which in turn would increase the perceived security of an appliance. None of the participants preferred control through gesture, motion or gaze. They believed that these interaction styles would be limited to one or two functions such as turning on and off and that appliances would not always be able to perceive the appropriate gesture, motion or gaze.

Expectations of Smart Household Appliances

Four themes were identified based on participants' expectations of smart household appliances. These both verify and complement previous work so are presented here by referring to related work.

Autonomy is Good, but not Always

The participants often talked about two activity types done at home: chores and pleasurable activities. The chores are repetitive activities that usually take too much time and physical effort. The pleasurable activities are the rituals they enjoy doing and included spending time with children, cooking, browsing the Internet and watching TV. Participants did not want technology to interfere with these pleasurable activities while wanting future household appliances to take over the full responsibility of chores such as cleaning the house. This expectation aligns with previous work stating that chores are unwanted tasks that need to be done through automation (Eggen et al., 2003). The findings also indicate that even though automation would save the participants from spending too much physical effort on housekeeping, the real value of automation would be the time it saves. Participants wanted to replace the time allocated for these chores with the ones they found more pleasurable.

Although the participants wanted full automation of daily chores, they still did not want household appliances to take over all the responsibility. This concern was especially noticeable among housewives. They wanted to keep their role as the master of commanding the house and of the task they were doing. One participant illustrated this for cooking in commenting, "I don't want an oven making all the work for me and even giving me recipes. Cooking is something I enjoy, that I create something valuable for my family. This is my territory, I don't want any interference. (P06)" Another participant who lived alone shared the same concern but for a different reason, stating, "I don't need a fridge creating a shopping list and ordering things for me. These are simple tasks not requiring too much effort. If I don't do such simple tasks, what am I going to do with my life? (P08)" These findings support the observation that people want to be in control of their lives, rather than controlling appliances (Davidoff et al., 2006; Eggen et al., 2003; Lee et al., 2006). However, they also indicate that people do not welcome autonomous appliances when they think that they are threating their role in the family, their identity and the things they value.

Participants wanted to be informed about the decisions autonomous appliances make and overrule these decisions if needed, because they regarded these appliances as computers that could crash or could be easily hacked and believed that although autonomy was beneficial, it would create safety issues as well. This concern resonates with the observations of Brush et al. (2011). However, the results also revealed that the need to monitor autonomous appliances and overrule their decisions could change in time. One participant illustrated this through saying: "First, I need to be sure that it [stove] makes the right decisions. After a couple months, if I am convinced that it is doing so, there is no problem in allowing it to take care of things" (P03).

Appliances Could Do More Than Just Increasing Comfort

One of the main objectives of the smart home is increasing people's comfort through automation (Mennicken et al., 2014). Our results expanded this idea by showing that smart homes can also provide guidance to improve users' skills in household activities. Looking at the expectations pertaining to guidance, the type of guidance desired by the participants might change to one's skill in household activities. People who regarded themselves as lacking sufficient expertise in daily activities wanted smart household appliances to guide them by giving suggestions on the task at hand. For instance, sharing a recipe and practical hints related to cooking or suggesting a washing program by sensing the level of dirt on the dishes. The comment of one participant living with her grandmother illustrates this:

> I enjoy cooking, but I do not know many recipes. Still I am totally open to trying new ones. Half of my cooking recipes are from the Internet and the other half from my grandmother. When I am cooking with the recipes from the Internet, I need to check more often as I can forget the amount of ingredients. But I prefer receiving instructions from my grandmother as she gives immediate responses unlike the Internet. So, an appliance giving me instructions like my grandmother does would be great for me. (P11)

People who regarded themselves as the master of household activities had a mixed attitude towards receiving guidance from smart household appliances. They did not want an appliance to interfere with household activities. This was especially prominent for housewives and for cooking. They believed that cooking is a creative and enjoyable activity done to show one's skill and make their loved ones happy. Still, findings indicate that housewives were not utterly against receiving guidance from smart appliances if they were trying a new recipe or cooking technique.

Performance is a Major Motivation to Renew a Household Appliance

The interviews revealed that a major motivation to renew a household appliance was the potential performance gains offered. At the beginning of the interviews when the participants were asked to list the things that they desire to change, 11 of them started by complaining about the performance of their existing appliances. They wished that these appliances could provide better cleaning (e.g., cleaner carpets), better washing (e.g., faster washing cycles and cleaner clothes), better heating and cooling (e.g., heating and cooling faster, reducing energy consumption).

> I tried 7-8 different irons since I was married 15 years ago. However, none of them was good. The result was not as smooth as I want. Same goes for the vacuum cleaner. I feel like vacuum cleaners do not clean well enough. Recently, I have bought a very expensive one, but still it did not perform as I expected. If there is a better performing vacuum cleaner, I will always pay for it. (P14)

For the participants wanting performance improvements, this was not necessarily related to an appliance's smartness. An appliance could have a better performance without having a smart feature, but during the second phase of the interview, when they were introduced to smart features, they added that autonomous appliances could also provide better performance over conventional ones. For example, they believed that a washing machine selecting the most suitable program, temperature and detergent according to laundry type would do less harm to laundry and a washing machine choosing the washing time according to electricity tariffs would be more resource efficient.

High Degree of Smartness Offering a Tangible Value Can Compensate the Cost of Ownership

Participants tended to see appliances enhanced with smart features as more expensive than conventional ones. Due to this perceived high cost of ownership (Brush et al., 2011), they were unwilling to purchase a smart household appliance unless they believed that it could compensate for the added costs. Twelve participants indicated that these appliances should exhibit a high degree of smartness to compensate for their price. The valuing of appliances with a high degree of smartness in augmenting consumers' senses and skills by knowing and detecting the things they cannot easily do is identified in previous work (Mennicken & Huang, 2012). However, the participants in the present study stated that smartness might not be enough to counterweigh the cost unless it also brought tangible value to their lives. Participants envisioned two scenarios in which a high degree of smartness could provide a tangible value. Seven mentioned that they often had to throw away food left inside the fridge. They reported that wasting food often made them feel guilty because food is a valuable resource; a fridge knowing the expiry date of food and informing the user when this date is approaching would show both a high degree of smartness and provide a tangible value for them. Moreover, fourteen participants emphasized that they found washing machine cycles highly confusing in linking them to laundry type. They reported that selecting the wrong program often made them feel frustrated because it could deform the clothes. The considered that a washing machine that could detect the type of textile inside and decide on the most appropriate washing setting would be very beneficial.

Differences in Expectations of Different User Types

As the participants included early adopters, early majority and people representing different household types, there were differences between the expectations of different user types. One of these differences was due to users' individual innovativeness level. Early adopters were more open to the use of autonomous appliances and to receiving guidance from smart appliances than early majority. For example, the concerns preventing people from preferring autonomous appliances and receiving guidance from these appliances (i.e., trust in appliances' decisions, their vulnerability to hacking and their potential threat to diminishing the housewives' role in controlling the home) were mentioned mostly by participants identified as early majority.

Another difference was in participants' preference for appliances that could be controlled remotely. While dual income families and single individuals (either they living alone or

with others) prefer appliances that can be controlled remotely, housewives did not see a tangible benefit in this feature. Dual income families had determined routines; regular schedules for work, school, holidays and leisure time activities. As the change in one of these routines as a result of being delayed by traffic, for example, could effect the entire plan for dinner, these families wanted to control the household appliances remotely. This feature was very important for singles as well, but for the flexibility it could offer. Singles did not usually stick to a pre-determined plan for household activities. One participant provided the following scenario as an example:

> Since I am living alone, I do not have many plates, glasses and utensils. I usually fill up the dishwasher slowly and turn the machine on twice a week when I get home at night, meaning that there are always a dirty dish in my dishwasher during the day. Suppose that my plans have changed, for example one of my friends decided to come over. It would be awful if I welcome my friend with dirty dishes. So, a dishwasher should always be there when I needed it. I would like to command my dishwasher to start washing the dishes and making them ready when my friend and I get home. (P08)

Housewives mostly have flexible routines. The household activities they perform in a day usually remain same, but their daily schedules might differ. This flexibility did not mean that they did not plan household activities. They were very organized in terms of managing and performing their activities, but since they spent majority of their time at home during a typical day, they did not ask to control appliances remotely.

Another difference was the personality associated with smart household appliances. Newly married dual income families and singles wanted to see appliances as tutors that could guide them through household activities. One participant living alone went one step further. He thought about smart household appliances as part of a smart home perceived as a mother. The following quote illustrates this expectation:

> It is like the house itself talking to you. Saying that "Do not leave the house without washing the dishes. It is time for you to pick up trash." Like my mother used to do before. This would be like a reminder to myself and at the same time breaking up my loneliness. (P17)

Housewives had different expectations in relation to the personality of smart household appliances. They either wanted to rule these appliances as a servant or wanted appliances to accompany them and share their experience. For example, three participants wanted to have a robot, which could serve as a companion while drinking coffee (P15), as a butler doing household chores (P14) or as a caregiver giving health related suggestions (P08).

Discussion

This study makes two contributions to the field. First, it provides evidence to support previous work on the benefits of smart home technologies (Brush et al., 2011; Davidoff et al., 2006; Eggen et al., 2003; Mennicken & Huang, 2012; Takayama et al., 2012). It also advances this work in relating these benefits to smart product features and exemplifying them with potential use cases (Table 4). Because perceived usefulness is the most influential factor in people's intention to use smart household appliances (Rothensee, 2008; Mayer et al., 2011), knowing these perceived benefits along with product features and prominent use cases is valuable in designing better products that meet user expectations. Second, the study presents four design recommendations derived from prospective users' expectations of smart household appliances, these being categorized as early adopter and early majority according to their individual innovativeness. The remainder of this section will discuss these recommendations.

Provide flexible autonomy: Previous smart home research indicates that people always want to be in charge of their home, not controlled by it (Davidoff et al., 2006; Eggen et al., 2003). This study showed that delegating the responsibility of household activities to autonomous appliances does not conflict with this value of controlling one's own life if people could decide *when* to automate and *what* to automate. Regarding when to automate, the results indicated that users' preference of autonomy can change in time. For instance, although housewives strongly opposed delegating control to household appliances, they would be fine with doing so once they observe an autonomous appliance makes the right decisions, because this observation would develop a trust relationship between them and the appliance. Regarding what to automate, the results showed that preferences for autonomy can change according to users' characteristics and their current mood. While cooking was a chore for many people, it was a pleasurable activity for housewives. In some cases, such as cooking after a long and tiring day, even housewives could treat cooking as an unpleasant activity. Providing flexibility in product control would address such changes in user preferences. For instance, a smart oven having flexible autonomy could allow users to select between three autonomy levels when cooking al dente pasta. When the user selects the full-autonomy mode, the stove can adjust the boiling time according to user preference, and automatically turn-off the heat after seven minutes, informing the user by sending a notification to their phone. When the user selects the semi-autonomy mode, instead of turning off the heat automatically, the stove can send a notification to the user reminding them of the need to turn off the heat to make the perfect al dente pasta. When the stove is used in no autonomy mode, the user performs all these steps manually. Providing flexible autonomy in appliances would allow users to better manage household activities by delegating some responsibilities to appliances and also would encourage them to take responsibility for the undesired outcomes of automated actions (Alan et al., 2016), which may in turn strengthen their feeling of control over the house and over smart appliances.

Design for increasing competence: Streitz et al. (2005) distinguish between two types of smart artifacts. System-oriented artifacts can take certain self-directed actions based on previously collected information. People-oriented artifacts empower users to make decisions and take mature and responsible actions. This study showed that people tended to prefer people-oriented

household appliances over system-oriented ones. There were two indications for this preference. First, participants wanted to be informed about why and how smart household appliances make decisions and overrule these decisions if necessary. Second, they wanted appliances to help improve their existing knowledge and skills regarding household activities. This finding emphasizes that smart household appliances, beyond increasing user comfort, should empower users by 1) presenting users with information on possible decisions and actions that can be made in a situation and their consequences and 2) helping them increase their competence in household activities. The first can be done by providing just-in time feedback to the user when an appliance makes a decision and performs an action (Intille, 2002). The second can be done by providing guidance to users when they are performing an activity (e.g., Mennicken et al., 2010; Reichel et al., 2011).

The results of this study revealed that an appliance can provide such guidance on two levels: guidance on how to do a household activity properly and guidance on how to do this activity better. For example, among the participants of this study, newly married couples, single living individuals and people who share a flat regarded themselves as inexperienced cooks although they enjoyed eating homemade food. These participants wanted to learn a new skill, e.g., how to bake a chocolate cake. An oven suggesting recipes and giving directions on the steps in the recipe, as envisioned by the participants, could be a desirable solution for these users. On the other hand, housewives who regarded themselves as experienced cooks and as the person who was in charge of cooking for the family wanted to improve their cooking skills, e.g., learning ten different ways of making a chocolate cake. An oven suggesting a set of alternative recipes according to their difficulty level and allowing the user to create and record their original recipes could be a desirable solution for these users. Thus, designers should take into account users' skill level and their motivations for improving or gaining their skills when they are designing appliances that can guide the user through a household activity.

Give feedback on performance improvements gained by autonomy: The study showed that superior performance was a major expectation of future household appliances. When the participants were first asked about their expectations before introducing the smart features, they indicated that an appliance should surpass the one they were currently using in terms of its performance. For them, this performance was not necessarily associated with smartness, but with the quality of service (e.g., cleanliness of the laundry) and a reduction in resource consumption (e.g., time, energy and money). When they were introduced to the smart features, however, they believed that smart features like autonomy could bring improvements over conventional appliances in these areas. Communicating these improvements has potential to increase mainstream users' willingness to use smart household appliances. Although this may seem a problem of marketing rather than design, the design of household appliances also has much to offer. First, seeing these improvements on an appliance's display would show users that they made the right decision in purchasing a smart appliance, potentially increasing their satisfaction. Such satisfaction when discussed with friends, family and acquaintances might encourage others in the users' social group to buy the same appliance. Second, when combined with the role of smart household appliances as *tutors*, giving feedback can serve as a mechanism for changing user behavior (Fogg, 2003). For instance, a smart washing machine can calculate the impact of different washing settings on performance by analyzing the type of laundry, time of the day, electricity tariffs and so on, guiding users to select the most desired setting. This could provide users with an opportunity to reflect on their current habits, learn about alternative behaviors and adopt new habits.

Integrate other household objects to the system of smart household appliances: The results showed that integrating other household objects such as furniture, clothes and utensils into the system of smart household appliances would help meeting two important user expectations. The first is the expectation of a high degree of smartness, which participants associated with doing things that they cannot do or doing things more efficiently than they can do. The most notable examples of appliances having a high level of smartness were a fridge knowing the expiry date of the food inside and a washing machine suggesting or selecting a desired program by knowing the type of laundry inside. In these cases, adding RFID tags to the clothes or packaged food could allow the appliances to detect what is inside and decide what to do the next based on this information (e.g., Rouillard, 2012). This would enhance the sensing capabilities of these appliances and lead to a perception of a high degree of smartness. The second expectation is having a seamless household experience. Participants wanted appliances to help them perform household activities without interruption. The most common request for appliances offering such an experience was ovens, stoves, fridges and cooking hoods that could communicate each other. For example, one participant envisioned a seamless experience based on a a smart bed that could perceive whether the user is going to sleep or waking up, sending this information to other appliances so that they can switch between waking up and going to bed mode. For this scenario, a bed with a weight sensor that could communicate with the water heater through Wi-Fi would increase connectedness between different parts of the house as well as between appliances and other household objects, helping to achieve a seamless household experience.

Conclusion

This study aimed at exploring mainstream users' expectations of future household appliances. Based on this exploration, we identified the most preferred smart product features, perceived benefits of these features, use cases in which these benefits are prominent, users' expectations of smart household appliances and differences in the expectations between different user types. Looking at the results, we conclude that the smart features of autonomy and ability to be controlled remotely have great potential for facilitating the widespread use of smart household appliances, thus offering a fruitful area for designers. However, designers should approach automation with care for several

reasons. First, automation is not a game changer for users (Mennicken & Huang, 2012); users want autonomous smart household appliances to have a role beyond increasing their comfort. Second, when to automate and what to automate can change depending on people's characteristics and daily routines. Third, autonomy could have detrimental effects on household experience if it takes over pleasurable activities and threatens social roles in the home. Fourth, early majority users, who are the main drivers of the mainstream consumer market, have more concerns about autonomy than early adopters. To design smart household appliances for mainstream users, designers should provide flexibility in product control, should be aware of the activities that are vital to identities and social roles in the home and should explore solutions that simultaneously automate household chores and offer other benefits such as increasing users' competence in household activities.

Another conclusion of this study is that mainstream users may still be unwilling to purchase smart household appliances because of their high cost of ownership. Communicating the financial and performance improvements gained by using a smart household appliance can be used to overcome this barrier. Another strategy could be designing appliances to have a high degree of smartness to offer added tangible benefits to consumers. For this strategy to be successful, however, the key would be identifying scenarios in which smartness would provide this added value. The present study identifies two example cases. Exploring these cases further as well as identifying new cases provides a potential direction for further work.

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Appendix

Interview protocol

We would like you to tell us about the details of your daily schedule. Let's start with the activities and appliances. We want you to think about the activities that you do on a regular day and the appliance you use during these activities. This illustration represents 24 hours of a day. We ask you to place the activity and appliance cards onto their respective time frames, and think aloud while doing this. You can use the ones provided as well as you can add some new activities and appliances on the blank cards.

Q1: Which is the activity that you like doing the most among these? Why?

Q2: Which is the activity that you hate doing the most among these? Why?

Q3: Which of these appliances do you use the most frequently?

Q4: Which activities would you like to be made easier for you? Why?

Q5: What kind of convenience would you want? Why?

We visualized your typical day. Now, it is time to enhance your overall home experience. Imagine that you are given a chance to renew your household appliances without any technological constraints. Note that it is choosing a feature is optional; you may want to keep an appliance as it is without adding a new feature.

Q6: What kind of features you expect from your future household appliances to have? Why?

You already mentioned several features. Now, we would like you to look at these appliance features and select the ones you want your future household appliances should have. You may choose as many features as want for an appliance.

Q7: Why are these features important to you?

Lastly, we would like you to decide on how you wish to interact with these appliances by placing the interaction style cards next to the relevant appliances. Note that, choosing a new interaction style is optional; you may keep the on-appliance controls without adding a new interaction style.

Q8: Why do you prefer that style of interaction?