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Smart Home Consumers: Comparing Self-reported and Observed Attitudes

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Abstract

The burgeoning landscape of smart home technology brings opportunities for home energy management (HEM) through energy efficiency, behavior change, and demand response channels. However, smart home adoption is lagging behind market projections. Research concerning consumer perceptions of benefits and barriers to smart home technology has tended to rely on stated rather than revealed attitudes (i.e., what consumers say rather than what they do), which could be inhibiting a fuller understanding of smart home adoption. As part of a comprehensive investigation of the HEM space, we conducted mixed method consumer research, involving survey, interview, and observational methods, to explore both stated and revealed attitudes regarding smart home benefits and barriers. Specifically, we surveyed utility customers and interviewed and observed retail customers while they toured smart home demonstrations. Stated attitudes were assessed via descriptive analysis of survey data and qualitative analysis of direct responses to interview questions. Revealed attitudes were assessed via inferential analysis of survey data comparing HEM product owners to non-owners and qualitative analysis of retail customer observations. Results regarding revealed attitudes suggested that benefits pertaining to nurturing and protecting one's household have driven adoption in this space and product cost and lack of knowledge (e.g., complexities of smart home technologies) presented the most significant barriers to smart home adoption. Differences and complementarities between stated and revealed attitudes are discussed.

Introduction

Smart home technology is on the rise in the United States. This technology, which typically refers to household appliances that incorporate additional sensing, communication, and actuation components, enables appliances to communicate wirelessly with each other and users, such that they can be accessed remotely and programmed to provide services for occupants [1-3]. Within the burgeoning smart home landscape are opportunities to support home energy management (HEM). HEM technologies enable households to better manage their energy consumption by providing information about how they use energy and/or by allowing them (or third parties) to more precisely control energy-consuming devices in the home, for example, via remote control of appliances, setting schedules or rules for operation, or integrating "intelligence" through learning algorithms.

For utilities, HEMS (home energy management systems) hold great potential for delivering on energy efficiency mandates and demand-side management (DSM) goals, both of which can contribute to a reduction in power grid operating costs. Industry also seems quite invested in promoting smart home technologies to consumers. For example, Sears has begun to deploy "Connected Solutions" retail displays in 200 Sears and 300 Kmart stores around the country [4], Target has rolled out Connected Life departments in 1,800 stores [5], and Wal-Mart now has a "Your Life. Connected: Home Automation" website [6]. Many consumers are also projecting a future with smart home technology; according to one survey [7], 60% of Americans believe a fully connected home will be achievable

within the next 5 years. In another survey [8], 68% of Americans claimed to believe smart homes would be as common as smartphones in 10 years.

Despite efforts and expectations, the market has yet to deliver. For example, in a market characterization survey in 2015 [9], 50% of the sample (North Americans) said they were likely to purchase a smart home product in the next 12 months. A similar study in 2016 [10] found that only 6% of American households owned a smart home device. The fact that many predictions have overshot smart home market potential may mean the benefits are not as attractive as preliminary researchers and product developers believed, and/or the barriers are more difficult to overcome.

The primary goal of this research was to explore reasons underlying the lag in consumer adoption of smart home, particularly HEM, technologies. We focused on consumers' perceptions of smart home benefits and barriers that motivate or discourage the decision to purchase. Furthermore, our intent was to go beyond what consumers say when asked about smart home benefits and barriers by also considering what they *do* in terms of shopping for and purchasing smart home products. We refer to this distinction as stated versus revealed attitudes.

In the field of behavioral economics, *stated preference* and *revealed preference* refer to research techniques used to understand how consumers value economic goods [11]. In stated preference studies, consumers are asked to choose among goods or state their willingness to pay for certain attributes of a good, always under contrived circumstances (i.e., experiments). On the other hand, revealed preference studies consider consumers' actual market behavior (i.e., purchase decisions).

Thus, the distinction between stated and revealed can be generally understood as the difference between what consumers say when asked and what they actually do. And there often is indeed a difference [11]—not because consumers willfully misrepresent their preferences, but because we are not always aware of all the factors that influence our own behavior. This concept is also relevant beyond the context of economic valuation. For example, people consistently underestimate the influence of social norms on their own behavior [12].

In this study, we generalized the notions of stated and revealed preference to assess consumer attitudes regarding smart home benefits and barriers. We analyzed consumer responses to survey and interview questions about smart home benefits and barriers to assess stated attitudes. To assess revealed attitudes, we compared survey responses of HEM-related smart home product owners to non-owners and observed customers touring and shopping in smart home demonstration spaces at retail stores. Before describing our study, we first review past research on smart home benefits and barriers.

Literature Review

In recent years, a number of large consumer surveys have been conducted to characterize and forecast the smart home market [9, 13-17]. These studies shed some light on consumers' perceptions regarding smart home technology benefits and barriers, though they rely predominately on what consumers say they like and dislike. For example, they ask participants whether they agree or disagree with a list of opinions regarding benefits and barriers to the smart home.

One such survey by Kelton Global and Nest in 2016 [14] found convenience to be the most frequently cited smart benefit (i.e., 54% of respondents agreed that convenience would be a benefit). Icontrol Networks in 2015 [9] found that security was the most frequently indicated benefit of the smart home (90%), followed by cost savings enabled by energy efficiency and monitoring (70%). Another survey by Coldwell Banker and CNET in 2015 [15] indicated that 42% of homeowners would consider the purchase of a smart home product if it could yield \$500 or more in yearly savings.

Barriers to smart home adoption have also been addressed in these studies. Data privacy and security are most often highlighted. For example, Icontrol Networks [9] found that data security and privacy was consumers' top concern, specifically, fear that their personal information might be stolen (71%) or collected and sold (64%). Similarly, Kelton Global and Nest [14] found that 82% of respondents were concerned about keeping their personal information secure.

In the Icontrol study [9], data privacy and security concerns outranked concerns about cost, but cost has also been highlighted as a significant barrier to smart home adoption. For example, the Harris Poll

in 2015 [16] found that 88% of respondents believed smart devices are too expensive. In a survey by Honeywell in 2015 [17] 66% of respondents cited cost as the reason they had not yet acquired smart home products, and in the survey by Coldwell Banker and CNET [15] 44% of respondents indicated they would consider purchasing smart home products if the price were lower. In the Icontrol study [9] a majority of participants also feared that smart home technology would have “too many bugs” (57%).

Academic research concerning smart home adoption has included more varied methods to assess consumers’ perceptions of benefits and barriers. For example, Balta-Ozkan et al. [1] conducted public deliberative workshops in the United Kingdom to better understand the social barriers to smart home adoption. Qualitative analysis of consumers’ discussions enabled a deeper and more comprehensive account of smart home barriers compared to the surveys reviewed above. However, like those market forecasting studies, the result is a list of potential barriers without much differentiation between concerns that consumers are more willing to overlook and those that significantly impede adoption. Likewise, given existing consumer research it is difficult to distinguish which benefits are sufficiently valuable to persuade consumers to adopt, and which are simply acknowledged.

One strategy to help decipher which benefits and barriers are most related to adoption is to compare attitudes of smart home technology owners to non-owners. Hargreaves and colleagues [18, 19] recruited participants to use smart home technology and assessed their experience, including motivations for participating (i.e., perceived benefits), which included saving energy and money, interest in new technology and automation, protecting the environment, and desire for improved control [19]. However, recruited research participants are not necessarily representative of naturalistic smart home technology adopters.

Mennicken and Huang [20] interviewed seven households who had adopted smart home technology naturalistically (not as research participants) to explore motivations for adopting. Their analysis revealed four themes: adopters perceive that modern homes should be smart homes; experiencing benefits of smart homes has a reinforcing effect leading to further adoption; “hacking the home is a hobby”; and saving energy. Although this study provided needed insights into naturalistic adopters’ attitudes, findings relied solely on stated attitudes, i.e., what adopters *said* motivated them to adopt.

Karlin et al. [21] surveyed naturalistic adopters and non-adopters of home energy feedback technologies in particular and found that users’ reported motivations largely pertained to a desire for knowledge about energy use--specifically, the ability to track energy use or to learn about energy consumption patterns. In addition to analyzing what adopters said their motivations were for adopting, Karlin et al. also statistically compared adopters to non-adopters and found that adopters were, in general, less motivated by financial considerations and more motivated by environmental considerations. However, these revealed attitudes were general rather than specific to HEM technology adoption.

Another strategy to reveal benefits underlying smart home technology adoption is to look at the products consumers buy. For example, the Chamberlain Group, Inc. in 2016 [22] found that the three most commonly used smart home devices were garage door openers, smart door locks, and security cameras, all of which are security focused. This implies that adopters seek and recognize security as a benefit of smart home technology. Further research into the experience of retail shoppers, when they are in the process of valuing the benefits and grappling with the barriers, could also help reveal the most potent benefits and barriers, i.e., those that truly inspire or obstruct adoption.

Methodology

The research presented in this paper was part of a comprehensive investigation of the HEM space conducted for Pacific Gas and Electric (PG&E), the largest investor-owned utility in California [23]. The project included an inventory and analysis of available HEM technologies, stakeholder analysis, and consumer research. The consumer research stream of this project was comprised of a survey of PG&E customers, customer observation and interviews at two smart home retailers in the California Bay Area, employee interviews at these same retailers, and content analysis of HEM product reviews on Amazon.com.

In this paper, data from the survey, retail customer and employee interviews, and customer observations are analyzed to explore and compare consumers’ stated and revealed attitudes regarding smart home benefits and barriers. Stated attitudes were assessed via descriptive analysis

of survey data and qualitative analysis of customer interview data. Revealed attitudes were assessed via inferential analysis of survey data (comparing HEM product owners to non-owners), and qualitative analysis of retail customer observations and employee interviews. Specific methods are described in the following sections.

Survey

We conducted an online survey in March 2016 to assess PG&E customers' perceptions of smart home, and particularly HEM, technologies. Questions were aimed toward measuring awareness of and attitudes toward smart home technology in general as well as specific HEM product categories. We also asked about ownership of particular HEM product categories (i.e., smart thermostats, smart lights, smart appliances, smart plugs).

There were two versions of the survey--one used the term "smart home" and the other "connected home"; participants were randomly assigned to one version. The purpose of this split-test was to determine which term was more popular in the vernacular and what their connotations were. Data from both versions are used in analyses for this paper.

Data from the following questions were analyzed for this paper:

1. How much does the idea of a smart (or connected) home appeal to you? (Not at all; A little bit; Somewhat; Very much)
2. In which of the following ways, if any, might smart (or connected) home products benefit your household? (Select all that apply; response options listed in Table 1)
3. Which, if any, of the following concerns do you have with smart (or connected) home technology? (Select all that apply; response options listed in Table 2)
4. Do you own a smart thermostat/a smart appliance/any smart lights/any smart plugs? (Yes; No; Not sure)



Figure 1. Infographic shown early in the survey to familiarize participants with the concept before asking about perceived benefits and barriers.

A key aspect of the survey was the use of infographics to introduce participants to the concepts of smart home and each product category; these infographics were presented after questions inquiring about awareness and before questions about attitudes. For example, participants were shown the smart (or connected) home infographic in Figure 1 *before* responding to questions 1-3 above concerning attitudes toward smart home technology. After questions about the smart home in general, participants were shown a similar infographic for each HEM product category, in turn, before they were asked question 4 (whether they owned a product within each category), which was four separate questions in the survey but combined for analyses in this paper in order to compare owners of any of the four HEM product types to non-owners.

The survey was implemented using PG&E's Customer Voice Panel, a voluntary pool of more than 15,000 customers who agreed to be contacted for research recruitment. A stratified sampling methodology was used to increase the representativeness of the sample in terms of region (Northern, Central Valley, Central Coast, Bay Area), sex, age, income, and housing tenure (own or rent). The resultant sample consisted of 1,414 customers (a 28% response rate). Sample characteristics are listed in Figure 2.

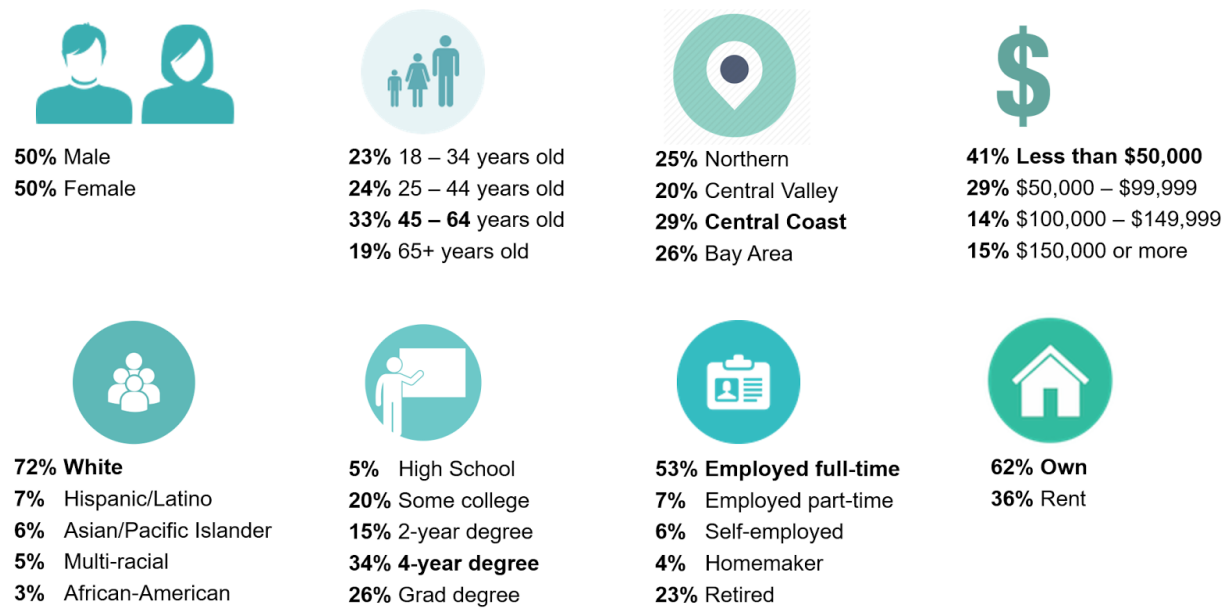


Figure 2. Survey sample characteristics; mode of responses in bold text

Retail Research

We partnered with two major retailers to conduct research at their smart home retail spaces. The retailers were selected because each had an innovative and unique smart home demonstration and display space in one of their stores in the California Bay Area. Our research with these retailers consisted of three methodologies: customer observation, customer interviews, and employee interviews.

Retailer A

Research at Retailer A was conducted by the lead author and three research assistants across two Saturdays, November 4th and December 5th, 2015, from 10 a.m. to 4 p.m. The smart home display area where the research was conducted was set up as a faux home, consisting of rooms decorated as typical rooms in a home: a nursery, gym, laundry room, kitchen with dining area, family room, garage, and patio. Product displays included interactive demonstrations and traditional shelf displays. Products on display included the following categories related to HEM: smart plugs and switches, smart lights, smart thermostats, and smart hubs.

Other smart home products on display focused on fitness and health (e.g., activity trackers), entertainment (e.g., smart speakers), security (e.g., smart cameras), cooking (e.g., smart coffee pot) and caregiving (e.g., smart infant scales). Posters displayed in the rooms indicated which products might appeal to different types of customers, i.e., wellness enthusiasts, new parents, busy parents, and family caretakers. In addition, products were labeled with tags to denote compatibility with various systems, e.g., “works with Wink”.

Customer research with Retailer A centered around employee-guided tours of the smart home display. The tours were led by either the department manager (of the smart home area) or the lead sales employee, both of whom were highly experienced touring customers and vendors through the space. The researchers collaborated with both employees prior to the research in order to develop the procedure for the tours, which was as follows.

Prior to each tour, announcements were made over the store intercom to alert customers to the opportunity to take a tour and receive a gift bag containing a \$5 gift card and a few other small gifts. There were four tours on the November date and three in December. Tours ranged in size, from 1 to approximately 30 customers. Due to the semi-structured nature of the tours and multiple opportunities for customers to ask questions, tours ranged widely in terms of duration, lasting between about 15 to 40 minutes.

The tour guide led customers through the space room-by-room, introducing the products and offering customers a chance to ask questions. Tours on the November date progressed from the entry to the space, to the kitchen and product area which focused mostly smart lights and smart plugs, onto the fitness area, and ending up at the patio and garage. On the December date, the tours focused more exclusively on products with energy implications: starting with smart lights and smart thermostats in the family room area, then on to smart plugs and hubs. The tour guide typically described product types rather than specific products except in cases where there was a product with unique features or only one product of a certain type displayed. Throughout the tours, the guide occasionally asked customers if there was anything they particularly liked or disliked.

In total, there were approximately 75 tour participants across both days. Customers ranged in age, sex, group composition, and ethnicity. Families included those with small children and teenagers, mother-only or two parents, and one family with a grandparent. There were couples and single adults; most were Asian or Hispanic.

Retailer B

Research at Retailer B was conducted by the lead author, a research assistant, and an in-house researcher for Retailer B, on April 18 and 19, 2016, from 11:30 a.m. to 7:30 p.m. This smart home retail space included product display tables with interactive touch-screens offering product information, and an interactive demo faux home space with products set up throughout five rooms: living room, bedroom, nursery, kitchen, and entry/exit. Each room contained a tablet with several vignettes (e.g., arriving home, bedtime) that, when selected, animated the devices in the room to illustrate a user scenario.

Research at Retailer B consisted of passive observation of approximately 250 customers at the product display tables and cashiers, as well as 21 customer interviews and 6 employee interviews. Customer interviews were conducted during self-guided tours of the faux home demo space. Interviewees were given \$15 store gift cards. Customer observation at product display tables and cashiers was conducted by a researcher stationed in the area for the duration of the research on both days (i.e., for approximately 16 hours). She took detailed notes describing customer interactions with each other, products, and employees, including purchases made. Additionally, we used a time sampling method whereby the researcher noted the location and activity of each customer in the space at regular 10-minute intervals, particularly noting which products were receiving attention.

Customer interviews were initiated by the lead researcher approaching customers, both individuals and groups, shortly after they entered the store and offering the \$15 gift card to each customer for participation. Two researchers then guided the participant(s) through the demo space and prompted them to independently explore the scenarios in each room via the tablet, taking as little or as much time as they wished. The tour and interview duration ranged from 5 to 45 minutes, depending on customer interest and responsiveness to questions. Demographic data on customers were not recorded.

During each interview, one researcher asked participants questions at the beginning and end of the tour, as well as after each room, while the other took detailed notes on customers' responses and non-verbal behavior. At the beginning of the tour, we asked customers if they had ever been to this retail space before, why they had come in that day, how familiar they were with smart home technology, and whether they owned any smart home products. Both before and after the tour we asked them how they thought smart home technology might benefit their household. After each room in the faux home display, we asked them what they thought about the different scenarios illustrated, which products or features they would want in their own home (and why), and which products seemed less relevant for them personally (and why). We asked additional follow-up questions based on customers' responses.

To capitalize on the rich experiences of employees, we interviewed six employees at this retailer. Their employment tenure ranged from 3 to 12 months. We asked them about customers' levels of knowledge about smart home products, what customers liked about the technology or tended to overlook, what products were most and least popular, etc. Interviews were 30 minutes long.

Data Analysis

We analyzed data from each method to assess both stated and revealed attitudes about smart home benefits and barriers (Figure 3). Specifically, stated attitudes were assessed via descriptive analyses of survey data and qualitative analysis of retail customer interview data. Revealed attitudes were assessed via inferential analyses of survey data (comparing smart home technology owners to non-owners) and quantitative and qualitative analysis of data from observations of customers in retail spaces as well as interviews with retail employees (regarding their observations of customers). When customer quotes are presented in support of findings regarding stated attitudes, they are direct responses to interview questions. When customer quotes are presented to support findings regarding revealed attitudes, they are spontaneous comments customers made to each other, employees, or researchers outside the context of the interviews.

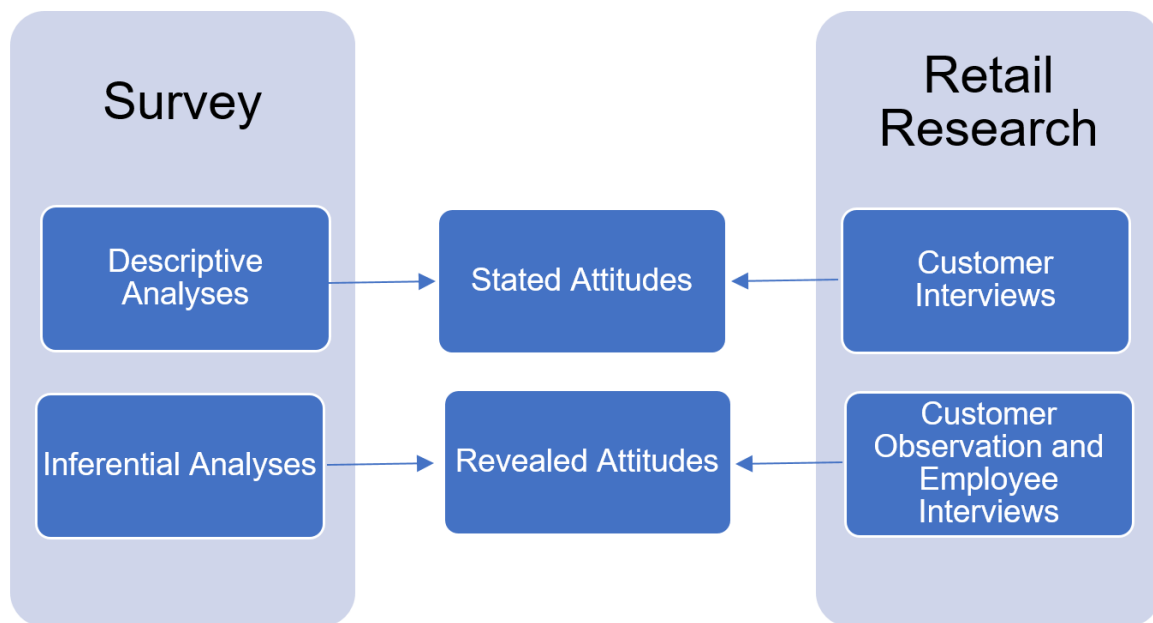


Figure 3. Triangulated methods and analyses to assess consumers' stated and revealed attitudes about smart home benefits and barriers

Results and Discussion

As expected, our findings regarding consumers' revealed attitudes about smart home technology contrasted with our findings regarding stated attitudes. We present the results concerning smart home benefits first, then smart home barriers. Within each section, we first discuss findings regarding stated attitudes, then revealed attitudes.

Smart Home Benefits

Stated Attitudes

When asked in our online survey to select among potential smart home benefits for their own household, a majority of participants indicated that smart home technology could help them save money on energy bills (83%), reduce energy use (83%), enable better management of household energy use (67%), alert them when household equipment needs attention (64%), and reduce negative environmental impact (56%). See Table 1 for the full list of perceived benefits and their prevalence. Interestingly, these dominantly perceived benefits are related to energy, efficiency, and environment, all of which participants might expect utilities (such as the one conducting the survey) to value. This could be indicative of demand characteristics, a response bias whereby participants respond based on what they believe the study is about. However, the prevalence of energy and cost savings as a stated benefit was consistent with past survey research [9, 15, 18-21].

Table 1. Survey data analyses of stated and revealed attitudes about smart home benefits

Stated Attitudes	Revealed
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Benefit	% Selected, Full sample N = 1,414	% Selected, Non-owners n = 1,066	% Selected, Owners n = 348	Attitudes
				Coefficient (SE)
Save money on energy bills	83%	81%	89%	.068(.244)
Reduce energy use	83%	81%	89%	.037(.249)
Enable better management of household energy use	67%	64%	76%	.171(.173)
Alert me when household equipment needs attention	64%	61%	73%	.122(.158)
Reduce negative environmental impact	56%	54%	63%	-.054(.154)
Make my home more comfortable	50%	45%	67%	.606 (.154)***
Protect home from theft or vandalism	43%	39%	56%	.323(.144)*
Save time	37%	34%	47%	.133(.158)
Enjoyable to have and/or use	34%	30%	45%	.159(.153)
Improve home resale value	34%	32%	41%	.045(.143)
Protect health of household members	25%	22%	34%	.071(.174)
Make household chores easier	22%	20%	31%	.017(.176)
Enable better care for pets	22%	21%	27%	-.211(.175)
Enable better care for children or elderly	19%	16%	26%	.130(.187)

* $p < .05$

*** $p < .001$

In interviews at smart home retailers, we asked customers how they thought smart home technology might benefit their household. A strong theme was convenience (e.g., “Simpler, faster, and easier”), as found in previous research [14]. We also asked customers directly about the importance of energy consumption and savings associated with smart home products. Although virtually all customers said they would appreciate energy savings, it was typically regarded as a secondary benefit (e.g., “Would like it to be efficient, but not a deterrent”; “Prefer low energy”; “If it could achieve energy savings that’d be great”). Only a few customers conveyed that energy and cost savings were a primary value (e.g., “I drag my feet at the idea of letting electronics control my house, but to save energy, I’m fine with that”; “It’s all about saving money and saving energy.”). More customers acknowledged savings as a benefit of smart thermostats in particular. Survey research that simply reports frequencies of each perceived smart home benefit may be interpreted to inflate the importance of energy and cost savings. Although many customers may appreciate these benefits, other benefits may be weighed more heavily.

Revealed Attitudes

In order dig deeper into the benefits that inspire adoption, we ran binary logistic regression analysis to determine which benefits predicted ownership of smart home technology among our survey sample. Although owners more frequently indicated every benefit compared to non-owners, and energy and cost savings were the most frequently indicated by both groups, only 'Make my home more comfortable' and 'Protect my home from theft or vandalism' predicted ownership in the model (Table 1).

We stress that “smart home owners” in this model was defined as owning only product categories with implications for energy management, i.e., smart thermostats, smart appliances, smart lights, or smart plugs. Therefore, perceiving benefits related to household comfort and security predicted ownership of HEM products, not just other smart home products that more explicitly and exclusively provide those benefits (e.g., smart security cameras). Although we cannot determine directionality from a cross-sectional survey, these findings suggest that consumers who perceive smart home benefits related to comfort and protection are more likely to adopt HEM products.

Complementary findings emerged from retail customer observations. High valuation of benefits related to protecting the health and safety of one’s household were implied by the popularity of the following products: smart doorbell, smart door lock, smart camera, smart carbon monoxide detector, and water leak sensor. High valuation of benefits related to fostering a nurturing home environment were implied by customers’ interest in the following products: smart sleep monitor/advisor; robotic vacuum, smart cooking scale.

HEM products at these retailers (smart plugs, switches, and lights) were relatively less popular, with the exception of smart thermostats. However, keeping in mind the findings of Mennicken and Huang [20] that adoption of one smart home technology may reinforce adoption of additional smart home technologies, our findings suggest products related to comfort and security may be adopted first and HEM products subsequently. This is a hypothesis that requires future research.

Smart Home Barriers

Stated Attitudes

When asked in our online survey whether they were concerned regarding five oft-cited barriers to smart home adoption (listed in Table 2), participants most frequently indicated they were concerned with data privacy and security (by selecting the statement ‘Smart home technology makes it easier for others to access my personal information without my permission’). This was the only barrier, of those listed, that a majority of the survey participants selected as one about which they were concerned. Cost was also a relatively frequent concern (40%), followed by the demands of installation and setup (38%), concerns about performance (31%), and perceptions that smart home products ‘make simple tasks unnecessarily complicated’ (29%).

We did not directly ask retail customers about “barriers” or “concerns”, but we asked them which products were less relevant or useful for them personally and why. Their responses included the following: product inapplicability to the consumer’s lifestyle/situation (e.g., smart thermostats not relevant for homes without central heating and air conditioning); lack of foundational technology in the home (e.g. no/unreliable Internet or household member without smartphone); structural incompatibility (e.g., smart light bulbs do not fit household light fixtures; old home has limited electrical outlets so would not be able to plug in products); redundancy with products/services already owned (e.g., home security system); and renting (e.g., having to uninstall products if one were to move).

Another theme emerging from the customer interviews related to concerns about smart home products being “excessive”, “overkill”, a “gimmicky” and unnecessary “luxury” or “novelty”; certain products or use cases were seen as promoting laziness or waste. For example, one customer noted that curtains should be opened for natural light in the morning rather than artificial lights coming on automatically. Customers also mentioned the concerns measured in our survey—cost, effort (particularly concerning smart thermostat installation and setup of multiple product integrations), data privacy and security, performance, and unnecessary complications, consistent with prior research [1, 9, 14-17].

Table 2. Barriers to smart home adoption assessed in the utility customer survey.

Barrier	Stated Preferences			Revealed Preferences
	% Selected, Full sample N = 1,414	% Selected, Non-owners n = 1,066	% Selected, Owners n = 348	Coefficient (SE)
I am skeptical whether smart (or connected) home products perform as well as basic devices and appliances	31%	33%	25%	-.282(.146)
Smart (or connected) home technology makes it easier for others to access my personal information without my permission	55%	56%	51%	-.132(.127)
Smart (or connected) home technology makes simple tasks unnecessarily complicated	29%	30%	26%	.038(.152)
Smart (or connected) home products are probably not worth the price	40%	44%	30%	-.536(.136)***
Smart (or connected) home products could be too much of a hassle to set-up/install	38%	39%	34%	-.108(.139)

*** $p < .001$

Revealed Attitudes

In order to dig deeper into the barriers that truly inhibit adoption, we ran binary logistic regression analysis to determine which barriers predicted ownership of smart home technology among our survey sample. Although data privacy/security was the most frequently indicated concern among both smart home technology owners and non-owners, only ‘Smart home products are probably not worth the cost’ predicted ownership. This suggests that consumers are willing to adopt HEM products despite having concerns about data privacy and security, but that the cost of smart home technology is a more difficult barrier to overcome. Again, we cannot show directionality of this relationship, but it creates an important hypothesis for future research.

Our customer observations and employee interviews enabled a deeper understanding of two key barriers. Knowledge barriers have been discussed previously [1], but our research highlighted the extent to which lack of customer knowledge truly inhibits adoption. First, we noted customers’ lack of knowledge regarding the extent of possible integrations between multiple products. This was revealed by customers’ surprise upon learning about these possibilities while touring the smart home demonstrations. Even customers who owned one or two products were unaware of the multitude of available connected products and opportunities for integration.

Furthermore, customers often did not have enough information to differentiate between products. Retail customers who were seeking a particular product may have done their research on a particular brand and not be aware of other similar products and differentiating features. For example, customers found it difficult to navigate the myriad of options for implementing smart lighting, i.e., smart bulbs versus smart switches versus smart plugs—each with multiple options in terms of brands and features. One couple came into a retail store with a coupon, intending to buy a product, but were unsure which to choose; they left without purchasing, conceding, “We have time to do more research” (before the coupon expired).

Customers' interest in multiple connected products working together to provide benefits was evident by their reactions to the smart home demonstrations. However, kits that contained multiple types of products, and more abstract/ambiguous products that help create an infrastructure for the smart home (i.e., hubs, smart plugs and switches) were relatively less popular. Instead, customers tended to purchase just one or two products with standalone value propositions (per retail employee interviews).

Kits, hubs, and multiple products have another thing in common: higher cost. An illustrative remark from one retail customer was, "Do you have to buy *everything* (to make it a smart area)?" This theme was also found specifically in discussions about smart lighting, for example, "Do I need to buy a switch for every lamp?" At the end of a tour, one customer remarked, "Wish I had the money to buy it all!"

Some manufacturers nudge customers toward adoption of systems, but this can backfire. For example, one customer was very interested in a water leak sensor that required a hub. The cost of the hub was much higher than the cost of the sensor. "Why do I need to buy this?" she remarked, perplexed about the need to buy the hub when, from her perspective, she just wanted the functionality of the sensor. Together, these findings suggest the value of whole-home systems is not high enough yet, given the cost and complexities.

Conclusion

In conclusion, we found considerable distinction and divergence between consumers' stated and revealed attitudes regarding smart home benefits and barriers (Table 3). Cost, energy savings, and convenience were most prevalent among stated attitudes regarding smart home benefits; however, retail customer interviews highlighted the typically secondary importance of energy and cost savings. Revealed attitudes centered on protecting and nurturing one's household as the key values underlying adoption. Stated attitudes regarding barriers to smart home adoption featured issues of data privacy and security; retail customers also highlighted a lack of perceived value for many products, calling them "unnecessary" and "excessive". Related to this perceived lack of value, revealed attitudes suggested that product cost and interactions between cost, consumers' lack of knowledge, and complexities of the technology presented the most significant barriers to adoption.

Table 3. Main benefits and barriers identified via analysis of each stated attitudes and revealed attitudes

	Stated Attitudes	Revealed Attitudes
Benefits	Save energy/money and convenience	Protect and nurture household
Barriers	Data privacy/security and insufficient value proposition	Knowledge/complexity and cost

It is important to understand both stated and revealed attitudes. For example, energy and cost savings are universally appreciated by consumers; therefore, it is important for technology and market development to enable and emphasize these benefits. However, energy and cost savings are not sufficiently valued by consumers to independently drive adoption in this space. Instead, benefits that enable users to protect and nurture their household are driving adoption; therefore, stakeholders in HEM technology should package energy and cost savings with these other services.

Similarly, though consumers' concerns about data privacy and security should certainly be addressed, moving the market forward requires addressing the cost barrier, as well as the void of adequate information available to help consumers navigate the smart home space. Hands-on demonstrations, such as the retail spaces involved in this research, that provide consumers with an experiential introduction to smart home and HEM technology may be a particularly powerful educational resource.

Most smart home market characterization research has focused on what consumers say they like and dislike about these technologies in the context of closed-ended survey questions. Relying solely on descriptive analyses of such stated attitudes may lead to inaccurate forecasts and ineffective marketing strategies. Our retail research findings regarding stated attitudes were relatively consistent with our findings concerning revealed attitudes, suggesting that qualitative engagement with consumers can produce a closer proxy for revealed attitudes. Market characterization studies could be improved by integrating open-ended questions into surveys and using inferential and qualitative

analyses. Further research into what consumers are telling us with their behavior, as well as more qualitative research, is required for the smart home and HEM market to reach its full potential.

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