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Acceptance of Future Home Technologies and Services: Comparing Different Tasks, Scenarios and User Characteristics

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Abstract

While capabilities and applications of smart and intelligent home technologies continue to be developed, not much is known regarding how users of various characteristics and backgrounds feel about the emerging possibilities. In this study, a large-scale online survey was conducted with a diverse group of respondents to describe preferences and acceptance of potential future home technology system concepts addressing different tasks and objectives, as well as utilizing varied degrees of technology integration and automation. Results indicated a sense of uncertainty regarding future home technology, with slightly positive but overall neutral levels of interest, and mostly neutral intention to use various presented system concepts. Findings also illustrate gaps in future home technology acceptance between individuals of different attitudinal and behavioral characteristics, in addition to basic demographic traits, with implications for future design and distribution to address expectations stemming from past technology experiences and overall lifestyle.

Keywords

Smart home, Technology adoption, User characteristics

Introduction

In recent years, home technologies have become smarter and more intelligent. "Smart" refers to a technology that can act independently while an "intelligent" system should be able to learn from the environment and adapt to new situation (Minerva, 2015). These capabilities have been implemented into home appliances to improve user lifestyle by more efficient ways of accomplishing tasks.

To explain what factors are involved in acceptance and adoption of smart home technologies, previous studies have used different technology adoption models and theories. For example, Shuhaiber and Mashal's (2019) survey results show that perceived usefulness and perceived ease of use, trust, awareness, enjoyment, and perceived risks significantly influence attitudes towards smart homes and consequently the intention to use. Yang et al. (2018) highlighted three critical factors for users: perceived reliability, perceived controllability, and perceived interconnectedness. Another study investigated the acceptance of AI-based intelligent products. Among the models, Sohn and Kwon (2020) found that Value-based Adoption Model is the strongest. In this study, enjoyment was found to influence user purchase intention the most followed by subjective norms.

In a review paper, FakhrHosseini et al. (2022) reviewed nine prominent technology adoption theories in the area of intelligent environments and discussed that there is little overlap and diverse views in this domain. Furthermore, their categorization of impacting factors in their suggested model shows the importance of other aspects such as user-related and social factors in addition to system-related factors that should be considered in the studies.

Morris and Venkatesh (2000) investigated the influence of age in individual adoption and sustained usage of technology in workplace. They observed 118 workers over a period of 5 months. Using theory of planned behavior, they showed that younger and older people's decisions are influenced by different factors. Data shows younger workers were more influenced by attitude toward using the technology and older people were more influenced by subjective norms and perceived behavioral control. In the context of smart home health technologies, other research (Pirzada, Wilde, Doherty, & Harris-Birtill, 2022) showed that older adults want these technologies to be personalized, to protect their independence, and to provide user controls.

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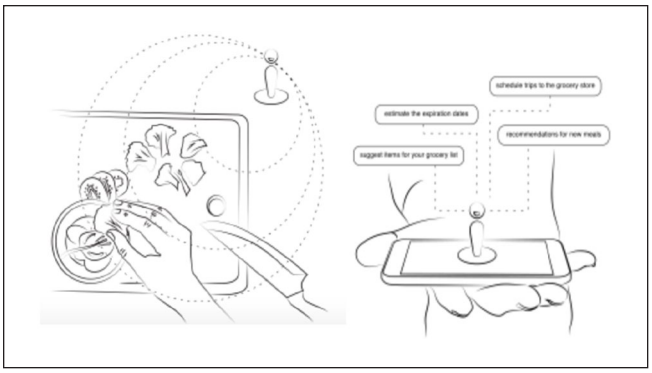

Figure 1. Example of concept introduction page, including descriptions, scenarios, and illustrations, for the "Housework assistant (informative)" concept.

Other factors such as living arrangement and lifestyle have been addressed in other studies (e.g., Dubois et al., 2022). Chang and Nam (2021) investigated the impact of user characteristics and differences in smart home adoption and benefits. They found that gender and age do not make a significant difference in people's intention to use. However, residential type was statistically significant. People living in apartments reported higher intention to use smart home services than those living in non-apartment residences.

Shin, Park, and Lee (2018) discussed how different technology adoption factors are influenced by demographic status. Their findings showed that perceived usefulness was greater in the older and male groups, while compatibility was more important in the high education and female groups. They also showed that older adults with higher income and more home technologies, reported their intention to buy a smart home service in an earlier time frame than younger people.

Many studies have investigated the predictive technology adoption factors. Depending on the task, interaction, and system, different variables may be involved. In the area of smart home technology, more research is required to explore the predictive factors to facilitate adoption of smart home technologies and increase future consumer satisfaction.

This survey was designed to investigate consumer acceptance, including perceptions around benefits and risks of possible future home technology/service system concepts to provide insights on user needs and desires. The data were analyzed to explain how acceptance differs by consumer characteristics in order to identify gaps that may exist in adoption and use of future home technologies and services.

Method

Study procedure

A large-scale online survey, in which a demographically balanced sample evaluated several possible future home technology/service system concepts, was developed and fielded to explore consumer perceptions and compare across consumer characteristics.

A total of 23 concepts were identified based on (FakhrHosseini et al., 2021) and (Lee et al., 2020) as potential emerging technologies and services of interest. The concepts are shown in Figure 1. The concepts were grouped into three categories. Concepts within the first category were technologies and systems related to the household environment such as energy management systems, and concepts within the second category were technologies and systems related to supporting residents e.g., a caregiving portal. The third category consisted of more futuristic concepts of types of homes such as a companion home. Within these categories, some concepts that were related to the same purpose were separated into two versions: "informative" and "automated." Informative systems simply provide information, whereas automated systems take an extra step to make a change based on the information. This division was designed to investigate public needs around automated systems in their homes. For example, the informative version of the "Energy management system" concept might alert residents that a certain device is using a lot of electricity, whereas the automated version might proactively disable a device to save electricity.

In the survey, participants learned about one randomly selected concept within each of the three categories, and then evaluated each one based on technology adoption factors and interest. In addition to evaluating the three concepts, participants answered questions about their general technology experiences and demographics.

Questionnaire

The flow of the questionnaire, as well as the names of the 23 concepts, is shown in Figure 2. Questions were developed to address three categories: 1) screener and technology experiences and attitudes; 2) concept presentation and evaluation; and 3) demographics. The questionnaire took participants approximately 20 minutes to complete.

The questionnaire began with screener questions to ensure fulfillment of quotas, followed by a set of questions about participants' attitudes towards and experiences with technology. This section included questions around self-rated technology experience and usage of existing systems and applications.

Next, participants learned about their first of three randomly-assigned concepts. Each concept was introduced with a page including descriptions of its functions and capabilities, potential benefits, and example scenarios. The introduction page also included original illustrations that demonstrated the concept or service. Participants were required to remain on this introduction page for at least 15 seconds to ensure their attention and comprehension. A sample of this page for one of the concepts is shown in Figure 2. Participants were then directed to another page with a summary of capabilities and functions.

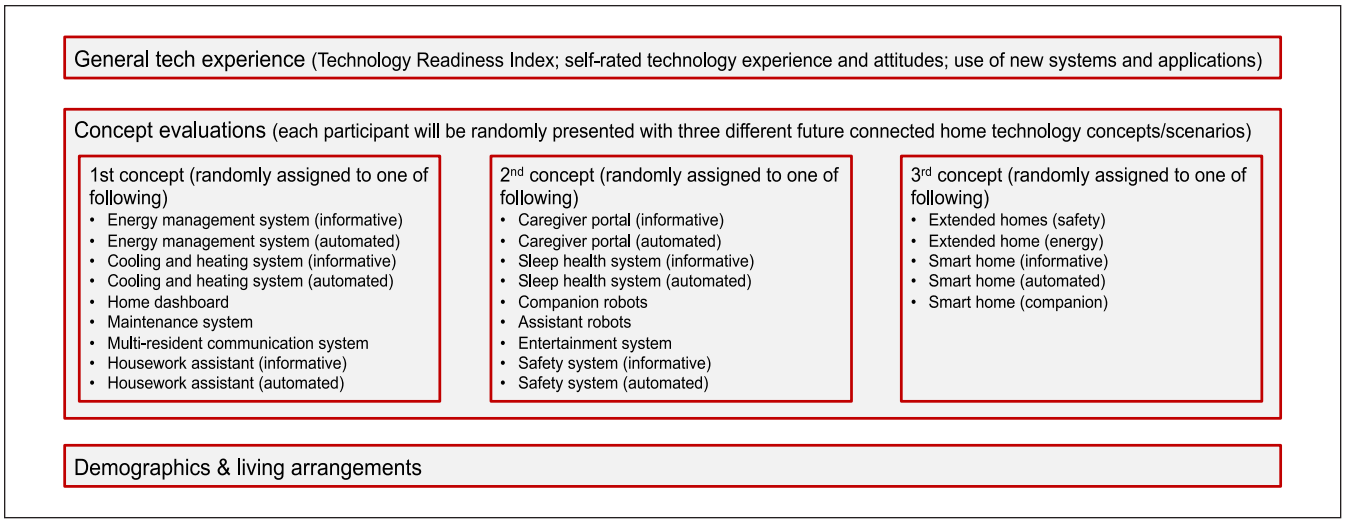

Figure 2. Questionnaire flow.

After learning about each concept, participants answered approximately 16 questions evaluating their attitudes and perceptions of the proposed concept. The evaluation questions addressed: initial impression (e.g., liking or disliking) & factors/reasons that affected their initial impression; familiarity and awareness of similar products or services; anticipated practical impacts (e.g., usefulness and impacts on productivity); anticipated emotional impacts (e.g., fun, perceived anxiety and intimidation), including fear of making mistakes; anticipated impacts on degree of user control; social influence and image (e.g., perceptions of how usage may be viewed by others); perceived risk, concerns around privacy and data security; perceived reliability; trust; and behavioral intention to use (e.g., willingness to adopt if available). Some questions were presented based on participants' answers to previous questions; for example, they were asked to select reasons why they reported liking or disliking each concept. Finally, after evaluating the three concepts, participants answered demographic questions addressing household characteristics, health and wellbeing, and caregiving status.

Participants

Inclusion criteria for this study included being 18 years or older and living in the United States. Participants were recruited by an online panel service to represent a wide range of demographic characteristics. Quotas were implemented for demographic and technology adoption questions to ensure representation of a broad and diverse group of respondents and to allow for meaningful comparisons. The questionnaire was fielded in March 2022. For the analysis, we utilized responses from a total of 1683 participants after performing data cleaning to address incomplete responses and outliers, such as those with significantly quicker than average response times. Participants' ages ranged from 19 to 94, and they lived in a range of locations across the U.S. including all 50 states and Washington D.C. The sample also represented a broad range of past technology experiences and household characteristics. Table 1 shows the demographic information of the participants and their living arrangements.

Results

General public interest and intention to use

For each concept presented, respondents were asked about their level of interest and intention to use once available in the market. Results show a significant difference between respondents' scores in their interest level and their intention to use of those concepts ($t(44) = 3.97$, $p = .000$). Overall, respondents reported significantly higher interest in products than actual intention to use the product (Figure 3).

Participants were asked to report how much they like or dislike the concepts using a Likert scale from 1 to 5 (1=strongly dislike, 2=somewhat dislike, 3=neutral, 4=somewhat like, 5=strongly like). Gray bars in Figure 3 show the average scores of all the participants across the concepts. Those concepts that scored higher than 3.75 are considered as the most popular ones. Results of the mean scores of all the respondents show people like the following concepts the most: 1) Caregiver portal (automated) ($M = 3.93$); 2) Caregiver portal (informative) ($M = 3.92$); 3) Cooling and heating system (automated) ($M = 3.91$); 4) Safety system (informative) ($M = 3.90$); 5) Safety system (automated) ($M = 3.86$); 6) Energy management system (informative) ($M = 3.84$); 7) Cooling and heating system (informative) ($M = 3.83$); 8) Maintenance system ($M = 3.78$); and Energy management system (automated) ($M = 3.77$).

Table 1. Participant demographics (N=1683).

Age	Silent generation (1945 or before): 13.5% Baby Boomers (1946~1964): 28.1% Gen X (1965~1980): 23.9% Millennials (1981~1996): 23.4% Gen Z (1997~2002): 11.0%
Gender	Male: 47.4% Female: 52.2% Other or prefer not to say: 0.4%
Residential environment	Urban: 25.5% Suburban: 51.8% Rural: 22.5%
Housing type	Single-family home: 71.8% Apartment: 14.3% Condo, townhouse, or duplex: 9.6% Other: 4.3%
Technology experience; "In general, how would you rate yourself as being an avoid or an early adopter of new technology?"	Avoid as long as possible: 6.5% Try after most others have tried: 17.5% Try after some others have tried: 28.0% Try after a few others have tried: 26.3% Try as soon as possible: 21.7%

Similar analyses were done on respondents' scores on their intention to use, also using a 5-point Likert scale (1=very unlikely, 2=somewhat unlikely, 3=neutral, 4=somewhat likely, 5=very likely). Since the overall scores were lower on "intention to use" than the "like/dislike" scale, all scores were below 3.5, the cutpoint for intention to use was shifted to 3.25, slightly above the neutral level. Results show a similar pattern: 1) Cooling and heating system (automated) ($M = 3.48$); 2) Energy management system (informative) ($M = 3.44$); 3) Cooling and heating system (informative) ($M = 3.35$); 4) Safety system (informative) ($M = 3.34$); 5) Safety system (automated) ($M = 3.33$); 6) Energy management system (automated) ($M = 3.32$); 7) Caregiver portal (automated) ($M = 3.25$).

The concepts which overall results suggest to be less likely to be purchased concepts and less liked are: 1) Communication systems, 2) Entertainment systems, and 3) Companion homes.

In examining participants' reasons for liking or disliking each concept, a divide has been uncovered between consumers seeing potential economic gains (cost reduction, increased home value) and those concerned about costs of purchasing, maintaining, and using connected home technology systems. Across the board, reasons for liking concepts include potential benefits that are closely tied to key features of described concepts. Reasons for disliking are highly focused on privacy and security concerns, and cost issues. Additional considerations should be given to building trust and allowing users to maintain control and autonomy.

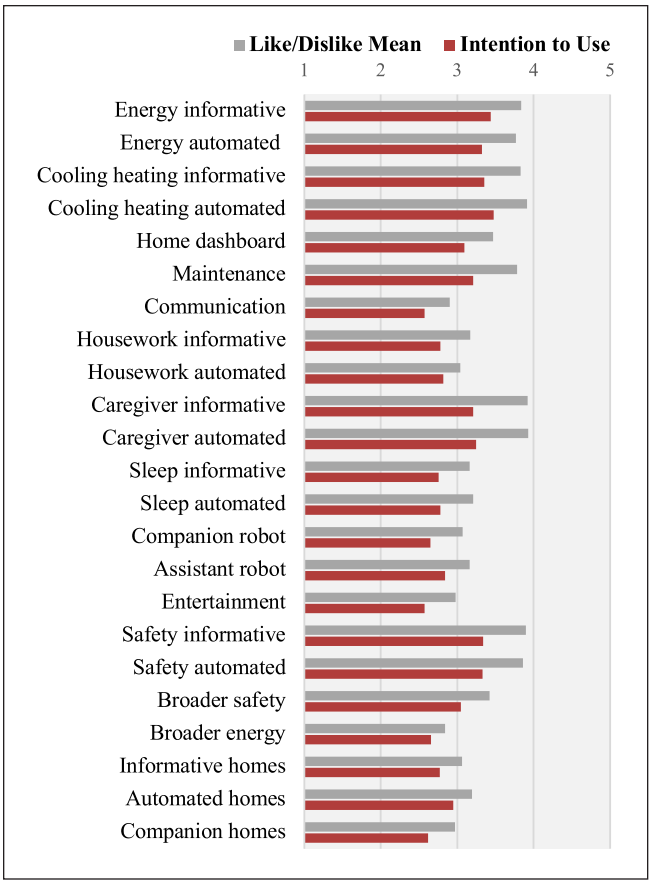

Figure 3. Means for like/dislike and intention to use (For like/dislike: 1=strongly dislike ~ 5=strongly like; for intention to use: 1=very unlikely ~ 5=very likely).

Acceptance differences by participant characteristics

In addition to general interest and attitudes, four major themes were investigated to learn more about respondents' needs and attitudes based on their background and lifestyle: demographic status, living arrangement, caregiving status, and technology attitude.

Demographic status. Several one-way ANOVAs were conducted to analyze the extent to which respondents of different generations have different interest and attitudes around the presented concepts. Overall, younger generations showed higher interest and intention to purchase the products.

To investigate males and females' interest, several independent samples t-test were run. Across all products, there were no significant differences between males and females' interest and intention to purchase ($p > .05$).

Living arrangement. Information regarding respondents' living environment was gathered to investigate whether there are differences among the residents' interest and opinions. Results show significantly higher levels of interest ($p < .05$)

or intention to purchase ($p < .05$) the following concepts in those who live in urban areas than suburban and rural places: Communication system (like/dislike), Automated housework assistant (intention), Informative (like/dislike and intention) and automated (like/dislike) sleep health system, Informative safety system (like/dislike), Broader energy system (intention), Informative home (intention), and automated home (intention). However, respondents living in suburban areas showed significantly higher interest and intention to purchase a Companion robot than urban residents.

Caregiving status. Participants were asked about their caregiving status. In total, 12.8% of participants reported that they receive care from family, friends, or a paid caregiver, and 36.1% reported that they provide care to someone else. Results show that care recipients and caregivers are significantly more interested ($p > .05$) in Companion and Assistant robots, Informative health system, and Communication system. They also showed higher intention to purchase ($p > .05$) informative sleep health system, broader safety system, automated caregiving portal, informative heating and cooling system, communication system, and automated energy management system.

Technology attitude. Participants scored their general attitudes towards new technologies on a 5-point scale: avoid as long as possible, try after most others have tried, try after some others have tried, try after a few others have tried, and try as soon as possible. Results show significant differences for all of the concepts excluding one (automated caregiving portal); those who considered themselves to be earlier adopters generally reported higher interest and intention to purchase the products and concepts.

Linear regression. General linear model was used to assess which factors or combination of factors significantly predict intention to use. At first, all of the variables that showed some significant differences in the previous section were included. Then, four of the variables (living environment, caregiving role, age, and anxiety factor from technology adoption theory) were removed since they did not have any significant role in the model. The new model can explain 77% of the variance, $R2 = .77$, $F(12, 1) = 435.41$, $p < .000$. Based on the results, perceived usefulness ($B = .52$, $t = 17.38$, $p < .001$), control ($B = .13$, $t = 3.48$, $p < .001$), risk ($B = -.09$, $t = -4.32$, $p < .001$), social influence ($B = .11$, $t = 5.14$, $p < .001$), trust ($B = .16$, $t = 5.14$, $p < .001$), and affordability ($B = .14$, $t = -6.85$, $p < .001$) as well as self-report technology adoption level ($p < .001$), reported number of technologies that respondents already have and use in their home ($p < .05$), and care receiving ($p < .001$) significantly predicted intention to use.

Discussion and Conclusion

As technologies advance to make home appliances, systems, and services smarter and more intelligent, there is a growing need to better understand the factors and criteria that determine acceptance, and to find implications for designing and developing home technology products that effectively address needs and meet expectations.

Findings from this online study of a diverse sample of adults in the United States point to general directions and applications that are more desired by current and future home technology users. Overall, respondents indicated a higher level of openness to future scenarios in which a technology product or service was carrying out tasks and addressing objectives in areas where we already see some established smart home applications, such as safety and home security, cooling and heating control, energy management, and home maintenance. On the other hand, unfamiliar and futuristic concepts that involved higher levels of integration and automation – including extended energy services, companion and informative homes, and robotic agents – were less preferred. Participants also indicated higher acceptance and preference for concepts that could potentially address high-strain needs such as a caregiver portal, while indicating lower levels of interest for concepts addressing less critical needs (e.g., communication and entertainment) and high-touch tasks involving physical activities such as housework.

The results pertaining to preferences and intentions to use showed remarkable similarity between the informative and automated versions of the system concepts. This finding was somewhat unexpected considering the notable differences between information systems and automated systems. One plausible explanation for this unexpected result might be that the majority of scenarios with such variations centered around integrated systems/portals, where data was aggregated and presented visually, rather than being related to physical devices or focused on more individualized and elementary tasks.

Further analysis of the large-scale survey data indicated that preference and acceptance regarding future home technology and service concepts vary by individual characteristics to some degree. While differences between subsets of the sample varied slightly by the concepts presented in the study, a large part of the data indicated that acceptance of advanced home technologies may vary by behavioral and attitudinal characteristics – such as living and household arrangements, and whether one is involved in providing care to or receiving care from a loved one – in addition to demographic characteristics and socio-economic background. This points to the need for understanding users and consumers of future home technology products and services beyond easily measurable and observable characteristics, and suggests that different tools and approaches may be needed to comprehensively describe and target future users.

Notably, respondent's self-assessment of their current technology adoption experience and attitudes were found to significantly and consistently impact levels of interest in and acceptance of future concepts. This suggests that technology attitudes and experiences may transfer easily, with past and

relevant experiences impacting how one perceives and forms expectations regarding future applications. This also implies that building positive general perceptions and consumer confidence may be key to promoting connected home technology adoption and utilization.

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